Using Computer-based Technologies to Support Farmers' Decision Making

A report for the Cooperative Venture For Capacity Building

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Foreword

Many Australian farmers own and use computers, yet only a fraction of Australian family farms use computers to aid their decision making, despite the availability and affordability of such packages. This study aimed to generate insights to help developers of decision support software for farmers avoid the common marketing failures associated with low adoption of this technology. This was done by exploring the significance of social interaction between farmers in the adoption process, and by investigating farmers' thinking processes in the adoption decision. The main technology investigated was cropping-systems simulation programs.

The research supports the view that social interaction is not very effective in helping farmers' appreciate the relevance and significance of the decision support tools investigated. Personal learning experiences by farmers, as well as the need for the technology to closely relate to their own experiences on their own farms, are factors in making decision support tools relevant. Farmers can vary in the way they mentally model and measure the performance of their farming systems. The findings suggested that developing analytical understanding (i.e. understanding the scientific basis of the production system) among farmers has facilitated an appreciation of the relevance of the technology. Farm advisers are obvious candidates for delivering simulation as decision support, and as an aid to production-systems learning. Given the high cost of providing facilitation to support learning on an individual basis, group processes appear to be a highly effective way of introducing the technology and providing user support.

This project was funded through the Cooperative Venture for Capacity Building in Rural Industries which is made up of the research and development corporations: Australian Wool Innovation; Cotton Research and Development Corporation; Dairy Australia; Grains Research and Development Corporation; Grape and Wine Research and Development Corporation; Horticulture Australia Limited; Land & Water Australia; Meat & Livestock Australia; Murray-Darling Basin Commission; Rural Industries Research and Development Corporation; Sugar Research and Development Corporation; and the Australian Government Department of Agriculture, Fisheries and Forestry.

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Peter O'Brien
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Abbreviations

BCG	Birchip Cropping Group
CLI	CSIRO Livestock Industries
DSS	Decision support software
FARMSCAPE	Farmers, Advisers, Researchers, Monitoring, Simulation, Communication And Performance Evaluation
FOO	Food On Offer
ESS	ENSO Sequence System
N	Nitrogen
PA	Precision Agriculture
PGR	Pasture Growth Rate
SOI	Southern Oscillation Index
YP	Yield Prophet

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Executive Summary

What this report is about

Many Australian farmers own and use computers, yet decision support software is not integral to the management of more than a fraction of Australian family farms, despite the availability and affordability of such packages. This study aimed to generate insights to help developers of decision support software avoid marketing failures associated with low adoption of these technologies.

Who is the report targeted at?

The report is targeted at developers for computer based decision support systems, and those who fund and use such systems.

Background

A portfolio of projects known as FARMSCAPE employed an approach that involved scientists engaged directly with groups of farmers to explore matters of tactical risk management and strategic planning in dryland cropping systems. Integral to this was the use of a computer-based crop-simulation model known as APSIM. Two key strategies have been tried to deliver the FARMSCAPE approach more widely, and in a cost-effective and commercially-sustainable manner: a) FARMSCAPE Training and Accreditation and b) Yield-Prophet® on-line. There are no guarantees that these strategies will result in widespread use of simulation, and a recent contribution to the diffusion literature (Moore, 1999) provided the stimulus for an investigation into the adoption potential of cropping systems simulation.

Moore (1999) proposed two distinct markets for complex technology products, separated by a 'chasm' between the early adopter (also termed visionary) and early majority (pragmatist) adoption categories. The chasm refers to a breakdown in social referencing between the two markets. Social referencing is a process in which one person utilizes another person's interpretation of the situation (or technology) to formulate his or her own interpretation of it (Feinman, 1992). This behaviour arises when there is uncertainty concerning the innovation and when one's own intrinsic appraisal processes cannot be used. In referencing, one person serves as a base of information for another, and it is a key process in technology diffusion – i.e. the process in which an innovation is communicated through certain channels, over time, among the members of a social system (Rogers 2003). The 'chasm' refers only to discontinuous technologies – i.e. technologies that require the adopter to change their behaviour or modify infrastructure in order to use them.

If the 'chasm' theory applies to the use of cropping-systems simulation, the implication is that successes with innovative farmers will not automatically result in widespread use of this technology, and there is a risk that the pragmatist market will be left behind. This exposes the possibility that cropping systems simulation, which has been highly valued by some collaborating farmers, will remain as niche products, only attractive and accessible to a very small fraction of farmers, and possibly not providing the critical market volume to allow agribusiness to viably retain this as a commercial service.

Aims

In the context of the two commercial delivery approaches introduced above, this study aimed to provide new knowledge about market segments and evaluate the significance of Moore's 'chasm' in the diffusion of cropping systems simulation. Likewise, the 'chasm' was also explored in a third case

study, which examined the use satellite technology designed to support pasture management decisions. The technology is branded ‘Pastures from Space’.

The study also aimed to identify the critical issues for effectively implementing computer-mediated decision support among a sufficient segment of the farming community to enable a viable commercial agribusiness service.

Methods used

The project adopted a case-study methodology and interviewing was the key method used for data collection. The research was conducted in two stages, and the report is structured accordingly.

Stage 1 of the research explored the adoption of cropping systems simulation and ‘Pastures from Space’ satellite technology through three case studies. In addition to these focus technologies, a number of other complex, or computer-based, technologies that were believed to fit the description of a ‘discontinuous technology’ were explored, including personal computers, precision agriculture technologies, and other decision support packages. The research entailed classifying farmers according to their visionary / pragmatist adoption category and investigating influences on their adoption decisions.

Stage 2 of research, planned after the first was completed, focused solely on the use of Yield Prophet® in four states of Australia. This stage of research investigated the cognitive, in additional to the social, processes influencing adoption.

Key findings

Was a ‘chasm’ in social referencing evident?

The test of Moore’s ‘chasm’ thesis is – are there some technology users that potential users of the technology would not reference? The findings are inconclusive. Not all pragmatists agreed that it was a prerequisite to reference other pragmatist farmers before making a decision to adopt the technologies investigated and there were cases where some self-assessed pragmatists referenced visionaries. There were, however, individual cases that provided a degree of support to the notion of chasm in social referencing between visionaries and pragmatists.

Is farmer-to-farmer social referencing likely to be an effective diffusion mechanism for the technologies investigated?

‘Adoption’ by interviewees of the focus technologies depended on the sense that the ‘virtual world’ created by the technology is *relevant* to the physical world it represents and an experience that outcomes are *significant* to farm management practice – i.e. benefits sufficiently outweigh the costs (including non-monetary costs) of adopting. The findings indicated that the process of social referencing was not likely to be sufficient as a means to facilitate farmers’ appreciation of the relevance and significance of the key technologies investigated.

In relation to the focus technologies, they key conditions for *relevance* were that the technology adequately represented the structure and behaviour of the biophysical production system and that the technologies’ output adequately relates to that experienced on the adopter’s own farm. In other words, relevance was established in the context of one’s own farm and the technology had to be credible and flexible. A personal learning experience (albeit socially facilitated in group events) also appeared to be a factor in achieving relevance.

Although a social referencing process can communicate potential relevance, resulting in an attitude of openness towards the innovation, it cannot be relied on to provide the subjective appreciation that goes the next step to establish the conditions for relevance described above. This launched a second stage of

enquiry for this study, which sought to identify what interventions, if necessary, could facilitate the cognitive experiences for farmers that expedite adoption of technologies.

Value of cropping systems simulation in commercial use

A detailed study of Yield Prophet® use in four states of Australia identified three current paths for cropping systems simulation in commercial practice:

1. A flexible simulator for systems analysis by a farmer and/or consultant, customised for a farmer's specific production environment and management issues, to explore the consequences of tactical management decisions;
2. A flexible simulator to facilitate farmer learning and development – i.e. creation of insights into farming systems and their management;
3. A tool for meeting external regulatory demands – e.g. corporate farming reporting, accountability, dealings with finance companies. This possibility was raised infrequently, compared with the first two.

These correspond with 3 of the 4 paths for model-based information systems identified by McCown (2002). In relation to Path 1, Yield Prophet's value is the provision of a flexible tool for managing climatic uncertainty by forecasting production outcomes in relation to contemplated tactical management alternatives. To date, this has largely involved Nitrogen (N) management, and there has been little use of Yield Prophet for other management decisions (e.g. pre-season planning) – a situation largely explained by the limited promotion of the latter. While demand for tactical management support would be expected on a continuous basis, it is questionable whether Yield Prophet will generate enough value to warrant ongoing use by subscribers if it is used solely for N management. Although N is an important management decision – it is a costly but necessary input, and the only in-season management option identified by interviewed farmers for dealing with climate variability – farmers varied in the degree to which their experience and judgment was augmented by Yield Prophet's explicit presentation of probabilities of certain crop outcomes occurring. The interviews revealed that Yield Prophet was not the only method for informing the N management decision. Not all farmers received the same value from Yield Prophet – for some, the value was a low marginal benefit, whereas other reported high value.

Among the clearest and most convincing reports of the value of Yield Prophet's probabilistic yield forecasts were those from subscribers who previously had no way of making structured comparisons between yield outcomes under different seasonal climate forecasts. While this points to a 'unique and compelling value' for Yield Prophet, there was poor understanding and/or trust in confidence in seasonal climate forecasts to guide tactical management decisions. This presents a challenge for Yield Prophet, but not a barrier given that interviewees clearly viewed seasonal climate forecasts as a component that could be separated from the rest of Yield Prophet.

Is cropping systems simulation cognitively compatible with the way farmers see their farming environment?

The results demonstrated that while interviewees had no conceptual representations of the farm production system that were fundamentally incompatible with Yield Prophet's representation of the production system, there was variation in the way interviewees mentally represented and measured the performance of their farming systems. Some interviewees clearly articulated a change in conceptualisation of their production systems that was a result of and facilitated their appreciation of Yield Prophet – this illustrates the nature of Path 2, above. Experienced Yield Prophet users and those who provided a clear description of a valuable Yield Prophet experience typically discussed the production system using objective, scientific measures. The shifts and differences in production system conceptualisation can be represented along a continuum between two forms of cognition – analysis and intuition.

Analysis or analytical thought involves working with an environment represented in abstract terms through a data interface, and this is required for Yield Prophet use. This means that for Yield Prophet

to make sense to farmers they must, to some degree, appreciate the logic (i.e. conceptual constructs, though not the mathematical representation) used by APSIM. In addition, to participate in setting up a simulation of a crop and to discuss simulation outputs, familiarity with quantitative measures is often necessary, and it may involve the farmer dealing with terms and measurements not normally used in the discourse of practical farming. The findings suggested that developing analytical understanding – i.e. scientific representations of the production system – among farmers in the Yield Prophet domain has facilitated an appreciation of its relevance.

Role of consultants and farmer groups in technology diffusion

Generally interviewees did not delegate crop management decisions in the Yield Prophet domain to consultants. However, to varying degrees, interviews revealed consultants' abilities to compensate for farmer deficiencies in analytical understanding and to facilitate farmer learning in the key steps of soil characterisation and monitoring, conducting APSIM runs, interpreting crops yields in relation to water and nutrient supply, and interpreting model output, presented as probabilities, for farmer action.

The research supports the view that farm advisers are obvious candidates for delivering simulation as decision support in relation to Path 1. In relation to the value of Yield Prophet to facilitate farmer learning (Path 2), previous FARMSCAPE activities have identified that decision support and learning is most effective in a participatory process that combines the strengths of practical knowledge and scientific knowledge, and this was also evident in this study. Given the high cost of providing facilitation on an individual-subscriber basis, group processes appear to be an effective way of introducing these technologies and providing user support.

Recommendations

These recommendations are particularly relevant to people who develop decision support software.

- Learn from other's experiences. There is a wealth of experience in DSS development and implementation captured in *Agricultural Systems* Special Issue Volume 74. This Special Issue is the collation and interpretation of a sample of in-depth experiences of scientists who built and implemented significant DSSs. The result is a combination of revelations about difficulties, and, significantly, about successes that stand out as exceptions.

- This study supports the view that decision support and learning is most effective when:
    - Used in a participatory process that combines the strengths of practical knowledge and scientific knowledge
    - Used in the context of one's own farm
    - The simulator has credibility and flexibility
    - The simulator is used as a way of 'gaining experience'
    - Farmers are contemplating a change in practice.

  Farm advisers are key candidates for delivering simulation as decision support, and could be targeted as delivery agents by developers of DSS. These results confirm the key learnings from the FARMSCAPE experience.

- Formal impact evaluation is critical to the continued growth and success of YP, and should be an essential ingredient of any other DSS development program. Evaluation should fit within an Action Research framework, whereby evaluation activities seek data and feedback from stakeholders in a manner that can inform future directions.

- Design evaluation activities that aid understanding of the adoption experience from a technology-user perspective. Put yourself in their shoes. Find out what current agricultural practices are, why people follow them and why they may see a DSS differently to you. Enquiries of this nature have implications for how evaluation is conducted. Such questions are unanswerable using techniques such as fixed-response surveying, whereas semi-structured and unstructured interviews are appropriate to the task.

Introduction

Background

Over a quarter of a century after the computerised decision support system (DSS) idea arrived in agriculture to provide tools for improving farmers' planning and decision making, 75 per cent of Australian grain farmers own and use computers (Hayman and Easdown, 2002), decision support packages are readily available and affordable, yet nowhere can it be said that distributed decision support software (DSS) is integral to the management of more than a small fraction of Australian family farms. This is despite the huge improvements that have been made to the competency of models and their user-friendliness (McCown 2001).

In what seems an incongruous development, Mullen (2002) reports that the role of Australian public research institutions in the design of *material* technologies to improve efficiency in farming practice will decline, and that there has been a marked shift in publicly funded research resources towards "*management* or *knowledge-based* disembodied technologies" on the grounds that this research is viewed as being in the public interest and as being able to deliver environmental outcomes that have consequences for the rest of the community. Rural research and development corporations are also making such investments.

Cognisant of the failure of DSS to generate sustained interest or impact, the farming systems research group APSRU[1] has conducted research since 1992 that has demonstrated a facilitated, participative approach, involving farmers, their advisers and researchers, to jointly explore the economic and environmental consequences of alternative farm management practices using computer simulation of farming enterprises and ecosystems. The cropping systems model known as APSIM (Keating et al, 2002) has provided the simulation capability. APSIM simulates crop growth based on paddock-specific inputs of soil type, pre-sowing soil water and nitrogen, rainfall, irrigation and nitrogen fertiliser applications, and climate data.

This research, conducted in a portfolio of projects known as FARMSCAPE (Farmers, Advisers, Researchers, Monitoring, Simulation, Communication and Performance Evaluation), has addressed two questions: (i) can farmers value simulation as a tool in helping to manage their farming system? (ii) if so, how then can it be delivered in a cost-effective and commercially sustainable manner?

Significant evidence has been collated and published[2] which positively answers the first of these two questions – that is, farmers have experienced significant learning and gained demonstrable benefits from utilising simulation in their management decisions. By 1998, farmers' demand for FARMSCAPE tools and services exceeded the research team's capacity and mandate to deliver such services (Hochman *et al*, 2000; Carberry *et al*, 2002). The FARMSCAPE model – that of scientists engaged directly with farmers in groups to explore matters of tactical risk management and strategic planning under high climatic risk, using simulation models – provided the proof of concept to warrant asking question (ii) i.e. how can it be delivered to a greater number of grain-growing enterprises in a cost-effective manner? Two key approaches have been tried: a) FARMSCAPE Training and Accreditation and b) Yield-Prophet On-line. Both are described below.

FARMSCAPE Training & Accreditation

Over 230 farmers had engaged in FARMSCAPE activities by 1998. It became clear that there was a significant market demand by farmers for the simulation-assisted learning that they experienced

[1] http://www.apsru.gov.au. The report authors are CSIRO employees who are affiliated with APSRU, or were at the time the research was conducted.
[2] A list of publications available at (www.farmscape.cse.csiro.au).

through FARMSCAPE's monitoring, simulation and “What if” analysis and discussion activities. The research priority had therefore shifted from developing a methodology for supporting farmers’ learning, planning and decision making about crop management in a risky climatic environment, to the need to develop a sustainable system for delivery of a customized service. An approach was needed to scale up the delivery of FARMSCAPE without sacrificing the quality of system simulation and of human interactions necessary to retain the level of interest and confidence that created the demand.

The need to develop a more sustainable way to deliver FARMSCAPE coincided with a period of change in the farm service environment, characterized by a decline in publicly funded extension and an increase in various forms of commercial consulting. Our learning from the previous 6 years convinced us that farmers who were enthusiastic about FARMSCAPE were prepared to pay for such a service. A key element of the service is a professional who is skilled in using the simulator and interpreting simulations of real farming situations, and who can lead the “what-if” discussions with farmer groups.

By working closely with agribusiness partners we learned that it would be necessary for researchers and agribuisness to collaborate in investigating feasible approaches together for (a) commercial service provision, and (b) APSIM training and accreditation for service providers. A FARMSCAPE training, and accreditation program was established to provide the scientific and technical training and on-going support for advisers to provide farmers APSIM simulations. After publicly advertising, four companies were selected to participate in the initial training and accreditation program, each contributing $15,000 per employee to the cost of training. In addition to seven trainees from these four companies, one trainee from QDPI and another from the Cotton CRC commenced the program.

The core of the program consisted of on-farm projects negotiated with trainees and built around trainees’ service to selected farmer clients. The initial project was the systematic monitoring of a crop that enabled project participants to track soil water and nitrogen supply and crop growth through the season. The monitoring projects provided the data needed to simulate the crop using APSIM and to test model performance. This was followed by training in the science behind APSIM, the practicalities and knowledge required to produce, quality-test and present results of simulations and to conduct a "What if Analysis and Discussion" session with farmers. Procedural manuals and interactive coaching from APSRU staff provided a practical, experience-producing, framework within which the formal technical and theoretical training modules were flexibly presented to maximize practical relevance and significance for trainees and their clients.

Yield Prophet

Yield Prophet®[3] is a web interface for the crop production model APSIM and was developed by BCG (Birchip Cropping Group) in collaboration with APSRU / CSIRO as a risk management tool for dryland farming systems in the Victorian Wimmera and Mallee, with an emphasis on decision support for nitrogen fertiliser inputs. It was first used for wheat at BCG trial sites in 2002, results of which were made available to all (approximately 500) BCG members, and its early predictions of the failure of that season generated sufficient interest and credibility to allow a commercial release to around 30 BCG members in 2003 as a monthly fax-out service. Continuing demand resulted in the development of the Yield Prophet® web-interface, which allowed a larger number of subscribers to receive up-to-date crop information and forecasts on demand in 2004. In 2005, the first year of general commercial release of the service, 338 paddocks were subscribed to the service from all over Australia. Over 6800 reports were generated during the season.

Yield Prophet works by farmers or consultants subscribing to the service in late summer and autumn. During autumn, subscribers also sample their Yield Prophet® paddocks’ for a range of soil physical and chemical properties. These data are entered by growers into the Yield Prophet® web interface. An appropriately measured soil characterisation is an essential input for Yield Prophet® to simulate crop growth, yield and protein accurately. During the season, subscribers enter paddock management

[3] More information on Yield Prophet can be accessed at: http://www.bcg.org.au/cb_pages/yield_prophet.php

details (sowing date, crop type, variety, nitrogen fertiliser and irrigation) and rainfall. When growers wish to find out how much water and nitrogen is currently available to a crop, the likely yield of their crop, or what the likely impact of a particular management action will be, they generate a report.

In order to make predictions about crop yield, Yield Prophet® uses the last one hundred years of climate data taken from the nearest Bureau of Meteorology weather station to continue the simulation of yield or protein from the date of report generation to the end of the season. The model simulates one hundred different crop yields and proteins, based on the current season up until the day the report is generated, and on the season finishes of the past one hundred years. These yields are then plotted as a probability curve, which provides growers with an estimate of the probabilities of obtaining different yields. This range of probabilities narrows as the season progresses and components of yield become more certain.

Market uncertainty

While the establishment of commercial delivery services is APSRU's key strategy to extend simulation technology to the mainstream, there are no guarantees that this will be successfully achieved. The focus of our learning has been with:

- just a small fraction of what we perceive as the potential market for simulation and
- in facilitated sessions with researchers whose involvement is not a feature of either commercial delivery arrangement.

Commercial delivery of APSIM-based services through a consultant may involve a level and nature of personal interaction with client different to that in a FARMSCAPE research project. Both APSRU and our agribusiness partners are dealing with uncertainty about the adoption potential of computer simulation of farming systems. If agribusiness fails to reach a significant portion of the market, we risk the possibility that the tools which have been highly valued by some of our collaborating farmers will remain as niche products, only attractive and accessible to a very small fraction of farmers, and possibly not providing the critical market volume to allow agribusiness to viably retain this as a commercial service.

A recent contribution to the diffusion literature by Moore (1999) has also stimulated our questions of the adoption potential of simulation. According to 'traditional' technological diffusion theory, adoption progresses through a community over time according to rates described by a continuous, 'bell'-shaped curve (Rogers 2003). The first adopters of a new technology are termed *innovators*, followed by *early adopters*. Efficient transfer of the technology to other adopter categories, which form the majority (i.e. the *early majority* and *late majority*), can progress through the leverage of the social process of 'diffusion', in which later adopters reference earlier adopters. Moore's (1999) challenge to this model is to propose that the diffusion of technology across adopter categories is not continuous. His alternative model presents two distinct markets for technology products, separated by a 'chasm' between 'visionaries' (innovator and early adopter types) and 'pragmatists' (the rest of the market), brought about by the failure of pragmatists to reference visionaries. Moore's theory relates to the adoption of *discontinuous technologies* only – i.e. technologies which require adopters to *change* their current mode of behaviour or to modify other products and services they rely on. Decision support and many other information technologies can be regarded as discontinuous. Moore's (1999) strategy for crossing the chasm is the deliberate creation of a satisfied pragmatist reference group. The 'chasm' theory in relation to discontinuous technologies is elaborated in Chapter 2.

In FARMSCAPE activities, researchers have tended to give attention to those farmers and farmer groups with the greatest enthusiasm for interaction, rather than target or tailor participation to particular market segments – i.e. the groups largely self-selected. If the 'chasm' theory applies to the use of cropping systems simulation, the implication is that successes with innovative farmers will not automatically result in a continuous adoption curve that results in these technologies in widespread use, and there is a risk that the pragmatist market will be left behind. Given the large size of this

market relative to visionaries, this implication is significant for both the cropping industries and agribusiness partners. A related, important question is the degree to which investment made in the delivery of FARMSCAPE can be reduced by farmers referencing other satisfied 'customers'. But any adoption strategy depends on being able to identify whether a farmer is a natural member of the early market or the pragmatist market.

Aims

Based on investigations into the 'real-world' implementation of APSIM-based simulation services in the two commercial delivery environments described above, and an additional study of the use of 'Pastures from Space' satellite technologies for supporting livestock management decisions, the project aimed to evaluate the significance of Moore's (1999) 'chasm' for the diffusion prospects for these technologies.

The study also aimed to identify the critical issues for effectively implementing computer-mediated decision support among a sufficient segment of the farming community to enable a viable commercial agribusiness service. The findings of such investigations were intended to support the broader project aim, which was to generate insights to help developers of decision support software avoid marketing failures associated with low adoption of these technologies.

Report structure

This report commences with a brief introduction to relevant literature from the field of adoption and diffusion of innovations, and expands on Moore's (1999) theory and strategies for crossing the chasm. The methodology section introduces the case study research, which was carried out in two stages – the first guided the design of the second. The results for Stage 1 of the research, which are reported as three separate case studies, with findings synthesized in a single discussion. The discussion also outlines the rationale for conducting Stage 2 of the research. Subsequent sections report the results of Stage 2 of the project. A major synthesis of the Stage 2 research findings is presented in the discussion section, and conclusions then drawn.

Adoption and Diffusion Theory

The diffusion of innovations is a process by which an innovation is communicated through certain channels, over time, among members of a social system (Rogers 2003). Contributions to the literature on the adoption and diffusion of innovations outnumber those submitted to any other field of behavioural science (Rogers, 2003). Innovation diffusion in agriculture has been studied since the 1940s and the literature is extensive. A seminal text is Rogers (2003), now in its fifth edition, which provides a major review of adoption and diffusion studies in relation to agriculture and other fields. Several reviews of the literature in the context of Australian agriculture have been conducted (e.g. Pannell et al, 2006; Black, 2000; Lindner 1987; Guerin and Guerin 1994) and, therefore, a comprehensive review is not provided in this report. Two major areas of inquiry in the literature are i) the study of characteristics of innovations that affect the rate of adoption, and ii) the characteristics of farmers that are associated with their timing of innovation adoption.

In relation to the first of these two areas of enquiry, rates of adoption are explained by:

1. *relative advantage* (extent to which it is perceived better than the idea it supercedes, and positively related to rate of adoption);
2. *compatibility* (degree to which innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters; positively related to rate of adoption);
3. *complexity* (degree to which innovation is perceived as relatively difficult to understand and use; and negatively related to rate of adoption);
4. *triability* (degree to which innovation can be experienced on a limited basis, positively related to rate of adoption); and
5. *observability* (degree to which results of innovation are visible to others, positively related to rate of adoption) (Rogers, 2003).

The second of the two areas of inquiry – i.e. the characteristics of farmers that are associated with their timing of innovation adoption, or *innovativeness* – is closely associated with the classical technological diffusion model (Rogers and Shoemaker, 1971). According to the model, adoption progresses through a community over time according to rates described by a bell-shaped curve (Fig. 1). The curve is divided into five adopter categories: innovators (the first adopters), early adopters, early majority, later majority, and laggards (the last to adopt). Each category has been associated with a unique, psychographic profile, although exceptions to these 'ideal types' can be found (Rogers, 2003).

Efficient transfer of the technology across the adopter categories can progress through the leverage of *social referencing*, in which later adopters reference earlier adopters. Social referencing is a key process in technology *diffusion.* It occurs when one person utilizes another person's interpretation of the situation (or innovation) to formulate his or her own interpretation of it (Feinman, 1992). In referencing, one person serves as a base of information for another. This behaviour arises under conditions of uncertainty and ambiguity when one's own intrinsic appraisal processes cannot be used (Campos & Stenberg, 1981, cited in Thomaz *et al*, 2005).

Referencing is one of the processes that takes place in what Rogers (2003) terms the *innovation-decision* process – i.e. the information-seeking and information-processing activity in which an individual is motivated to reduce uncertainty about the advantages and disadvantages of the innovation. The process has 5 steps: knowledge, persuasion, decision, implementation and confirmation. Others have described the adoption process in similar ways, as summarized by Pannell *et al* (2006).

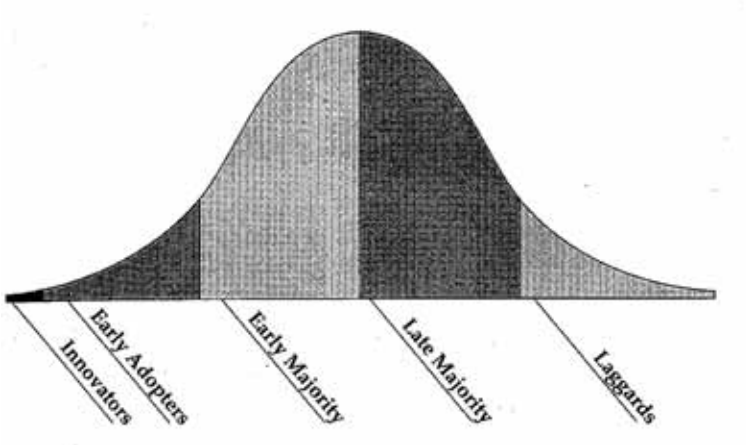

Figure 1. Technology adoption model. Source: Moore (1999, p.12)

Rogers (2003, p.18-19) notes the importance of referencing to the persuasion stage:

> "*Diffusion investigations show that most individuals do not evaluate an innovation on the basis of scientific studies of its consequences, although such objective evaluations are not entirely irrelevant, especially to the very first individuals who adopt. Instead most people depend mainly upon a subjective evaluation of an innovation that is conveyed to them from other individuals like themselves who have already adopted the innovation. This dependence on the experience of near peers suggests that the heart of the diffusion process consists of modelling and imitation by potential adopters of their network partners who have previously adopted. Diffusion is a very social process that involves interpersonal communication relationships*."

The structure of the social system can facilitate or impede the diffusion of innovations, but compared with other aspects of diffusion research, there have been relatively few studies of how the social or communication structure affects the diffusion and adoption of innovations within a system (Rogers, 2003).

The 'chasm' challenge to the diffusion model

Challenges to the diffusion model include its pro-innovation bias (i.e. that innovation should be diffused to and adopted by all members of system) and individual-blame bias. A discussion of these and other criticisms of the model are summarized in Rogers (2003).

A challenge on another front has come from Moore (1999) who postulates that the curve in Figure 1 is not continuous. According to Moore, a significant break in the curve (Figure 2), which he terms the *'chasm'*, separates the early adopters (termed *visionaries*) from the early majority (which he re-labels as *pragmatists).* The result is two distinct markets for technology products, that lie either side of the chasm. Moore defines a market as containing actual or potential customers who reference each other when making a buying decision. Referencing is identified as critical in a marketing program because of leverage – i.e. no technology developer can afford to pay for every marketing contact made. The chasm exists because pragmatists do not reference visionaries. This is because pragmatists do not view visionaries to be sufficiently like themselves to warrant referencing them. Moore asserts that the chasm is the greatest point of peril in the development of a 'high-tech' market and that the transition between these two markets is not smooth.

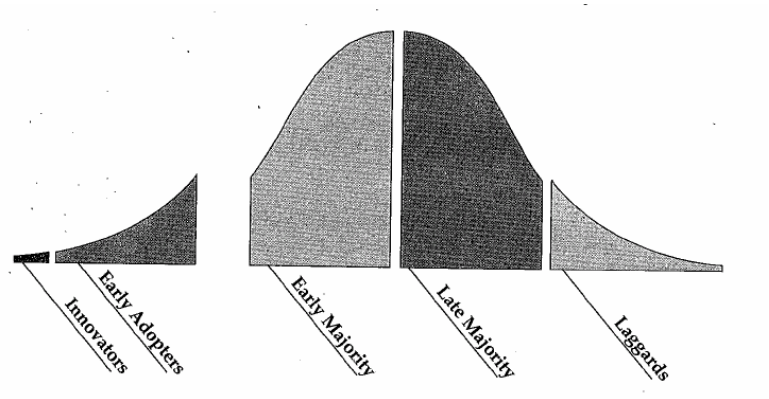

Figure 2. Revised technology adoption model. Source: Moore (1999, p.16).

Moore's theory relates to the adoption of 'high-tech' or *discontinuous technologies* only – i.e. technologies which require adopters to *change* their current mode of behaviour or to modify other products and services they rely on. Decision support and many other information technologies can be regarded as discontinuous. Taking the example of Yield Prophet, adoption of the technology may not only require a change in infrastructure by requiring a hardware component (computer and associated software) but could also involve a change in behaviour in terms of the cognitive processes behind a crop management decision. The contrasting term *continuous* innovations refers to the normal upgrading of products that does not require us to change behaviour e.g. the normal upgrading of wheat variety. Rather than an either/or continuum, the descriptions 'continuous' and 'discontinuous' lie at each end of a spectrum of demands for change.

For discontinuous technologies, this prospect of change carries with it uncertainty concerning the consequences of the change, and constitutes a disincentive for adoption, and an incentive to acquire the information that will dispel the uncertainty. Like Rogers (2003), Moore (1999) assigns psychographic profiles to the adopter categories. The innovator/early adopter types (visionaries) readily dispel their uncertainties about such technology by aggressively taking opportunities to learn its potential for them. This is rationalised by them as an investment to gain competitive edge. They expect a discontinuity between the old ways and the new. But pragmatists and other observers know that many visionaries are 'psychologically compelled' to try a new technology in spite of high risks that it won't prove practicable. Because pragmatists are concerned with progressive improvement of what they do now, they view the referencing of visionaries as risky. Pragmatists want to minimize the discontinuity with the old ways. Pragmatists also want to look to other pragmatists before adopting such technology, but this raises the intriguing capacity development question of how to get initial pragmatist references.

Moore proposes that the way to cross the chasm is, to create a pragmatist customer base that can be referenced – people can, in turn, provide access to other mainstream customers. To capture this reference base, it must be ensured that the first set of customers completely satisfy their *buying* objectives. This means that the customers get not just the technology product but what Moore calls the '*whole product'*- i.e. the complete set of products and services needed to achieve the desired result, and this includes user support. As Moore (1999, p68) states "Whenever any thing is left out from the set, the solution is incomplete, the selling promise unfulfilled, and the customer unavailable for referencing. Therefore, to secure these much-needed references, which is our prime goal in crossing the chasm, we must commit ourselves to providing, or at least guaranteeing, the provision of, the whole product" (p68).

Rogers (2003) does not support Moore's (1999) theory. He maintains that innovativeness is a continuous variable, and that there are no 'chasms' between adopter categories. However, what both have in common is the recognition of important differences between adopter categories. Furthermore, Rogers (2003) promotion of *audience segmentation* as a strategy in which different communication channels or messages are used to reach each sub-audience is a closely related concept to Moore's (1999) discussion of market segmentation. Rogers (2003) describes audience segmentation as breaking down a *heterophilous* audience into relatively *homophilous* sub-audiences, noting that interpersonal channels of communication are particularly effective with a homophilious audience.

Methodology

Stage 1 of Research

The project adopted a case study methodology. Each of the three group case studies – two relating to the commercial delivery of cropping systems simulation in two grains producing regions (Victoria and Darling Downs, QLD), and a third focusing on delivery of the Pastures from Space program in WA (further detail provided over page) – represent three different contexts for studying the market setting relevant to discontinuous technology transfer.

Stage 1 of the research entailed research on classifying farmers according to their visionary/pragmatic adoption category. Within each group case study, this involved the elicitation of individual farmers' personal histories and intentions in relation to innovation adoption and exploration of the patterns of relationships between people within each case study group – e.g. who is influencing whom? Whose practical 'experiments' do individuals take most seriously? The key research method for collecting and analysing information was interviewing. An interviewing protocol was developed for exploring technology adoption dispositions and for discriminating between visionary and pragmatist farmers. Although the terms 'visionary' and 'pragmatists' are used by Moore (1999) to specifically refer to the 'early adopter' and 'early majority' adoption categories, respectively, we apply them as a means of assigning farmers to one of two market segments. This means, for example, that a farmer assigned to the 'visionary' category could be an 'innovator' or 'early adopter'. Likewise, the 'pragmatist' category refers to any farmer allocated to the right side of the hypothesised chasm.

The interview protocol is presented in Appendix B for one of the case studies. Questions for the other three case studies only differed in the list of 'knowledge intensive' technologies that interviewees were asked to comment on, as not all technologies investigated were relevant to all industries. For the discontinuous technologies investigated, interviewees were asked about their awareness of these technologies, the reasons they adopted (if at all), their experiences with the technology, and their intentions to continue using. They were also asked questions about information sources influential in their adoption decision, including whether they referenced other farmers. To investigate interviewees' timing of technology adoption, they were asked to nominate where they were positioned on the adoption 'bell' curve (see previous chapter) specifically in relation to the technologies discussed.

Appointments for interviews were always made by phone in advance of the interview. A semi-structured interview technique was used. Two researchers participated in each interview[4], one asking the questions while the other took notes. Interviews were also audio-recorded[5], and transcribed using a professional transcription service. Prior to the interview commencing interviewees were briefed on the research project and data confidentiality arrangements were discussed.

Farmers from all case study groups were interviewed by November 30, 2003. A subsequent round of interviews in Birchip was also held in August 2004. Interviews with each farmer were generally 30 minutes to one hour in duration. In all cases, our agribusiness / research collaborators identified a group of farmers, provided farmer contact details, and, in some cases, made contact with the farmers on our behalf. In all cases we explained to interviewees how their names were provided. All interviewees except two were male, though in some cases their wives and mothers also took part in the interviews. In the results sections, all interviewees are referred to as males to protect the confidentiality of the female interviewees.

Further details specific to each case study are presented below, including a description of the interview sample, how many were interviewed, when, and how.

[4] With the exception of the April 2003 Birchip interviews
[5] With the exception of the April 2003 Birchip interviews

Group case study 1: Evaluation of technology adoption among grain-farming clients of the FARMSCAPE-accredited firm Landmark, Darling Downs, QLD

Discontinuous technology adoption was explored in the Darling Downs, Queensland – the region in which the original FARMSCAPE project activities were undertaken. Of particular interest was the opportunity this case study provided to explore awareness and use of the cropping systems simulation model, APSIM, approximately 15 years after it was first used in FARMSCAPE project activities with Darling Downs farmers and 3 years after FARMSCAPE training and accreditation was completed by a local Landmark consultant.

Interviewees were drawn from the grain-farming client group of FARMSCAPE-accredited consulting firm Landmark, based in the Darling Downs town of Dalby. Landmark is one of four agribusiness companies with accredited agronomists for commercial delivery of FARMSCAPE tools to their clients. We interviewed 16 clients in August and September, 2003. Landmark agronomists were requested to identify 20 members of their client group for interview, who they believed would represent a full range of technology adopter categories, including those who may be among the 'pragmatist' category of farmers.

Group case study 2: Evaluation of technology adoption among livestock producers participating in the Pasture from Space project, Western Australia

The 'Pastures from Space'[6] program provides estimates of pasture production during the growing season by means of remote sensing. Satellite data are used to quantitatively estimate pasture biomass or Feed On Offer (FOO). When combined with climate and soil data, FOO may be used to produce pasture growth rate (PGR) estimates. The technology has been widely trialled by Western Australian farmers and assessed for its potential to assist with management decisions such as grazing rotations, feed budgeting and fertilizer application. Twelve livestock producers in south-west Western Australia who have collaborated with researchers of the CSIRO Livestock Industries (CLI) division to use this technology were interviewed in November 2003.

Unlike the other case study groups, which involved face-to-face interviews, WA livestock producers were interviewed by telephone. A CLI staff member, who had worked with group of livestock producers as part of the Pastures from Space project, assisted in arranging farmer participation in the telephone interviews by briefing them about this project and then providing us contact details of producers which had agreed to participate. The users of the technology were described as being at varying levels of technical capability.

Interviewees were sourced from five groups in different locations, which, in total, covered a geographical spread of about 300 km. Three groups were located in farming systems with an equal proportion of grains-based cropping and grazing, while for the other two groups, livestock represented primary component of the enterprise (75:25 livestock to cropping ratio). Not all groups had the same facilitators but we were advised the groups' facilitators followed similar protocols.

Group case study 3: Evaluation of technology adoption among grain-farming members of the Birchip Cropping Group, Victoria, with focus on Yield Prophet

Like the first case study, the Birchip case study focuses on the adoption of APSIM, but in the form of the on-line simulator Yield Prophet. It represents a less mature study to the extent that the farmers in the area had less familiarity with APSRU and APSIM compared with those in the Darling Downs. Another key difference is the delivery of simulation – professionally-facilitated interactions around computer-simulation of farming systems and soil monitoring activities were not integral to the service, however, some may have experienced such interactions, either with their consultant or FARMSCAPE researcher.

[6] Further information can be accessed at http://www.pasturesfromspace.csiro.au/

The interviewee sample was larger than for the other two case studies – a reflection of where future commercialisation effort will be directed. A total of 32 interviews were conducted in three rounds: April 2003, September 2003, and August 2004. In total, 20 farmers were interviewed: 12 were interviewed once, 4 were interviewed twice, and 4 were interviewed three times. For repeat interviews, the interview protocol focused only on experiences with Yield Prophet. BCG and project staff identified and contacted farmers to invite them to participate in interviews. In selecting farmers for interview, we aimed to achieve a mix of Yield Prophet subscribers and non-subscribers, including those who had not renewed a subscription. Table 1 summarises the interview sample.

Table 1. Interview sample for the Birchip study

Subscript'n status	When interviewed (round ID and date)		
	1 (April 03)	2 (Sept 03)	3 (Aug 04)
Never subscribed	x		
	x		
	x		
		x	
		x	
2003 & 2004 "renewers"	x	x	x
	x		
	x	x	x
	x	x	x
	x		
	x		
		x	x
		x	
2003 only "non-renewers"	x	x	
	x	x	x
		x	x
		x	x
2004 only "new"			x
			x
			x

Stage 2 of Research

After analysing the results of Stage 1 of the project, a second stage of research was planned. The detailed justification for the design of the second stage is presented in the discussion of the Stage 1 research findings. Based on a revised hypothesis that the technology diffusion 'chasm' relates to cognitive rather than social processes, a new data collection activity was designed, focussing on the use of Yield Prophet in four states of Australia: NSW, Victoria, South Australia and Western Australia. Each location represents a case study, differing not only in relation to the biophysical environment, but also in terms of the degree of prior experience with Yield Prophet, and the nature of the client-consultant relationship.

As for Stage 1, an interviewing protocol was developed (Appendix C). Compared with the first stage of research, the interview route for this stage had a reduced effort on understanding market segments and social referencing processes and placed greater emphasis on exploring the critical aspects of value creation. In particular, attention was given to understanding what learning needs to take place for the new scientific concepts associated with Yield Prophet to be viewed as meaningful and relevant to farmers. Also under investigation was whether Yield Prophet offered significant (in relation to cost : benefit) value to management in comparison with existing strategies and opportunities for management change. The client/ consultant relationship was also explored, specifically: What decision

do farmers delegate, what do they retain? How do agronomists value and use Yield Prophet? What processes expedite credibility and appreciation of Yield Prophet by consultants?

For each case study, a consultant and Yield Prophet subscribers were interviewed. Two case studies involved interviews of consultants and their clients. A third case study also involved interviews of Yield Prophet subscribers and a consultant, but none of the subscribers were clients of the consultant. The consultant in this case was selected because the Yield Prophet support team knew that he had concerns with Yield Prophet and it was considered important to explore this perspective. Understanding the reasons for not renewing was regarded important and therefore this case also included two interviewees who were subscribers in 2004, but did not renew their subscription in 2005. The fourth case study explored the use of Yield Prophet through a non-commercial delivery arrangement, i.e. as part of a research activity with a farmer group, alongside a number of other decision support aids. In this case, the professional facilitator of this activity was interviewed. All interviewees except one were male. In the results sections, all interviewees are referred to as males to protect the confidentiality of the female interviewee.

Selection of interviewees was undertaken in conjunction with BCG/Yield Prophet staff, and all interviews were scheduled by BCG Yield Prophet staff and conducted in September 2005. The timing of interviews was selected to coincide with likely period in which interviewees would be applying N fertiliser to their crop. As for the first stage of interviews, all interviews were transcribed for data analysis. Details of the interview sample are summarised in Table 2. To protect interviewee confidentiality, the names of the locations are replaced with a location number.

Table 2. Summary of Stage 2 Interview Sample

Location 1	Sep 6 – 7	1 consultant 5 current subscribers
Location 2	Sep 20 – 22	1 consultant 3 subscribers (2 were 2004 renewers)
Location 3	Aug 29 - Sep 2	1 consultant 6 current subscribers (all 2004 renewers) 2 non-renewers (2003 &/or 2004 subscribers only)
Location 4	Sep 13 – 15	1 consultant 4 current subscribers

On-line quantitative survey of Yield Prophet subscribers

An on-line survey of all Yield Prophet subscribers was conducted so that the evaluation could benefit from a different data source. This was motivated by the notion of triangulation, which injects checks and balances into the research through different data collection strategies and sources. Triangulation allows the research to benefit from the combination of the different strengths of data and correction of deficiencies associated with a single source of data.

The survey was designed after the Stage 2 interviews were conducted, and was administered in late March 2006, after subscribers had received an end-of-season Yield Prophet report, which allowed comparisons to be made between actual and simulated crop performance. As for the interviews, the survey investigated: subscribers' assessments of Yield Prophet in 2005 in relation to a number of management decisions; factors limiting their use of Yield Prophet; the extent of discussion of Yield Prophet reports among consultants and others; opinions about simulation accuracy; and the value-for-money aspect of Yield Prophet.

All subscribers were invited to participate in the survey by an email sent by a Yield Prophet/BCG employee, which contained a hyperlink to BCG website where the survey (presented in Appendix D) could be completed and submitted on-line. Submitted responses were confidential and anonymous.

Stage 1: Discontinuous technology adoption in three group case studies

This chapter reports the results of interviews conducted for the three group case studies described previously. Case Study 1 concerns technology adoption in the Darling Downs, QLD, among grain-farming clients of the FARMSCAPE-accredited firm Landmark. Case Study 2 examines technology adoption among WA-based livestock producers participating in the Pastures from Space program. Case Study 3 focuses on the use of Yield Prophet by grain farmers in Birchip, Victoria.

All interviews followed a similar three-part format, and the results for each case study are presented in this order. First, interviewees were asked to comment on their use of a number of discontinuous technologies (e.g. personal computers and the internet, cropping systems simulation (APSIM), other DSS products, and precision agriculture). Interviewees were then asked to nominate a technology-adoption category to which they belonged. Finally, interviewees commented on sources of information used in their technology adoption decision.

Case study 1: technology adoption among grain-farmers, Darling Downs, QLD

Computer use

Timing of and reason for first computer purchase

Fifteen of the sixteen farmers interviewed owned at least one and up to 4 computers. A computer was used for at least one function associated with the farm business in 14 of these. Three distinct phases were identified for computer purchase: the early 1980s, the 1990s and 2000 (Table 4).

The two farmers who purchased computers when personal computers first became commercially available (in the early 80s) were enthusiastic about new technology and liked ‘gadgets’. Most computers were purchased in the mid-1990s, primarily for “doing the books”, but also for their children’s education. The next phase for computer purchase was the Australian Tax Office requirements for quarterly reporting of Business Activity Statements (BAS) in 2000. This government regulation provided a strong incentive for small businesses such as farms to report on their business income and expenditure in an electronic format.

Table 3. Timing of and reason for computer purchase

	1980s	Early – mid 1990s	2000
Number	2	10	4
Reason for purchase	Enthusiasm for new technology	Farm financial records (8) or children’s education (2)	BAS reporting requirements

Computer users

Primary computer use varied within the farm family (Table 4). In our sample, wives (and /or mother) were the primary computer user in six instances, followed by husbands in four situations. On two farms computer use was evenly shared between spouses. In one instance the son, who was in his twenties and assuming more a management role in the farm business, was the primary user. Two farmers delegated data entry and analysis to an off farm service provider.

Table 4. Primary user of computer

Primary user of computer	Number
Wife	6
Husband	4
Both husband and wife	2
Children	1
Externally sourced	2

Current computer and internet use

Accounting was the predominant reason for purchase and the most used functionality of computers (Table 5). It was the most frequently mentioned (14) and without exception it was the first (if not the only) application mentioned when farmers were asked what they used their computers for. Other off-line computer uses related to farm or paddock record keeping (4) and drafting programs (2). While all computers were connected to the Internet, only one had a broadband connection. Most common Internet uses were online banking and email (6 users) followed by "information gathering" related to farming and other interests (5). Other internet-enabled uses were weather reports, ordering farm machinery and trading shares. No one acquired marketing information online. Slow line speeds and frequent "drop outs" were identified as reasons for people not using the internet as much as they would have liked to.

Table 5. Current computer use

	Accounting	Internet Banking	Email	Internet – Information Resource	Farm/paddock record keeping	Children's Education
Number	14	6	6	5	4	2

Computer adoption score

Interviewees were assigned a score (1-6) to classify interviewees according to use of computer technology, with '1' indicating highest and '6' lowest. The six adoption categories were based on a combined consideration regarding such factors as the time of first purchase of a computer; the degree of computer confidence displayed in the interview; the extent to which computers are integrated into the farm business; the degree of online use and any sign that they were referenced by others as pioneers in computer usage. Those who did not own a computer (1 farmer) or did not use one for any aspect of their farming business (2 farmers) were allocated a score of 6. The rating was based on our assessment of the primary user of the computer for farm and is summarised in Table 8.

Farmers' assessment of barriers to using computers and the internet

Farmers volunteered a number of insights on barriers to greater use of computers and the internet. The selection of quotes provided below is accompanied by the interviewee's computer adoption score:

Computers

"I rely on others for most computer based work. My time is more usefully spent in the paddock" (3).

Reply to question on using computer for farm/paddock record keeping:

> *"No I don't. I would actually like to. I guess there are 2 things, one is probably I'm slow at it and I've got to learn more and I'm not fast enough so I can write it down quicker and I can do whatever. Two, you've got to have different programs. There's this program and then I'll need that one" (5).*

> ***"**When I talk computers I mean anything that's in the tractor I can do anything with but when it comes to in the house here, no I'm hopeless. My wife is about to buy a laptop. She is a [profession deleted]. She's got a few brains. Hopefully she's going to teach me" (5).*

"Faxes are my best information. I'm probably old-fashioned, whatever, but you get a fax, you get it out, pick it up, read it and the job's done. If you go on the computer, start it up, warm it up and go through the thing. Unless you are on it all the time, it just doesn't. I'm not one of those sorts of people. It either interests you or it doesn't. You have to be using it regularly I think." (5)

Internet

"Oh, I've tried. I do a little bit, everyone tells you how great the internet is, I could never find what I'm looking for so I give up" (5).

"Time consuming, you wade through trash to get to it, especially it not sure what you're looking for – can be very daunting – too much trash mixed in with it. Need to be able to tell search engine exactly what you are after" (3)

"The original problem [pre ISDN] was that it kept dropping out and especially in the bank they got into security things. If you're in there too long they just switch off and you can get half way through what you're trying to do and bingo. You couldn't even download emails. More than 5 or 6 pages would drop out" (2)

Cropping systems simulation (APSIM)

Knowledge of APSIM

Knowledge of APSIM varied from nil to detailed. Of the 16 farmers interviewed about APSIM seven had immediate brand recognition; five were confused between APSIM and APSRU (the research group which developed the APSIM model) but had varying degrees of knowledge of APSIM once the difference was explained by the interviewer; and three had not heard of APSIM before the interview. Interviewees' APSIM knowledge is summarised in Table 6.

Table 6. Knowledge of APSIM

Knowledge of ASPIM	High	Medium	Low	Nil
Number	2	4	6	4

A "High" score was given to a user who discussed integration of soil monitoring, SOI (seasonal climate forecast) and simulation; benchmarking yields against their yield potential in a given season; "what-if" simulations for making crop-choice and plant/don't plant decisions; comparing water use efficiency of various rotation options and using APSIM as a research tool in conjunction with on-farm trials to introduce a new crop into the system.

A "Medium" Score was typified by the following comment, which indicates a general understanding of most of the main elements of APSIM:

"I guess it's a computer based management decision/assistance tool that uses weather forecasting and puts in a big range of parameters to help you generate a decision for a particular requirement… whether we should be planting late or early or what variety choices for specific results for a summer crop."

A "Low" score was given for a comment such as the one below, which indicates recognition that soil water is one aspect of APSIM, but the computer-based simulation capability is not articulated.

"Some of the things are ongoing and the tests on how much moisture is in the ground and how much moisture the soil will hold. I suppose there is a pattern there if you've got this much moisture and average sort of rainfall and what stage your crop will get through to and the risks involved."

Use of APSIM to support decision making

Four interviewees reported use of APSIM to support management decisions, and two indicated their intention to continue using it. In all cases, consultants operated APSIM - interviewees did not directly use the model themselves.

The interviewee who articulated the most extensive use of APSIM used to it address decisions concerning crop choice (e.g. decision to grow corn in a la Nina season), time of sowing and opportunity cropping. It was also used to support the evaluation of field trial designed to explore the performance of lucerne in a crop rotation. His latest application of APSIM was in negotiating a crop loss insurance claim where he used APSIM to demonstrate the potential yield of crop.

Another interviewee described APSIM's application to the decision of crop choice, which resulted in a decision not to grow cotton on marginal soil moisture:

> *"Because of the modelling we made a decision to plant sorghum not cotton and it was a combination of price and but more importantly the fact of that sub-soil moisture was quite limited."*

A fifth interviewee, after asking for and receiving an explanation of APSIM use in farm management could visualise APSIM's potential, as illustrated through the following father and son conversation which took place immediately afterwards:

> *Son: One of the part and parcels of this zero tilling was to be opportunity cropping … but every year we seem to look at the double crop and say "do we do it or don't we do it". You um and ar and this year it was just "well we've got the seed, it's going to be thrown out next year so we'll put it in the ground and see what happens".*
>
> *Father: We have been really really cautious haven't we?*
>
> *Son: We could probably be verging on too cautious but we don't know.*
>
> *Father: Had we used that modelling we might have planted those in some situations. But really if you look back to the last few years if the APSIM had of said yes, it would have been wrong. It might have confirmed our gut feelings and said no as well." "Say it cost $2,000 a year to run but you went in and put in chickpeas but just made a few dollars compared with fallowing and then you could be $10,000 or $15,000 in front of what you would be with chickpeas, if that's what it [APSIM] told you to do than its going to pay for itself in one hit."*

Soil water and nitrogen monitoring

A number of interviewees also indicated they participate regularly in deep soil water and N monitoring (soil characterisation of soil water and N is required for APSIM use), including three of those who reported APSIM use, and two mentioned this information was provided through a consultant. An indication of the significance of soil water and N monitoring is illustrated in quotes from two interviewees:

1. *"I guess the soil coring is just a big thing we take for granted these days. Looking into moisture and also being able to budget our crops that we use on a regular basis I guess. Especially with cotton, it's one we've learnt the hard way …that if we don't know exactly what we started with, we would get our bum kicked big time. Not so much the nutrition ...but more the moisture side of it. We might think we have a full profile then we find there's only 50% to 60% wet."*

2. *"You just can't farm today without soil tests. You just got to have it, that's all there is to it"*

Reasons for not using APSIM

Four interviewees provided reasons for not using APSIM included:

1. *"I'm a dry land farmer – I can only plant when it rains, so the model is not relevant."*

2. *"Climate variability overrides everything else."*

3. Not sure how useful it is: *"No one knows how much rain there will be. 1000 years of data still don't know how much there will be this year."*

4. One farmer provided three reasons:

- *"I've had a few discussions with [consultant] about this lately and I suppose it involves a whole lot of things but basing any decision now on history, there is a component to the APSIM that is based on historical yields and things and weather. This weather is definitely changing."*
- *"My biggest problem is weather forecasters can't get it right so how's APSIM going to be right?"*
- *"It takes a lot to convince me because everything costs money. That's the bottom line. Everything costs money."*

Of these, two had not participated in any discussions about APSIM or FARMSCAPE.

APSIM/FARMSCAPE discussion

Six interviewees indicated they had participated in discussions about APSIM/FARMSCAPE, which included all five interviewees who had used or could visualise a use for APSIM in management decisions. Four indicated that a consultant has been involved in the discussions. Two indicated that this had been through the consultants' discussion groups, and one interviewee reported a direct link with FARMSCAPE researchers. Another also reported a history of involvement with the FARMSCAPE project. One interviewee indicated his intention to use APSIM, in conjunction with his consultant, for the upcoming season.

One interviewee, who was not an APSIM user, but indicated that he was able to visualise its use, reported that his neighbour, who had participated in discussions about APSIM with him and 2 consultants, was sceptical, but nominated two other farmers who are satisfied with it.

APSIM adoption score

APSIM adoption scores were determined on the basis of the knowledge and use of APSIM (Table 7, over page). This was assessed qualitatively on a multi-criteria basis that included: brand recognition; knowing the inputs that are required for using the model; understanding the biophysical processes simulated by APSIM; knowing the model outputs; ability to interpret the outputs for decision making; using the product in decision making. Table 7 also identifies interviewees by the location of their farms and by their consultant.

Table 7. Relationship between APSIM use, location and consultant

Farmer code	Location code	APSIM score	Consultant code
F1	A	1	A, B
F2		2	A, B
F3		2	A, B
F7		4	A
F4		3	B
F5		2	B
F12		4	A
F11		5	A
F13	B	6	C
F7		4	C
F9		5	
F8		4	D
F10		5	C
F14		6	C
F15		6	D
F16		6	D

Location A has a production environment characterised by level topography and soils of high water holding capacity. Location B, while still highly productive, encompasses more variable landscapes, including hilly country and is generally regarded as less productive than Location A.

Interviewees referred to four consultants in total (represented by codes A, B, C, D). Consultants A&B have a history of interaction with the FARMSCAPE project researchers – one through participation in FARMSCAPE project activities, and the other through completion of the FARMSCAPE Training and Accreditation process outlined in Chapter 1. Consultants C and D had no prior FARMSCAPE experience.

The farmers in Location A are associated with APSIM user scores ranging from 1 to 5, and one or both of consultants A&B. Location B farmers were restricted to scores from 4-6, and one or both of consultants C&D. The incidences of high knowledge and use of APSIM occurred only in Location A. In Location B, with consultants C and D, farmers had low brand recognition, and low understanding of the potential for APSIM to add value to farm management decision making. The results suggest a strong relationship between who the consultant was and farmer understanding and use, or potential use, of APSIM.

It is important to note that FARMSCAPE project staff had worked with the more innovative farmers in Location A during the FARMSCAPE project. However one interviewee, who reported benefits from, and ongoing demand for, APSIM, as illustrated by the following quote, had no previous interaction with FARMSCAPE researchers:

> *"So we, yes, in fact we've just only been onto him a week ago saying it is time to run a model for this year to work out what we are doing. So, yeah, we use that all the time. In fact that model last year, we are probably $500, 000 better off than what we would have been than if we hadn't had that model, because that model said plant in the last couple of weeks of December and the first couple of weeks of January. My friends who aren't in the group, and just had a gut feeling, they planted in October and they grew ¼ tonne to the acre, and I grew 2 ½ tonnes to the acre. So it was very worthwhile, and that is why I am absolutely sold on it. There's a lot of, the information you feed the model, it is all logic, it is all common sense anyway, and if you don't have moisture you should probably wait. But this just emphasises that, and can plot dates and things like that, so I'm very much a believer in that".*

The results do not provide evidence of diffusion of APSIM beyond the geographic region where the original FARMSCAPE team had worked, and nor beyond the client group of consultants who had liaised closely with the FARMSCAPE team.

Other DSS products: Howwet?, Whopper Cropper and WheatMan

WheatMan and Whopper Cropper are decision support tools incorporating cropping systems simulation. Whopper Cropper[7] is a database of pre-run APSIM simulations and, as for APSIM, scenarios can be constructed showing the range of potential yield or gross margin outcomes generated from 100 years of weather data. WhopperCropper differs from APSIM in that it is a database and uses data appropriate for a *district* and does not provide data at a point or paddock scale. Intensive modelling of a paddock requires running the APSIM model specifically for that paddock.

Howwet[8] uses APSIM soil routines and farm rainfall records to estimate how much plant available water has been stored in the soil and the amount of organic nitrogen that has been converted to an available form during a fallow (non-crop period). HowWet? provides an approach to learning about what is happening to soil water and soil nitrate, and also calculates yield expectations and nitrogen fertilizer needs.

A majority of interviewees had heard of Wheatman and about half had heard of HowWet. Only two had heard of Whopper Cropper. However, though some attended workshops, demonstrations and field days in which one or more of these products were demonstrated, none had used any of these products. One had a copy of HowWet but has never used it. Two indicated that they expected their consultants to know about these products.

The following response is from a farmer who knew about Wheatman and HowWet:

> *"We used to have grower meetings with a group and it was run by Wesfarmers and they did put it together. That's where we did see a lot of this sort of stuff. There would be a group meeting with a computer and a program and you would play with it probably in the earlier stages. We don't tend to do that any more or as much. Occasionally they would have a meeting, but not like they used to. I also think back then we probably did a lot more changes then. There are always a lot of changes but I think there were some bigger steps just back then and the need was greater too. It gets to the stage now that I might be on the wrong track again but I think that there is only so much time you can sort of do and sometimes the agronomist has to pick up some of that sort of space there and try and feed that to you. You just get bogged down. You just can't stretch yourself far enough at times because we are expected to work more and do more."*

Controlled traffic technologies

Controlled traffic farming may be viewed as the leading edge in a progression from conventional cultivation, minimum tillage and zero-till farming as technologies that seek to minimise the harmful impacts of modern cropping on soil physical conditions. Controlled traffic requires that all machines travelling in a paddock be restricted to fixed tracks (hence reference by farmers to tram lining or tram tracking). This technology is discontinuous in that while standard tractors, harvesters, seeding gear and spray rigs come in different widths and wheel configurations, controlled traffic requires that all this gear be standardised so that wheels of all machinery travel on the same tracks and implements (harvesters, seeders, fertilisers, spray rigs) cover the same span (usually based on 3 m centres). The technology also entails the use of a guiding system to allow accurate re-tracking of tram lines, though some farmers attempt to do this manually. Entry into controlled traffic requires significant financial

[7] See http://www.apsru.gov.au/apsru/Products/Whopper/NationalWhopperCropper.pdf
[8] See http://www.apsru.gov.au/apsru/Products/HowWet/HowWet%20Fact%20Sheet.pdf

inputs, re-design of paddocks and often redesign of machinery and learning about new technologies such as remote navigation systems. Farmers getting into this technology need to have a strong belief in the final outcome of improving soil structure and the financial benefits that will follow into the future.

Four of fifteen interviewees (one farmer not interviewed on this technology) were practicing controlled traffic and using BEELINE guidance systems (a product combining GPS and automatic steering technologies; available since 1997). Two had installed BEELINE systems recently. Another four farmers reported that they were in the process of converting to controlled traffic. Three were considering it but not convinced of the value, given the high cost of converting. Two were still struggling with converting from conventional tillage to reduced tillage.

As for computer purchase/use and APSIM, a controlled traffic adoption score from 1 to 6 was assigned. An example of a farmer profile or response provided in most categories is given below.

Score 1: The farmer assigned as an innovator has been practising controlled traffic for 8 years having re-designed and re-engineered all his equipment including machinery required for growing and harvesting cotton. He is now looking at selective weed spraying technology; there is no commercial product on the market, looking to modify research gear for counting weeds, is aware of history of failure of commercialisation of Australian patented technology. His rational for pursuing this is that he could use more expensive chemicals if the rate per hectare is reduced to 10%. He would then use a mix of herbicides to avoid development of herbicide resistance.

Score 2: Those receiving this score were more recently converted and were mostly buying purpose built equipment rather than pioneering the technology:

> *"We've got BEELINE. All our operations are computer controlled. We've got a sprayer. [Name of another early adopter] got one too but I mean he jumped after I jumped. I was the first one in the district to buy this high clearance, high productivity sprayer. It's very big and very fast. It's all computer controlled inside. The BEELINE is now in that also.*

Score 3: This group was in the process of converting to controlled traffic. Most were taking a gradual approach in order to spread the cost. A typical farmer in this group started tram-tracking 10 years ago to make spraying easier and has been gradually changing gear to fit in with controlled traffic technology. He is waiting for "a good tax year" to change all the rest of his machinery in one go. When asked about steering guidance technology he replied: *"If you supply me the 80 grand - I'll fit it right now"*.

Score 5: *"I think in our country, if we never did [get into controlled traffic] I don't think it would ever worry us because the self mulching black clays they seem to form themselves back into shape pretty well plus we haven't had a wet harvest since '98…. [Neighbour's name] over here, he's looking at going into tram tracking. Well I sort of am looking – it just makes it easier to spray and all that, but I don't think I'll get really serious about it until GPS's get a lot cheaper and then I think everybody will jump in then. GPS's are good, but they're a bit dear for what you get."*

Score 6: *"With discs which is the main no till implement, once you get heavy dew you're stuck. You can't go. If you get a shower of rain in the afternoon and you've got 2 hours to finish the paddock you've got to knock off. It's time to go home. If it sticks to your boots when you're walking on black soil you've got to stop. It's no good. Whereas conventional you can plough through it and keep going."*

Integrated Pest Management (IPM)

Eleven of the sixteen farmers interviewed grew, or had grown cotton. They had all practised integrated pest management (IPM), and those from one location had participated in an area wide management programs. Most farmers employed an insect scout, although one of the most innovative IPM users preferred to do his own scouting.

> *"That cotton experience [with IPM] has translated right through the whole farm. It's a big mindset/attitude change. It's a big thing to go from 'I think I have a problem and I've got to whack them' to 'I think I've got a problem and we'll just wait and see what happens'. That's as simplistic as it gets. But that is the hurdle."*

Yield monitoring and mapping / site specific management

Three interviewees had either installed a yield monitor or employed contractors who used yield monitors. Two farmers had used satellite technology to identify the variability on the farm. Another two farmers were yield mapping but neither had moved to variable-rate input application technologies. Two other farmers expressed interest in yield mapping, and could visualise how the technology might be applicable to their farming system. These included improved monitoring of spray drift, and looking at the impact of water movement across the farm.

Reasons given for not using variable rate technology related to the cost of changing equipment, as indicated by the following statement:

> *"I can't see the benefit… to get the yield mapping to reduce your fertilizer. The complexity in air seeders and mechanics to drive those variable rates is expensive. The headaches aren't there. You're better off (without it). You lose half a day because your variable rate has got its knickers in a knot……. Simplicity is important. You can't afford to have complex things and they break down on you, you've got to be able to fix them quickly."*

Other practices mentioned

Interviewees were also asked to nominate any other high-tech innovations on the farm. Practices mentioned, by interviewee, included:

- Trickle irrigation trials with T Systems Australia and DPI (WUE), and DNR&M Lysimeters for deep drainage measurement. The same interviewee also has tissue analysis done, measure yield of cotton and lint.
- Centre Pivot irrigation
- Disease free piggery
- Experimenting with Industrial Hemp
- Using saline water to grow prawns in dam (trial at DPI facility)

Technology adoption classification

Table 8 summarises the technology adoption scores assigned to interviewees for selected technologies. The group of Wesfarmers agronomists who nominated the interviewees were asked at the same time to describe, using the technology adoption bell-shaped curve, the adoption category to which they thought interviewees belonged, and this is also presented in Table 8.

Table 8. Classification of farmers into technology adoption groups, as defined by agronomists and the adoption scores for three discontinuous technologies

Interviewee Code	Computer/ Internet score	Controlled Traffic score	APSIM score	Agronomists' Nomination
F1	5	1	1	Innovator
F2	2	2	2	Early adopter
F3	5	2	3	Late majority
F4	5	5	3	Early majority
F5	3	3	2	Innovator
F6	3	3	3	Early majority
F7	3	2	4	Early majority
F8	3	n/a	4	Late majority
F9	5	5	4	Early majority
F10	5	5	5	Late majority
F11	3	3	5	Late majority
F12	3	2	4	Late majority
F13	5	3	4	Late majority
F14	6	3	6	Conservative
F15	3	6	6	Early majority
F16	6	6	6	Conservative

It is apparent from Table 8 that very few interviewees are consistent in their technology adoption behaviour across the three technologies. For example, two of the most innovative users of APSIM (a score of 1 or 2) were relatively slow to purchase a computer.

Self assessment

In addition to technology adoption assessments made by the interviewers and agronomists, to conclude the interview, interviewees were shown the bell shaped adoption curve, given a brief explanation of the technology adoption groups, and asked to nominate where they thought they fitted.

A minority of interviewees appeared comfortable in assessing themselves. One of the two classified by the Wesfarmers agronomists as an innovator had no hesitation in answering:

"I suppose I'm the [colloquialism implying foolishness] up the front end [of the bell curve]".

However, many struggled to come up with an answer, for example, one interviewee who was categorized as Late Majority by the agronomists, offered the following reply:

> *"Well maybe we're up the top [mid majority]. We're definitely not in here [late majority]. For instance, IPM - I would say that I was probably in that section [early adopter]. I wasn't the earliest but I caught on pretty quick. Controlled traffic I guess I'm really about half way. BEELINE has been out for quite a number of years. It was just the matter of the money side of it that was stopping us and trying to justify it but now that we've got it I should have had it years ago. When it comes to computer use as in the farm books and things like that, I think you would have to nearly put us back to this side [late adopter]."*

An interviewee who was categorized as an Early Adopter by the Wesfarmers agronomists responded with:

> *"We were talking about IPM, I'm probably in this [innovator]. If you're talking about BEELINE and tram lining I'm probably down here [early majority]. You've got to remember that the guru of tram lining lives in this area. I'm probably not here [Innovator] because …….[I] hate spending money and I hate a sandpit full of machinery. I don't know. You'll have to work that out yourself. You put across there whatever you like. I suppose I'm pretty innovative. I'm also a bit pragmatic in that I have no desire to be the first. I'd much sooner somebody else made all the mistakes and I can come along and pinch his idea and do it better.*

An interviewee who was categorized by the Wesfarmers agronomists as Late Majority responded:

Interviewee *Sometimes I sit right down here [conservative].*

Wife *Depends on your interest.*

Interviewee *But what's interesting is - like zero till now and we started that years ago and we saw the benefits and all that, but as much as we knew it was good, we stepped out of it, because grain prices collapsed and we went into cotton, and I firmly admit, we've suffered more damage here in the ten years we grew cotton from soil erosion than what we have in the last 100 years. But that's something you have to wear.*

The other thing is technology. Some people pick it up, others don't. It's a matter of are you forced into it in a way, or do you recognise the problems. Like zero till, all this water comes out of these valleys at a speed, so once you could see some sort of technology that looked like helping you, you go for it, or start with it, but then there are other areas over on [another region]. They're just ploughing around and around and around the paddock like they did fifty years ago, because they don't get any water that runs across their paddock. There's no need to change, they're just not suffering any damage so there's no need to change.

Wife *It's working so they don't change.*

Interviewee *That's right, but we were getting gullies, it's a case of sometimes you're forced into picking up a technology, not because you think oh that's a good idea, but oh yeah, I'd have to sit in here [late majority] and whatever.*

Interviewee *And sometimes you're forced into change. Like simply forced, like, well I know when I came home from school to go farming, and bought this place, well I thought all I need's a tractor, a scarifier and a shearer combine, a set of harrows and that's it – whoopee! But today if you still farm like that, well we know the damage: compaction, and you lose your micro-organisms all that, and over time, people have said they're getting into zero till or reduced till and they've just seen the advantages, so that's the biggest thing that I think makes people change, is they can see the benefits.*

Sources of information that influence the adoption decision

We attempted to ascertain how interviewees went about gathering information and their knowledge networks (Table 9). We captured both the answers to the direct question "Where/to who do you look for information before adopting?" and references to sources and people that were made during the interviews. Table 9 shows the range of responses obtained from "visionaries" and "pragmatists". Given the difficulty in classifying farmers into one of the two groups on the basis of self assessment, the approach used to classify interviewees into the two categories was based on whether the interviewee showed innovativeness in any of the technologies investigated (a score of 1 or 2), and if so, were allocated to the visionary category.

Table 9. Information sources of Visionaries and Pragmatists

Information source	Subtypes	Visionaries (6)	Pragmatists (10)	Total
Farmers	Neighbours	4	4	8
	Leading farmers[1]	2	2	4
Farmer groups	Wesfarmers	3	1	4
	IPM Group	2	1	3
Rural Press		1	3	4
Specialist magazines			3	3
Media		1	2	3
Agronomists		3	5	8
Accountants		1		1
Scientists		3	2	5
Kondinin			1	1
DPI&F/NRM&E		3	3	6
Ag. Input suppliers		2	1	3
Technology supplier		1	3	4
Field days		1		1
Interstate travel		1		1
Overseas Travel		1		1

[1]Farmers mentioned by name who are locally known as pioneers/leaders in the area being discussed.

There were only small differences between the two groups in the type of sources referenced (e.g. only Visionaries mentioned an accountant, field days and travel, while the Kondinin group and specialist magazines were only mentioned by pragmatists) the 6 "visionaries" referenced nearly as many sources as the 10 "pragmatists". This is only partly explained by the fact that a few of the pragmatists were less inclined to elaborate when responding to questions. Significantly two pragmatists specifically referenced visionaries, as illustrated by the following quotes:

Example 1 - Pragmatists referencing visionaries:

Father: *A lot of things that are happening on the Downs now are happening as a result of him.*
Son: *You've only got to look at what he did with the cotton picking. He thrives on doing something different, and he's lucky enough because he has the bank balance to do that.*
Father: *It's like anything, you've got to see how every other poor bugger goes doing it first and then you jump on the bandwagon.*

The same pragmatists also referenced other innovators (not in study sample):

Father: *I know fellows, who are doing it [using ASPIM] and are quite happy with it.*
Son: *Over here at [Innovator's location and name] and [Innovator's name] are pretty well into it, aren't they?*
Father: If we did take the step of actually used it...

Example 2 - Pragmatists referencing visionaries:

> *"[Innovator's name]'s had a lot of advantages. If we've been farming the way we farm now with control trafficking and zero till, we would probably be 100% ahead. We've done well to get where we are. We could probably be 100% better again if we had that may be 5-10 years earlier, which is what [Innovator's name] did but in saying that he's had to make an awful lot of mistakes to get to where he is now. We just jumped in and really didn't have to make any mistakes. We made a few little mistakes but really compared to what [Innovator's name] done…. He's had to all the hard work and that's why it's important to have blokes like that."*
> *"It's not as dramatic as what [Innovator's name] did but you sort of have a bit more courage to be the first one."*

The visionary and ‘Location A’ farmers were commonly referenced by farmers from both locations in relation to tillage technology, and there was no evidence to suggest that referencing these farmers was a high-risk activity. Visionary farmers’ systems had attracted a lot of interest, and the pragmatist farmers appeared comfortable with the notion of implementing these innovative farming techniques on their own land.

There were no instances of farmers indicating that they rejected a technology because a visionary farmer uses it, or that they regard following such a farmer’s practices as high-risk.

In summary, the interview data has not provided evidence of a referencing chasm between visionaries and pragmatists, which could explain the adoption or non-adoption of discontinuous technologies within the group we studied. Also significant that interviewees who display innovative adoption behaviour in relation to one form may not do so in relation to others. The implication of these results are discussed further in Section 4.4.

Case Study 2: Technology adoption among WA livestock producers, with focus on "Pastures from Space"

Computer ownership and use

All of the 12 interviewees owned a computer and the timing of the first computer purchase ranged from to 1- 24 yrs ago (Table 10). Most had been connected to the internet for between 3-6 years. One interviewee, who had purchased a computer in the 1980s, indicated that his connection took place 10 years ago, whereas the shortest period of connection was 1 year, reported by an interviewee who had only owned a computer for one year. Table 10 shows a range of reasons for the computer purchase, but, unlike the Darling Downs interviewees, none mentioned the purchase of computers for BAS requirements and none indicated that their enthusiasm for new technology was behind the purchase.

Table 10. Timing of and reasons for computer purchase and timing of internet connection

	80s	1990s	00's
Timing of first computer purchase (number of interviewees)	5	5	2
Reasons for purchase	- financial recording / office work - grown up with computers	- to make tasks easier - because computers were becoming popular - family member wanted one	- purchased for child's study - felt he should learn more abut computers

When asked what the computer is currently used for, all interviewees' answers fell into one or more of three broad categories: record keeping (production and/or financial), communication (e.g. emails) and information/research. Two volunteered that the computer was used for accessing the Pastures from Space technology and one mentioned that it was used for digital photography. All interviewees indicated that the internet was used for email, five used it for accessing weather information, and other internet applications mentioned included banking and accessing research/technical/marketing information.

All interviewees except one identified themselves as being either the main user of the computer in the household or using it at least as much as other users in the household. One user said his wife looked after record keeping on the computer, and his response suggested she was the main user.

Interviewees were given two scores (both from a range of 1 to 3) in relation to computer ownership and use, which appear in Table 12. One referred to the timing of computer purchase, using the timeframes reported in Table 10, and the other related to computer use. Interviewees who indicated high use and a wide range of computer applications were assigned a score of 1 and, at the other end, interviewees who reported minimal use or low skill in computer use were assigned a score of 3.

Pastures from Space

Motivation to use Pastures from Space technology

Interviewees reported a range of, and sometimes more than one, reasons for becoming involved with Pastures from Space, but most did so by responding to an invitation to participate in activities to learn about the technology from either a researcher or consultant (Table 11). Of these, four interviewees indicated that it was through participation in a farmer group that they became aware of the opportunity to participate.

Table 11. Reasons provided by interviewees for becoming involved with Pastures From Space.

Reason for involvement with Pastures from Space	Number of responses
Invitation to participate in Pastures from Space activities from researcher or consultant	9
Introduced to opportunity through farmer group	4
Interested in new technology	4
Inaccuracies /inefficiencies in feed estimation	2
Desire to be guided by objective information	1

Four interviewees indicated that their interest in new technology motivated their participation. Two nominated inaccuracies/inefficiencies in feed estimation as the motivator to adopt. One interviewee said that he was attracted by the opportunity to be guided by objective information for pasture management, and reflected on the difference in his cognitive style, compared to his father. The quote below elaborates:

> *"My father farmed, very much by the seat of his pants and he was quite good at it, and he's still alive now. He's still got a reasonable feel for what's happening, but I'm afraid I just don't have that – I'd like to have facts and figures in front of me, and I like to make decisions based on that, and just to do things on intrinsic… quite a lot of what we do is fairly intrinsic, but I'd much rather have facts and figures before me. So it was just another tool to assist us and that's probably what attracted my attention."*

Experiences with Pastures from Space

Interviewees reported that they were using Pastures from Space for the following tasks:

- to quantify the amount of feed in the paddocks (3 responses)
- for problem diagnosis and treatment (i.e. identify poor performing areas and target these for soil sampling) (3 responses)
- to conduct enquiries on a larger scale on their farm (e.g. large-scale on-farm trials and monitoring) (3 responses)
- To adjust stocking rates in response to information (4 responses)

Nine out of twelve interviewees said that Pastures from Space has helped with pasture management decisions. Not all elaborated on the benefits.

One interviewee reported a level of confidence in Pastures from Space, such that technology *superceded* his visual estimation approaches.

> *"It bricks up what we thought we were doing visually, by using, what is it, a tenth of a square metre, and walking in the paces, and doing it again, and that sort of thing, and estimating the amount of FOO that was available to sheep. And so the Pastures from Space does that more accurately, and we tend to rely on that more now than we did on our visual assessments."*

Others were more reserved in reporting benefits. For example the two interviewees below indicated that the technology was a valuable *supplement* to existing estimation approaches. However, their comments indicate that their existing way of making decisions has not been replaced by the new technology. The technology is valued for confirming 'gut feeling' for higher-risk management strategies (i.e. high stocking rates)

> *"I think the first thing is it puts actual measurement back-up to your own estimates or your own gut feelings and this was particularly necessary when we are pushing things as hard as I am because I am trying to achieve pretty high stocking rates. And when you are on the edge [pushing up against max achievable stocking rate] you need to be reassured that what you expect to grow or what you are seeing that there is available, as in the feed on offer, is supported by actual measurement".*

"It's a tool that aids decision-making. I don't think it's the be all and end all, it's just another string to our bow to aid decision-making" …. "I don't know whether we're one pace away, or five paces away, but we have a higher than average district-stocking rate so for me" …. " I'm able to sleep at night because I'm more confident in the decisions that we've made based on substantiated facts rather than just intrinsic feeling".

Another interviewee indicated that the greatest benefits of Pastures from Space were aiding problem diagnosis in the performance of the pasture, rather than as a direct guide for stocking rate adjustment.

"The decisions that we've probably made the greatest use of is the decision to say, well this pasture's not performing very well, we'll re-test the soil for major elements, and minor elements, and then re-seed it. That's been good, and also its been good that we can trace back our activities over a number of years and find out why something's happened, which we probably could have done anyway, but it makes you think a little bit more".

Two more interviewees also indicated that the problem identification and diagnosis benefits of the technology offered value, elaborating that it was the scale of enquiry enabled by the technology that offered the advantage over existing methods:

1. "What I wanted to see if I could get from Pastures in Space, was to try and get some way of measuring responses to fertilisers that were easier than rushing out in the paddock and trying to work out whether the sheep had eaten more of this grass, and more of that grass.

Currently when scientists do measurements, they rush out and do tiny 300mm or 250mm square patches of grass, and dry it and weigh it and say what the whole paddock does. We know that that is hit and miss and unreliable at the best, but I was hoping that Pastures from Space would give me a better handle on larger scale trial work. Like on a 30 hectare trial or something, you could get some sort of a handle on it".

2."Because we have a really large property, it enables us to monitor that in a much more efficient manner, hopefully in the long term. We can't go over 96 paddocks in a day, and we're always looking at trying to push the 8 ball.

"But as far as benefits of the enterprise, we saw that being able to monitor more effectively what the productivity was occurring on our paddocks, and to change our stocking rates, and the timeliness of those, and to match them with market specifications and turn offs, we could see in the long term, that would increase our profits."

One interviewee reported difficulty quantifying the benefits, and proposed that this presented a challenge for wider adoption of the technology:

"And at the end of the three years we're still working out how we can get it adopted on a wider scale because we can't work out how we're making a big killing out of it". And (same interviewee) "I think it's reasonable to say that I've been proven stone motherless wrong yet, it being the same way, I can't stand up and say we are doing so much better than everybody else in the district. So we haven't been proven right, but we haven't been proven wrong either."

While interviewees rarely reported difficulties in applying the technology, one interviewee highlighted the discontinuous nature of the technology:

"I don't think it's just a one step process of receiving information instantly and then knowing what to do. Whereas the process would probably take us three years or longer maybe to actually work out how to use it".

Accuracy, reliability and credibility concerns Most interviewees did not have difficulty visualising the benefits of the technology. However, some indicated that the benefits are not being delivered to their full potential or as initially expected. Five interviewees' expressed concerns with the timeliness and reliability of delivery of Pastures from Space satellite images, associated with cloud cover.

While one interviewee reported that Pastures from Space's satellite technology was 'extremely accurate' in determining pasture quantity, 3 reported concerns
Problems with accuracy and reliability appeared to be tolerated by some interviewees for three primary reasons:

- Firstly, some see themselves as participants in the technology development process. For example, in response to a question on his intention to continue using Pastures from Space, one interviewee reported: *"There are a couple of riders I would put on that [ongoing use of the technology] and one is that they have got to be able to deliver on a more certain basis than they are doing now. That isn't a complaint, that's just a comment because I know that we are still very much in a research era".*
- Secondly, some have indicated long time frames for full evaluation. For example one reported: *" I don't think it's just a one step process of receiving information instantly and then knowing what to do. Whereas the process would probably take us three years or longer maybe to actually work out how to use it"*
- Another interviewee reported that he spent the first year just thinking about whether the satellite was a credible proxy for what he saw on the ground.
- Thirdly, there was a comment indicating that problems will be tolerated when there is no financial cost involved: *"Yes, I'd be very interested to keep using it, and keep picking holes in it, and keep getting them to think about what they are doing so we can get it better, but under the current reliability and whatever else is available from it, there's no way I'd pay very much money to use it."*

Intention to continue using

Despite some doubts about reliability and accuracy, most interviewees intended to continue using the technology.

One interviewee who was possibly going to discontinue use cited succession issues in the farm business. His son, who was about to take over management, was less enthusiastic about the technology than him.

Another said that despite his high level of interest in the early stages of involvement, his interest was waning due to the technology not delivering on its benefits quickly enough, which provides an indication that not all interviewees will allow lengthy time frames for evaluation.

One interviewee, who also works as professional facilitator of other groups, commented on the importance of having technology reliability issues resolved in order to have success in the broader market. The interviewee highlighted the importance of providing professional backup and "hand holding" for Pastures from Space users, indicating that once users experience problems, they will rarely return to the technology.

Precision agriculture technology

Three interviewees used Precision Agriculture (PA) technology – two had adopted guidance systems and the third owned a yield monitor that came with the header, the latter being regarded as a costless bonus, rather than a deliberate purchase. His following statement illustrates his attitude to the technology:

> *'I have a header with a yield monitor, but I only just got that so that'll be the first season this year that'll be used. ….*

I think people get a bit wrapped up in saying, precision agriculture, yeah involves technology, I think technology isn't necessarily a computer. It's more how you apply information and how you change and how you react, or whether you react to changing conditions. So people talk about precision agriculture, I think people get a bit fixated in the technology and not so much in the actual action. That's very evident in cropping where people are spending enormous amounts of money on latest whiz bang bit of gear and probably not really thinking about its application. They probably could actually do the same job for virtually nothing just by changing the timing of when they do things.'

This interviewee said that he expected that yield monitoring equipment may be able to support his diagnosis and management of variable paddock performance. He also said that his expectations about the technology are somewhat tempered by his perception that the research is inconclusive.

Reasons provided for non-adoption of PA by other WA interviewees included:

- PA adoption not relevant, given the dominance of livestock enterprise on the farm
- uncertainty about value for money of this technology
- belief that the farm has too much soil variability for the technology to be suitable
- PA technology is not reliable.

In the technology adoption summary presented in Table 12, interviewees are assigned a score (1-4) in relation to PA technology. The scores are:

1 = PA technologies in use, interviewee clearly describes potential value
2 = PA technology in use, interviewee appears uncertain about value
3 = no PA technology in use, but interviewee has evaluated the potential value of the technology
4 = no PA technology in use, and interviewee does not appear to have evaluated its potential

Cropping systems simulation

There was very limited knowledge of cropping systems simulation among interviewees. Only two reported experience with APSIM and another technology called CropMan, and interviewees did not appear to be clear on the differences between the two. A third indicated that he had limited experience of cropping systems simulation on other peoples' computers to explore phosphorous use, nitrogen application, and time of sowing. However, he indicated frustration with a gap between the modelling and the practical implementation. He was unsure of the names of the models he had used and has not heard of APSIM.

The interviewee with the most experience with APSIM was interested in this innovation but indicated difficulty seeing how to apply the model to decision making. Despite this he appears to have experienced new learning about the crop production system:

Farmer: *They said, well, we've got this model, you put in your soil characteristics, and the model was right, it sort of said, no, you can't get any more than 4 or 5 tons of wheat. So we were very interested in that and then using that model we were going to try and put all sorts of different things through and try and determine where we were going and the difference between yield and time of sowing and variety and all these sort of things. So that's how I got interested, and I've been toying with the program ever since, trying to work out what's been going on. I've been having a little bit of trouble getting the program to run, mind you. It's thrown up a few interesting things but I think we're still no further down the track than we were before.*

Facilitator: *So has it helped you make decisions to this point?*

Farmer: *No, I don't think so. I think we're trying a few different things because of it. Like for us it showed up a couple of interesting things, there's the long season and the short season wheats and there's a critical time when you've got to switch from long season to short season wheats and that was very interesting. We've actually used that, and this is the first year we've done that. []So we'll see how that goes. But it showed up a few other things, it showed up probability of achieving yields, those sort of things were very good. It's interesting looking at the 100 year rainfall and it's got that history part of it, and you can sort of go back and say, well, this year was a bit like year whatever it was, 78 or something, what happened then? And then you can go back and run that and see what happened there. So on that side it's really interesting.*

Facilitator: So what's the main thing you'd hope to gain from cropping system simulation?

Farmer: *A best bet, I guess. It's interesting just to run your theories, it's very good for running an idea. So you say, well, what if we put it in really early and so on and all these sort of things you think about. It runs them and if it comes out as a really big difference you think, oh well, maybe that's worth trialing on ground. So it's really good, I really like it actually.*

As for PA, some reported that cropping systems technologies such as APSIM are of limited interest given the dominance of grazing in their farms.

In the technology adoption summary presented in Table 12, interviewees are assigned a score (1-4) in relation to cropping systems simulation technology. The scores are:

1= cropping system simulation technologies in use, interviewee clearly describes potential value
2= cropping system simulation technology in use, interviewee appears uncertain about value
3= no cropping system simulation technology in use, but interviewee has evaluated the potential value of the technology
4= no cropping system simulation technology in use, and interviewee does not appear to have evaluated its potential

Other DSS

No other DSS appeared to be in use by interviewees. One had previous exposure to PYCAL (The Potential Yield Calculator) developed by Department of Agriculture, Western Australia, (DAWA) to support decision making at planting and within season. Another used a model for estimating breeding values (in trial form obtained from CSIRO and DAWA), while another used "Pasture Watch" in association with research organisations.

Technology adoption summary

A technology adoption profile of each interviewee is provided in Table 12. By listing interviewees individually, the table highlights consistent early adopters, but also reveals individuals are not always consistent in their timing of technology adoption.

Table 12. Technology adoption summary.

Location	ID	Self assesment	Computer purchase	Computer score	Precision Agriculture	Crop simulation	Other
3	1	Visionary	3	3	3	4	
4	2	Visionary	2	1	3	4	Unreleased sheep DSS
3	3	Pragmatist	2	2	1	4	

5	4	Visionary	1	1	1	1	PYCAL
2	5	Split	1	1			
5	6	Visionary	2	3	3	4	DSS for sheep (trial version)
1	7	Visionary	1	1			
5	8	Visionary	2	3	4	4	
4	9	Visionary	3	2	4	4	
5	10	Visionary	1	1	1	1	MIDAS
4	11	Visionary	1	1	4	4	
5	12	Visionary	2	1	1	4	

Scoring outlined in text and summarised as follows:
Computer purchase / computer score: 1= high use / wide range of computer applications; 3= minimal use / low computer skill
Precision agriculture: 1 =PA technologies in use, interviewee clearly describes potential value; 4 = no PA technology in use, and interviewee does not appear to have evaluated its potential
Cropping systems simulation: 1= cropping system simulation technologies in use, interviewee clearly describes potential value; 4= no cropping system simulation technology in use, and interviewee does not appear to have evaluated its potential

Adoption category

Interviewees were asked to describe where they sat on an adoption bell curve. Ten interviewees identified themselves as innovator/early adopter types, but two qualified this, saying that they were not innovators, but early adopters. One interviewee said that he mainly fell into the majority category. One interviewee said that he was an early adopter on livestock technologies, and majority on cropping technologies

Interviewees were not consistently innovators/early adopters for other technologies. Timing of computer purchase was no predictor of innovativeness. For example, one interviewee who identified himself in the majority category was one of just three who had adopted PA technologies.

Two interviewees pointed out that cost of the technology influenced timing of adoption.

Influences on adoption and sources of information

Farmers' responses to the questions on their sources of information are summarised in Table 13. Of the responses indicating that CSIRO, Dept Ag, scientists/researchers (organisation not specified) were a source of information, six indicated that this took the form of direct, personal contact. Of these, one interviewee indicated that he had tertiary level agricultural training and was part of a professional agricultural science association, and had connections with DAWA and the University of WA over the years; and another interviewee was himself a consultant, and another worked as a part time modeller.

The only interviewee to identify himself in the pragmatist (majority) category, nominated other farmers only as his information source prior to adopting. For the remaining interviewees who nominated farmers as an information source, farmers were not offered as the first answer and any confirmation that farmers were used was often in response to prompting.

Table 13. Farmers' sources of information

Information source	Visionaries (no.)	Pagmatists (no.)
Experience	1	
Other Farmers	11111	1
Farmer groups / networks	11	
Rural media	1111	
Agronomists / consultants	1111	
Scientists	11111	
Dept Ag	111	
CSIRO	11	

Sources of information mention in other case study interviews – i.e. family, accountants, chemical retailer, technology suppliers, field days, travel – were not mentioned by any interviewees in this case study.

Comments on farmer referencing

All of the WA interviewees who placed themselves in the innovator/early adopter category indicated that farmer referencing was not required to complete the decision to adopt a new technology. The only farmer in the pragmatist category indicated that he referenced early adopters (Table 14).

Table 14. Farmers' comments on referencing.

Category	No. responses	Comments on farmer referencing
Visionary (innovator or Early adopter)	8	All farmer referencing not required
Split between visionary and pragmatist	2	Will reference others if others using technology; will reference if the innovation is financially risky; looks to other producers "a fair bit" - about 50% of the information for the decision is based on others' experience, but doesn't always reference innovators.
Pragmatist	1	Looks to other producers for feedback on technology and generally requires evidence from other farmers before adopting; looks to early adopters

Case study 3: Technology adoption among Birchip grain farmers, with focus on Yield Prophet

Motivation to subscribe to Yield Prophet

Interviewees were asked why they became interested in subscribing to Yield Prophet. Table 15 summarises the one or more reasons provided by each of the 15 interviewees who had a Yield Prophet subscription (either current or expired).

Table 15. Reason for first subscribing to Yield Prophet

Reason	Introduced through association with BCG and/or CSIRO	Approached to become involved by consultant or others	Desire to learn what YP had to offer	Family connection	Credible performance of YP in 2002	Improve N management and/or production systems knowledge
Number	9	5	7	2	4	3

Most interviewees indicated that they became involved with Yield Prophet through their association with BCG (some occupied positions on BCG committees and/or BCG board). Two furthermore

indicated that they subscribed to support the BCG with a new initiative. Two interviewees said they were involved with Yield Prophet since its inception in 2002 and also had direct contact with CSIRO researchers at this time.

Three stated that they became involved in Yield Prophet because the principal consultant supporting Yield Prophet approached them to do so. They indicated that they had a high level of confidence in the consultant's judgement of the value of the technology. Two others said they got involved because they were approached to do so. One did not identified the person who approached them, the other said the BCG invited him to participate to supply a paddock in the program he supplied a paddock in 2002.

Some family influence was evident, with one interviewee noted that having his father on a BCG committee was influential in his decision to subscribe, because his father was enthused by Yield Prophet. Another noted that he had been watching his brother's Yield Prophet paddock with interest, but did not say this was the main reason for getting involved. Both interviewees who cited a family connection, were new subscribers in 2004 after obtaining feedback from family members who subscribed in 2003.

Several subscribers also indicated their interest in Yield Prophet related to wanting to learn more about what the model had to offer, indicating that the technology was "novel", "seemed promising" and "worth evaluating". For some this was in addition to citing their association with BCG as a motivator to adopt. Three interviewees pinpointed specific areas of interest as their reason for subscribing:

- to improve knowledge of cropping systems, including water use, subsoils and crop wilting point
- to fine tune N input in wet years
- to better target N input.

Another contributor to the decision to subscribe for four interviewees was the performance of Yield Prophet's simulation of trial sites in 2002, which was regarded as credible, and this contributed to the interest in Yield Prophet. Three of these interviewees mentioned that the motivation to subscribe arose out of a desire to assess the information in their own farming environment after seeing the Yield Prophet in 2002.

Two interviewees specifically mentioned that Yield Prophet was worth investigating because it was a not a costly technology to trial (this issue was also raised by the WA interviewees).

Interviewee expectations from Yield Prophet

When asked what they expected to gain from Yield Prophet, three interviewees were not specific and indicated that they simply wanted an opportunity to evaluate it. Others said they would evaluate Yield Prophet for specific purposes including:

- to guide an N management decision (5 responses)
- to support other management decisions e.g. crop mix / rotations, risk management (2 responses)
- measuring and monitoring of crop performance (2 responses)
- to stimulate discussion of new ideas, improve knowledge of production systems (soil, water, crops, climate and their interactions) and possible improvements that could be made (10 responses), rather than rely on their observations for understanding the production system (1 response) and another to add to current gut feeling in farm management (1 response)
- to improve forward planning and/or risk management (2 responses)
- to improve farm management practices to make more money (1 response)

Some stated that they were not expecting to change management, in the short term, as a result of the technology because it could take several years to be confident with the technology.

In 2003, the expected applications were less defined whereas later subscribers (i.e. 2004) were more specific in their expectations of Yield Prophet, which often related to N management.

2004 re-subscribers

Four of the interviewees in 2004, who were also interviewed in 2003, were in their second year of subscription. They were asked what motivated them to renew their subscription in 2004. Two interviewees who resubscribed were uncertain about the value of Yield Prophet to management and suggested that their reason for renewal was their connection to the cropping group and desire to support the initiative. Both reported accuracy concerns. A third similarly indicated that the 'people' involved in Yield Prophet was the main motivator to renew, but that Yield Prophet provided an objective supplement to his assessment of the crop's performance during the year. In other words, because Yield Prophet indicated that the chances of a good yield weren't high, it confirmed his decision not to spend money on inputs, even though the crop appearing to be going well when assessed visually. A fourth interviewee renewed to continue receiving information on the likely prospects of the crop.

Subscribers' experiences with Yield Prophet

In the April 2003 interview round, interviewees indicated that it was too early for them to describe how Yield Prophet was being used to support management decisions. For the September 2003 and August 2004 interview rounds, subscriber comments on the use and value of Yield Prophet are summarised below:

Yield Prophet and crop input (N) management

Five of the 15 interviewees indicated that Yield Prophet was an input into their decision-making on N management, but believed that they would have made the same or a similar decision in the absence of Yield Prophet. In these cases, Yield Prophet was often described as having a reassurance value – in other words, reinforcing their gut feeling, or confirming their existing management intentions. The remaining interviewees did not indicate that Yield Prophet influenced their management decision or explicitly said that Yield Prophet didn't contribute to the N management decision, although one did indicate that Yield Prophet was consistent with his own thoughts and actions. The quotes below highlight the difficulty some subscribers were having in seeing what value Yield Prophet adds to their current knowledge of their farm and/or management decisions.

> *"You know farming and you get a feel for things and you know at the moment that until we've had a bit of rain, it's high risk. And then you know also your paddocks that grow, that's a low fertility paddock, that's a strong fertility paddock and you say well you shouldn't have to worry about that one, this one perhaps needs some if you have certain amount of moisture then it makes it worthwhile. Then you'll get an economic response to it. But it [Yield Prophet] was good to play around with."*

> *"I don't suppose I've found it overly helpful in a lot of ways but I believe it's reinforced what we've been thinking and I appreciate it from that point of view. It's just reinforced our gut feelings." …..."I daresay you'd get some people interested but myself personally I don't believe that they're going to be able to do any better job than what we can do by gut feeling at the moment…"…. "the only advantage [to Yield Prophet] I can see is that supplying someone with the information from someone looking from the outside, that hasn't got gut feel, and is not emotionally attached to the operation -- and perhaps from that point of view it is a good idea. It certainly never hurts to get someone else's opinion. That is the only advantage that I can see - that is, that someone else is monitoring my operation and they might pick up something that I don't because I am attached to it emotionally".*

Three other interviewees also discussed the emotional element to farming. One elaborated on Yield Prophet's role in tempering an "emotional" inclination to fertilise a crop that is visually performing well during the growing season but has not had sufficient water to guarantee a good yield at harvest.

> *" [Yield Prophet] takes the emotion out of it."…. "Sometimes you get carried away with yourself. You look at your crops - nice and green, they're not under water stress. And then I'll*

go and make sure I get all the right chemicals out - expensive chemicals. I will go and top dress. ….But the reality is, in a month's time the days are going to get long and hot and with the amount of moisture we've actually had, they could fizzle out and die anyway. Whereas that Yield Prophet - it can't see the nice big green leaves on the short days. It just says, well, probability is that the crop is not good."

During the August 2004 interviewees, interviewees were asked to react to the climate reports generated by Yield Prophet. Subscribers appeared uncertain of the value of the seasonal climate forecasts and none provided a convincing account of how climate forecasting has been factored into management decisions. Another frequently noted issue was a belief that SOI (Southern Oscillation Index) is not relevant to the Mallee. Despite this, there was interest amongst interviewees in climate information – five said that they currently, or have previously, used a climate forecast service.

There was a strong indication from subscribers that Yield Prophet has limited value in a dry season because the appropriate management action to take under dry conditions is already known (7 interviewees), i.e. apply minimum inputs under water limited production, and that Yield Prophet needs to be used in a wet year in order to fully evaluate it. Two interviewees indicated Yield Prophet could be used to support N management in a barley crop, which is a more complicated N management problem (2 responses). There were statements from subscribers indicating that more experience with Yield Prophet is required before they can feel confident using it to support management (8 responses). Some were talking in time frames of years (2 responses). On the other hand, there were indications from farmers that Yield Prophet must show its value in a short period of time otherwise it will fail to make an impact (2 responses).

The value that interviewees placed on their personal experience in guiding management decisions is also highlighted by suggestions from two interviewees who suggested that Yield Prophet would be ideal for farmers who managed their farm remotely, or didn't have much experience on their farm. Two other interviewees also identified Yield Prophet as having potential to support finance applications – again, an application for Yield Prophet in situations where a farmers' intrinsic experience may not be regarded highly in the assessment of the application.

Supporting learning

Even though two thirds of interviewed subscribers expected Yield Prophet to provide a learning experience, only two reported new biophysical system insights, both resulting from the soil characterisation activities associated with Yield Prophet. One reported that he learnt about subsoil constraints and the other learnt more about soil N at different depths in the profile. Two interviewees indicated that Yield Prophet has provided a stimulus for discussion in group learning activities, with one indicating that he has learnt about Yield Prophet through group activities.

Two interviewees implemented on-farm trials to support their evaluation and use of Yield Prophet.

Model interpretation, accuracy and credibility

Use and interpretation of probabilities

The interpretation and use of model simulations in the form of probabilities of yield and protein outcomes was not specifically explored in the 2003-2004 interviews. However, it was noted that Yield Prophet output was generally not described by interviewees in terms of the probabilities of possible yield and protein outcomes. It was not clear from this round of interviews how interviewees made use of the probability distribution.

Two interviewees suggested that there could be difficulties in interpreting information presented as probabilities – both saw the value in probabilities but explained they took some time to understand, and thought they could be problematic for other farmers. One of the two, however, was the only interviewee to communicate the probabilistic information during the interview. One also thought that the biggest problem in making use of the probabilities is that at the time many crop decisions are made (e.g. nine months prior to harvest), the probabilities are so wide. In other words, the range of possible crop outcomes (e.g. crop yield) is so wide that it is difficult to know what target yield to plan for.

Model credibility and accuracy

Concerns with model credibility/accuracy did not emerge as a significant issue in the 2003 interviews. Given that this was first year of subscription, subscribers, at the time of interview, had not received an end of season yield prediction. The exception was one farmer who was concerned that given the contrasts in soil type across the paddock (often changing every meter), only soil testing 5 points within a paddock did not really capture and correctly represent the soil type in the paddock.

In the August 2004 round of interviews, interviewees expressed concern about inaccurate:

- yield predictions (6 interviewees)
- N comparison predictions (3 interviewees)
- sowing date comparison predictions (one interviewee).

Three of these interviewees noted that the consultant made adjustments to the model during 2003, but not always to the satisfaction of the interviewee (2 interviewees).

Not all of the interviewees reporting concern with inaccuracies and offered explanations of the discrepancy between simulated and actual yields. Where explanations were offered these included:

- a hot, dry day in Oct 2003 (3 reports)
- the APSIM model is not sufficiently customised to represent their local conditions, particularly soil properties are not currently correctly represented in APSIM (2 interviewees).

Three subscribers interviewed in August 2004, who thought that Yield Prophet's simulations were credible when interviewed on earlier occasions, had identified inaccuracies and lack of confidence in the model when interviewed in August 2004.

Among the subscribers who identified a prediction inaccuracy, or believed local conditions were not correctly represented, some treated the issue with greater concern than others. Model credibility was not necessarily the same issue as model accuracy. This quote illustrates this:

> *"We put a hundred kilos of urea on the wheat crop because its potential was so good and it did look really good. But it wasn't Yield Prophet's fault that it didn't rain in the Spring. If we had've got a wet Spring let alone that hot awful day or if it had've been an inch of rain that day and not 38 degrees and the wind from the north it probably would've met Yield Prophet's expectations." " We made the decision on the nitrogen on the basis of Yield Prophet".*

Belief that the model had inaccuracies were not necessarily a barrier to resubscription. Five interviewees reported inaccuracies but all intended to renew their subscription (see section Future Use). However, 2 of the 3 non-renewers reported model inaccuracies and included this among their reasons for non-renewal.

Some interviewees said they expected problems with the model to be resolved with time. Four interviewees expressed trust/expectation/hope that Yield Prophet would get better, despite current inaccuracies. These interviewees conveyed the impression that they identify themselves as part of a technology development process, and therefore view the 'teething problems' as a normal part of this process.

One interviewee gave an account of how the process of resolving differences between Yield Prophet and own knowledge is part of a learning experience for him.

Support and discussion

The interviews explored the level of support (e.g. facilitated interpretation and discussion of Yield Prophet reports) subscribers were receiving with their Yield Prophet subscription, particularly the extent to which consultants played a role in providing the support. Not all subscribers had the same consultant.

Based on the comments provided by the September 2003 and August 2004 interviewees, there had been generally minimal discussion of Yield Prophet reports with a professional facilitator. Three indicated they had not discussed their Yield Prophet reports with anybody. Five interviewees mentioned some form of contact with CSIRO-Yield Prophet staff, and one mentioned participation in on-line meetings with CSIRO-Yield Prophet staff.

For those who had no or little discussion about their report, this did not mean that subscribers identified problems with their support, but for some there were unresolved questions and concerns. Three interviewees indicated that accompanying support service delivered alongside Yield Prophet would be valuable. One commented that Yield Prophet won't be taken on by many farmers unless it came with an agronomic service, otherwise farmers won't know what Yield Prophet can be used for, and another indicated that farmer education will be required.

Two interviewees indicated that they wouldn't ask for support unless there was a really baffling problem that may have a critical management implication. Two other interviewees explained that because they already knew what their management plan was for the season, there was no need to urgently draw on any support in interpreting the model or sorting out any uncertainties.

Not all consultants mentioned by interviewees appeared to be as equally engaged in the delivery of Yield Prophet. Two indicated that their consultant suggested that Yield Prophet had little to offer over farmers' management experience, and another indicated that his consultant did not conduct soil testing with sufficient detail required for Yield Prophet soil characterisation, and felt his agronomist needed to take a more detailed approach to soil characterisation.

Future use of Yield Prophet

The ten interviewees in the 2004 round of interviews (three of whom were subscribers in 2003 only and did not renew in 2004) were asked if they intended to resubscribe to Yield Prophet. All seven of the 2004 subscribers in 2004 indicated their intention to continue subscribing. One interviewee indicated an intention to resubscribe out of a desire to see the technology succeed, even though he had uncertainties about the benefits of the technology. Two said their motivation to resubscribing was because of the interaction and discussion opportunities it provided. One said he would resubscribe because he saw potential in the technology. Another indicated he would subscribe because it was a relatively small expense, and another indicated he would resubscribe as part of a 2-3 year trial period.

Three interviewees in 2003 made comments indicating that Yield Prophet was not ready for commercialisation, and one added that farmers would reject it if it was not showing value quickly. There were, however, no similar comments made in 2004.

Reasons for not renewing subscription – 2003 subscribers

Of the three non-renewers, none said that they had plans to subscribe in 2004. Two, however, could see value in the technology but identified that the seasonal conditions needed to be right to get value from it. One of the two expressed a clear vision for the benefit it could play. The others had difficulty in visualising a benefit.

Reasons provided by the three non-renewers are summarised below, with the number of responses in brackets are as follows:

- satisfied and confident in the existing method for managing N, particularly in a dry season (3)
- higher priority demands on his time (1)
- could not see its value for money (2)
- concerns about model accuracy (2)
- difficulties interpreting information (1)
- it can't predict weather and therefore not offering anything more than existing information (1).

All had existing processes for decision making based on experience about how things work in their local area and said they do their own yield predictions based on rainfall deciles[9]. One Interviewee, had also been measuring soil water for 15 years and said this, combined with rainfall deciles has worked very well in the past.

Non-subscribers

Five members of the BCG who had never subscribed to Yield Prophet were interviewed in 2003. Two of the five didn't seem to initially know about Yield Prophet. One said that the information is "interesting, but doesn't tell you what to do", indicating an understanding of the probabilistic nature of the information. Three said they were interested to hear what other farmers think of the Yield Prophet technology. One said that he didn't understand the terminology in the Yield Prophet newsletters (e.g. SOI). Another said that he couldn't visualise a need for Yield Prophet because he had limited opportunities to manage differently to his current practice.

Other technologies

Computer ownership and use

Table 16. Computer ownership and use

	1980s	1990s	2000s	Never purchased
Number	8	9	2	1

All but one of the interviewees owned computers, which were used for paddock and/or financial record keeping (Table 16). The one interviewee who didn't use the computer for record keeping outsourced records management and his relatively late purchase of the computer (2002) was to provide computer facilities for his children. No other interviewees reported this as a reason for computer purchase, although two reported acquiring their first computer reported for their own schooling – both purchases were in the 1980s.

[9] Rainfall deciles are used to rank historical rainfall data by arranging the years into categories which each contain one tenth of the historical years. Deciles provide a measure of the spread of rainfall experienced in the past. Rainfall data in the current year can be compared against decile information to see where it stands in relation to historical records.

All interviewees used the computer for internet use. The most common applications were information and research (9), communication, banking and weather (5 responses for each) and marketing (3). Four interviewees reported limited use of the internet – of the two who elaborated, one cited slow connection constraints, and the other, lack of confidence in using it. The two interviewees who reported limited internet use purchased their computers in the 1980s.

Precision agriculture and controlled traffic

Twelve interviewees mentioned use or ownership of one or more of the following PA technologies: yield monitoring (nine responses) and mapping (five responses), satellite and/or infra-red and aerial imagery (three responses), EM mapping (one response), GPS guided spraying (three responses) and controlled traffic (two responses).

Nine reported owning a yield monitor on the header, but three said they made no use of it. One who elaborated on the reason for this indicated that while the technology generated detailed records, he was uncertain how to act on the data generated. The other reason he provided was the prohibitively high cost to purchase the technology – a cost of $30 000 - $40 000 was cited. Another of the three explained that he had not aquired the GPS for the yield monitor to enable him yield map because he was not certain that yield mapping would offer value to his crop management.

Of the five interviewees who used yield mapping, only one indicated that yield maps were being used to support variable rate input management (fertiliser) and this was after several years of using it to measure farm trials. Another used the maps to assess large-scale paddock trials rather than manage inputs variably. One indicated that he had only started yield mapping this year and another two didn't elaborate on the ways the technology guided management. Two interviewees who yield mapped discussed time frames in the order of several years to be able to evaluate the technology.

One interviewee who didn't have yield monitoring and mapping expressed an interest in the technology but was lacking clear evidence demonstrating the profitability of these technologies. Reliability of PA equipment was also an issue.

Two indicated that guidance technology was a more attractive PA investment than yield mapping. One said he wouldn't use variable-rate application technology because patterns of variability are not consistent from year to year.

> *"Yield mapping only gives you a map and you've got to work out from then what's happening. Whereas I don't think the science hasn't quite caught up with it yet. If I got a yield map on my place right now, I could describe what is causing the differences, probably soil type, could be weeds, headland. I know myself without a yield map of what's happening to that paddock but then I'm small enough to know my paddocks reasonably well…… But I don't think science is up to it to say I should have 40kg more nitrogen, or more urea on that part, or too much there. Soil tests don't tell me anything about what should happen because you don't know how much rain you're going to get. APSIM's probably closer than a soil test in that it actually helps you in the decision making of your prediction whereas still I don't know whether to put out 40 kg or 60 kg of urea, even though I get soil tests – it still doesn't tell me. I don't know what I'm targeting. I think the science isn't up to using yield mapping for me."*

Other DSS technologies

Two interviewees had used a DSS designed to support N management decisions, called PYCAL (this was also mentioned in the WA case study). However neither elaborated on the impacts this had on management. Two interviewees reported the use of innovative farm machinery (e.g. air seeders), and 4 indicated that they had or were growing novel or uncommon crops.

Adoption of technology across technologies investigated

Table 17 summarises the technology adoption scores assigned to interviewees for selected technologies. To conclude the interview, interviewees were shown the bell shaped adoption curve, given a brief explanation of the technology adoption groups, and asked to nominate where they thought they fitted (Table 17). Most interviewees appeared comfortable in assessing themselves, and several indicated that their self-assessed category is dependent on the specific technology. For example a number of interviewees who self-assessed as pragmatists in relation to information technologies indicated that they were visionary in relation to machinery and engineering innovations.

Table 17. Classification of farmers into their Yield Prophet subscription category, self-assessed technology adoption groups, and the adoption scores for discontinuous technologies.

Subscript'n status	Inter-viewee ID	Computer Purchase*	Computer use**	P.A.***	DSS ***	Adopt'n Category
Never subscribed	3	1	2	2	2	P
	6	N/a	1	2	2	P
	10	2	1	1	2	P
	12	3	1	2	2	P
	18	1	1	1	2	P
2003 & 2004 "renewers"	1	1	2	2	2	V
	2	1	1	1	1	V
	7	2	1	1	1	V
	8	1	2	2	2	P
	9	2	1	1	2	V
	11	2	1	1	2	V
	14	2	1	2	2	P
	16	2	1	1	2	V
2003 only "non-renewers"	4	1	1	2	2	V
	5	1	1	2	2	P
	13	1	1	1	2	V
	15	2	2	1	2	P
2004 only "new"	19	2	1	2	2	?
	20	2	1	2	2	V
	21	3	1	2	2	V

* 1= purchased computer in 1980s, 2= purchased computer in 1990s, 3= purchased computer in 2000s
** 1 = broad range of PC and internet applications in use, 2= limited (or less extensive) use of PC and internet applications
*** 1= Precision agriculture (PA) technology adopted, but excludes responses where yield monitor was installed in header but not used); 2= PA technology not adopted
**** 1= other DSS use reported; 2= other DSS use not reported
V= self-nominated visionary; P= self-nominated pragmatist

As evident in the other group case studies, some interviewees were consistently early adopters of all technologies investigated and could easily visualise the possibilities of new technologies, whereas others were consistently slower to visualise the benefits and adopt new technologies. None of the non-subscribers identified themselves as visionaries, however two were using PA technologies and the same two were actively engaged supporting some R, D and E activities.

Information sources

We captured both the answers to the direct question "Where/to who do you look for information before adopting?" and references to sources and people that were made during the interviews. Table 18 shows the range of responses obtained from "visionaries" and "pragmatists".

There were some differences between the two groups in the number and types of sources referenced e.g. visionaries mentioned an average of 3.6 sources per person compared with 2.4 for pragmatists; visionaries mentioned more scientists, accountants, a farmer group network (FM500) and "leading" farmers while chemical resellers were only mentioned by pragmatists.

Table 18. Sources of information used by interviewees

Information source	Subtypes	Visionaries (no.)	Pragmatists (no.)
Experience		11	
Farmers	Leading farmers	1111	1
	Farmers	111111	111
Family		11	1
Farmer groups	BCG	1111	11111
	FM500	1111	
Media		1	
Agronomists		1111	111
Accountants		1	
Scientists*		111	
Kondinin		1	11
Vic Dept Ag			11
Australia Grain		1	
Chemical retailer			11
Technology supplier		11	11
Field days			1
Travel		1	1

* Included references where individuals' names and/or professional affiliation not identified

The "leading farmers" categorization was used if interviewees said that they would reference farmers like themselves (if they were an innovator or early adopter) or specifically said "leading" farmers were referenced. The box farmers is ticked if the interviewee did not specify any type of farmer, or explicitly said that is was not necessary to reference farmers who were considered innovators, indicated that they referenced a wide range of farmers, or farmers with a specific expertise in something, but not necessarily innovators.

Six interviewees (without any prompting through questioning) noted the independence of the information was significant – e.g. independent from fertiliser / chemical companies. There appeared to be some suspicion towards receiving advice from companies that sell products to farmers.

Non-subscribers

All non-subscribers self-nominated themselves on right of the bell curve, ranging from early majority to late majority. Two said their timing of adoption depends on the type of technology – e.g. indicating that they were more innovative with machinery innovations. One interviewee appeared more innovative than his self assessment suggested, based on his early adoption of other technologies. Two of the non-subscribers indicated that they did not look to innovators for referencing. Rather they identified with farmers who had a certain approach to farming (but not necessarily related to timing). For example, one was guided by 'farmers with a practical approach" and another referenced "quiet achievers" who were low profile but successful.

Social networks

One interviewee (a Yield Prophet subscriber in 2004, but not 2005) commented on differences between farming groups, noting that BCG comprised "very much a lot of scientists and high-up people" and "go getters [who] think outside the square" whereas groups such as a local Top Crop Group was described as 'grass roots' and with membership described as the 'everyday farmer'. The following quote illustrates a possible 'chasm' between social groups:

> *"You don't get people going into groups like that [BCG] if they're not interested in it [crop modelling and other scientific tools and data]. …..And it's the same with local Top Crop groups, or your local farmers groups or whatever. They're a lot more laid back, they're not into the high tech type stuff like I was saying earlier."*

Discussion of Results: Stage 1

We propose that the processes for 'adoption' of *continuous* and *discontinuous* innovations can be usefully analysed using a series of categories of *meaning* to the practitioner in which each adds to the previous: *potentially* relevant, *relevant*, and *significant* (McCown, 2001). Relevance refers to the subjective meaning of facts, actions, and tools associated with the innovation, independent of their costs. Significance concerns the costs relative to the benefits of the innovation.

This framework highlights the difference between continuous and discontinuous technologies. Upon the presentation of a new innovation as a *continuous* technology, the question is mainly concerning the margin of increased *significance* for practice between the new and the current technology, since *relevance* is already established, as evidenced by use of the current technology. With *discontinuous* technology, however, which involves *change* and *development* in management thinking and process, adoption requires the establishing of *relevance* to practice, which is preceded by an event of 'attention focusing' because of an imagined *potential* relevance.

We investigated the adoption of discontinuous technologies in three group case studies, focusing on cropping systems simulation (APSIM /Yield Prophet) and 'Pastures from Space' satellite imagery, but also on a number of other technologies we regarded as discontinuous e.g. personal computers, precision agriculture technologies, and other DSS. On applying such a categorisation to these technologies, however, the research team reflected that the difference between discontinuous and continuous technologies is not always clear cut. To highlight, some applications of personal computers are not discontinuous - the transition from manual to computerised record keeping, for example, has a continuous, rather than discontinuous, element because the relevance of the practice has already been established, and this, along with the 'maturity' of this technology is reflected in widespread uptake personal computers. All but two interviewees owned a computer, with most of these indicating competence using it for production and financial record keeping and a number of internet applications, particularly email and information gathering. Barriers to computer and internet use were often technical issues (e.g. line speed) as much as issues concerning the skill of the operator.

In contrast, the focus technologies of cropping systems simulation (APSIM, Yield Prophet) and Pastures from Space are clear forms of information technology, and for nearly all interviewees, these sit well on the *dis*continuous end of the continuum – most interviewees have never previously used or encountered anything like these technologies as a potential innovation. The use of other DSS products was very limited, and very few interviewees were using the PA technologies of yield monitoring and mapping to the full extent possible. To illustrate the discontinuous nature of the technology further, APSIM *generates* complex information about the agricultural production system from abstract models of select aspects of the production system, which is a substantial contrast to PC use for database or a management information system e.g. in relation to paddock/financial records management.

'Adoption' by interviewees of the focus technologies depends on the sense that the 'virtual world' created by this technology is *relevant* to the physical world it represents and an experience that outcomes are *significant* to farm management –practice – i.e. benefits sufficiently outweigh the costs (including non-monetary costs) of adopting. One condition for *relevance* often expressed by interviewees for both cropping systems simulation and Pastures From Space technologies is that the demonstration that the technology adequately represents the structure and behaviour of the biophysical production system and that the technologies' output adequately relates to that experienced on the adopter's own farm. For users of cropping systems simulation, this condition is dependent on specifying the model for a specific paddock, using local measurements and driving the simulation using this measured input data. To deal with the latter issue, a farmer must have some familiarity with the model's data interface used in the monitoring and simulation of a crop production system, which may involve the farmer dealing with the production system in terms and numerical quantities not normally used in the discourse of practical farming.

The big question for developers of discontinuous technologies aiming for widespread technology adoption is "what intervention can cost-effectively facilitate farmers' construction of relevance and significance of these technologies". According to Moore, diffusion – the process by which an innovation is communicated through certain channels, over time, among members of a social system – cannot be relied on to achieve this to widespread effect. This project set out to investigate whether Moore's 'chasm', which we restate as a 'chasm of relevance' in social referencing – i.e. a chasm in the diffusion of relevance from one farmer to another – was likely to limit the effectiveness of diffusion as a means to cost-effectively facilitate farmers' appreciation of relevance and significance of these technologies.

The results of our interviews leave us questioning the applicability of Moore's theory for three reasons:

1. Some self-assessed pragmatists referenced visionaries
The interview sample included interviewees who exhibited the personality characteristics that fit Moore's description of pragmatist types, and they self-assessed accordingly. Pragmatists represented a minority of interviewees for the Pastures from Space and Yield Prophet interviewees, but dominated the Darling Downs sample. Not all pragmatists agreed that it was a prerequisite to reference other pragmatist farmers before making a decision to adopt a new technology. There was also generally little difference in the information sources used by interviewees for supporting their adoption decisions. One reflection of the project team was that interview data does not provide a transparent picture of the nature of social referencing – i.e. how are interviewees' technology appraisal processes influenced by others' interpretations?

The test of Moore's thesis is - are there some users that potential users would not reference? Despite the findings above, we cannot totally dismiss the 'chasm' theory. There were individual cases providing a degree of support to the existence of a chasm in social referencing. Some Birchip farmers who were not subscribers of Yield Prophet indicated a preference to reference farmers not described as innovators. Rather, descriptions such as "quiet achievers" or "practical farmers" were used. On issue that could be explored further is a chasm in social referencing between social networks. As discussed in section 4.3, one Birchip interviewee provided support for the latter when suggesting a chasm existed between two different farmer groups in the same region, but this may not be an entirely different situation from a visionary-pragmatist chasm, depending on the composition of the social network.

2. *The timing of technology adoption is not necessarily a personality characteristic*
Yield Prophet and Pastures from Space were in their second year of delivery when the interviews were conducted, and the Pastures from Space and Yield Prophet subscribers who identified themselves as pragmatists were therefore among the first 'adopters' of these technologies (although it is debatable whether those who were experiencing discontinuous technologies through participation in a facilitated (and often subsidised) trial of the technologies qualify as adopters of these technologies – many current users are in an evaluation phase and it is hard to be sure who can be confirmed as an adopter.).

It follows that if these farmers were being categorized strictly according to the timing of adoption of these technologies, they would be visionary-types – innovators or early adopters. However, such farmers did not display the technology adoption dispositions that would be expected for early adoption of technology – e.g. they did not actively pursue the new technological innovations and did not find it easy to visualize the benefits of the new technology with little experience with it. Such findings raise questions about the applicability of Moore's theory if farmers with pragmatist personality characteristics are engaged early in the technology adoption process for the investigated technologies. Our results suggest that social networks i.e. farmer groups and consultants (particularly for the Darling Downs) were stronger influences in the technology adoption process than personality factors.
It was also clear from the interviews that individuals could not be assigned to the same adoption category across the range of discontinuous technologies investigated. Individuals' varied in their timing of adoption of discontinuous technologies. This confirms others' findings that the timing of technology adoption cannot be explained solely as a personality characteristic (Pannell *et al*, 2006).

Our sample of pragmatists, particularly for the Yield Prophet and Pastures from Space studies, was scant – a function of our use of social networks to construct the interview sample, and because most of the innovations are in the very early stages of the diffusion process – and was certainly insufficient to provide us with confidence to make any broader assessment of the applicability of Moore's chasm of social referencing beyond these case studies. Furthermore, interviewees' self-categorisation was a subjective assessment, with no standard benchmark against which they could rate themselves. Against some alternative and perhaps more objective measures for guiding self-assessment it is possible that pragmatist adopters of these discontinuous technologies could better be described as early adopters.

3. The 'chasm of relevance' may be better explained as a chasm concerning cognitive experience.
As indicated above, in the Pastures from Space and Yield Prophet cases, interviewees' interest in these technologies as *potentially* relevant was achieved through interaction with representatives of the organisations delivering the technology or through a consultant. Delivery of APSIM on the Darling Downs was also via consultants. Interviewees' connection to the various networks of farmers (e.g. the Pastures from Space groups and BCG) greatly facilitated the appreciation of potential relevance across a range of adopters types. It appears possible that a tentative state of acceptance of discontinuous technologies as *potentially* relevant can be also achieved through farmer-to-farmer social referencing – there was some evidence of this among the first-time subscribers of Yield Prophet in its second year of delivery. Given that Pastures from Space and Yield Prophet were in the second year of delivery we were not provided with the opportunity to explore farmer-to-farmer referencing in facilitating appreciation of the relevance of these technologies. On the other hand, the Darling Downs interviewees provided an opportunity to explore APSIM use in a mature market. Here, we found no evidence of diffusion of APSIM beyond the geographic region where the original FARMSCAPE team had worked, and nor beyond the client group of consultants who had liaised closely with the FARMSCAPE team.

When asked in a general sense, many interviewees indicated that they referenced other farmers as a source of information before adopting a new technology, although it was not a pre-requisite for adoption for visionary farmers.

Although a social diffusion process can communicate potential relevance, resulting in an attitude of openness towards the innovation, our hypothesis is that it cannot be relied on to provide the subjective appreciation that goes the next step to establish *relevance* for individual farmers. According to Moore's theory, the *relevance* required for adoption is achieved by referencing another person judged to be 'like me'. For the radically-discontinuous innovations in farmer practice, we propose that this can achieve **potential** relevance only.

In both the Yield Prophet and Pastures from Space some interviewees noted the long time frames, in the order of years, to move from a belief that a technology is *potentially* relevant to believing that it is *relevant.* A personal learning experience (albeit socially facilitated in group events), closely tied to the condition for users of these technologies that the technologies represent closely to their own experiences on their own farms, appears to be a factor in achieving relevance. The nature of the learning experiences of interviewees was not clear from this round of interviews, but warrants further investigation.

In Stage 2, the *persuasion stage*, of Rodgers (2003) five-stage model of the innovation decision process, which precedes the decision and implementation stages, an individual will mentally apply the new idea to a current or future situation. Rogers (2005) states that at the persuasion stage, general messages are not important. In other words, various mass media are not effective for diffusion, rather, the individual requires information specific to their circumstances. Therefore interpersonal channels are the most persuasive means for an individual to accept a new idea. If, however, the learning experience needed for the innovation to be relevant to practice requires a change in the farmer's cognitive representation (mental models) of the production system, we argue that this would be difficult to achieve through social referencing.

The conditions under which the original success of FARMSCAPE originated involved farmers, advisers and their consultants engaged in face-to-face, facilitated learning activities. In contrast, at the time of interviewing, Yield Prophet allowed the whole process of information exchange to take place through the Yield Prophet web site, controlled by subscribing farmers in their own time from their own home office. For one season, delivery of Yield Prophet was also by fax. While the internet-based approach to delivery was viewed favourably by Yield Prophet subscribers, particularly because of its timeliness, it has also meant that subscribers have been able to access the technology with much lower levels of facilitated discussion from professionals than the original FARMSCAPE experiences. The results showed that internet subscribers' experiences ranged from the use of Yield Prophet with no discussion about the technology to participation in well-organised group discussion, facilitated by one or more consultants and researchers. Internet delivery highlighted problems with the interpretation of the information, which is problematic in the absence of facilitated support. Some of the interpretation problems have been registered as concerns by farmers, where in other situations we identified interpretation problems that were not recognized by farmers. There was no clear link between the level of discussion and the perceived adequacy of support and not all interviewees were proactively seeking help to resolve questions.

While the internet provides great opportunities for reaching large numbers of farmers in a timely and less costly manner than traditional methods of technology delivery, we believe a 'diffusion research' need is to identify the learning experience needed for potential adopters to appreciate the relevance of these technologies to their own practice. The interview data does not provide a clear picture of the nature of the learning experiences of interviewees, but experiences did appear to vary greatly amongst interviewees. The results however suggest a need to boost opportunities for support, discussion and interpretation (this was also recognized in discussions with the Pastures from Space research team – like Yield Prophet, Pasture from Space was delivered through the internet for the first time in 2004). The chasm of cognitive experience associated with discontinuous technologies – reflecting that learning needs to take place before relevance can be achieved – can also be related to a number of Rogers' (2003) perceived innovation attributes which have been used to explain the rate of innovation adoption and predict potential adopters' reaction to an innovation. *Observability* is the degree to which the results of an innovation are visible to others, either through observation or communication, and is positively related to its rate of adoption. Information-based technologies possesses less observability than material technologies (Rogers 2003). While farmers may be able to observe neighbours' choices of crops and techniques, neighbours cannot easily observe the payoffs from adoption of cropping system simulation and evaluate in the context of their own practice. *Compatibility* is also relevant, interpreted in this context as the degree to which innovation is perceived as consistent with existing knowledge and as such is positively related to adoption. If Yield Prophet technology is incompatible with existing knowledge, meaning that some form of knowledge reconceptualisation via a learning experience needs to take place before relevance is established then the technologies don't perform well on this criterion.

Performance of discontinuous technologies against another of Rogers' (2003) key innovation attributes positively related to rate of adoption – *relative advantage* (the degree to which the technology is perceived as better than the idea it –supersedes) – appears to provide a challenge for expediting uptake. This also relates to the third stage of our innovation decision framework – *significance*. With one particularly notable exception (Darling Downs), users of the focus technologies rarely expressed the value of these technologies as an economic advantage quantifiable in monetary terms, and value was ill-defined by some interviewees. Others indicated that they needed time to establish value. A number of interviewees in each case study indicated an intention to use these technologies in the future. In considering the relative advantage or significance of the focus technologies, it is worth noting that most interviewees did not express deficiencies with the current mode of decision making that the new technology was designed to assist. An exception, however, is found in the Pastures from Space users wishing to overcome the problem of monitoring pasture over large scales. Yield Prophet interviewees were not seeking to rectify deficient approaches to N management. Some interviewees explicitly stated a desire for more objective representations of the

their production systems, but no interviewee expressed the advantage of Yield Prophet relative to current ways of making the decision, and frequent reference was also made to the importance of their own experience, described by the term ‘gut feeling’.

McCown (2005) made a case that under normal routine practice, farmers are not motivated to overcome the cognitive challenge and inconvenience involved in fitting a DSS into the management system. Farmers will be motivated upon the presentation of a problematic situation which could be one of three things:

1. Farmers are more likely to feel a need for assistance when normal practice is interrupted by a problem or uncertainty in a farm management problem
2. A significant prospect of a novel beneficial change about which they are uncertain
3. Some farmers welcome opportunities to engage scientists on relevant issues when useful learning seems a possibility and respond favourably to a request for attention to participate

In these interviews 2 and 3 were the motivating adoption factors. That is, the interviewees were relatively content with current farm management but open to improving their management.

In summary, Moore’s ‘chasm’ is a chasm of relevance in social referencing – pragmatists don’t see visionaries as relevant referees. While the ‘chasm of relevance’ could pertain to farmer referencing, it is likely to simultaneously be a chasm concerning cognitive experience and this possibility is the subject of the second stage of enquiry that was introduced in the section on Methodology.

The focus of the second stage of research was entirely on Yield Prophet, allowing us to develop understanding in a context that we have the capacity to study closely and subsequently intervene in participatory action research mode. The hypothesis concerning a chasm of cognitive experience prompts a round of research questions in relation to how farmers currently mentally represent their farming environment, and what learning needs to take place for Yield Prophet’s scientific concepts to be viewed as meaningful and relevant? The alternative hypothesis – that Yield Prophet can be valued as an addition to farmers’ current sets of information subscriptions, without a learning experience, also warrants consideration. The first round of interviews suggest that professional facilitation, either via a group or consultant, plays a role in helping farmers’ gain value from these technologies, and this is explored further in the second round of interviews. Specifically investigated is how the value obtained from Yield Prophet is influenced by the client-consultant relationship (i.e. the role of consultant in establishing relevance). The inquiry was expanded from Birchip to include a study of the use of Yield Prophet in three other locations: WA, NSW, and South Australia. This allowed exploration of Yield Prophet use in other environments, both socially and bio-physically.

Stage 2: Use of Yield Prophet in four Australian regions

The Methodology section introduced the second stage of research for this project, which focused on the use of Yield Prophet in four grain-producing regions of Australia. The rationale for such research was presented in the discussion describing Stage 1. Here we present the results and a discussion of the Stage 2 research.

How farmers conceptualise their farming system

Current agronomic management strategies for dealing with season-to-season climate variability

Interviewees indicated a range of agronomic strategies for managing season-to-season climate variability (Table 19). The most widespread and frequently reported strategy was managing N input according to the season. The interviewee responses indicate that there are few options for dealing with seasonal variability once the crop has been planted. N management was also the only strategy mentioned that involved a management adjustment within the cropping season. Location 3 was differentiated from others through the use of dry sowing, and only Location 2 interviewees used a soil water rule for planting.

In Location 2 (2 responses), Location 1 (3 responses), and part of Location 4 (1 response), some interviewees mentioned that the climate was typically reliable, indicating they felt that variation was less of an issue in their region compared with other grain-growing regions, although this is not say that the variability was not still an issue requiring consideration. All three Location 2 interviewees indicated that the climate had been anomalous (e.g. "out of character") in recent years, indicating a disruption in their expectations about climate.

Table 19. Agronomic management strategies for dealing with climate variability by location (number of citations by region)

Strategy	Location 3 (n=8)	Location 2 (n=3)	Location 1 (n=5)	Location 4 (n=4)
Tactical adjustments to N	6	3*	5*	4
Dry sowing the crop	6	1	1	2
Soil moisture conservation (stubble management, weed control, no till, fallow, don't plant)	2	2	2	
Use of a soil water planting rule		3	-	
Change area of crop planted		-	-	1
Change crop rotations or varieties	7		5	1

* In Location 2 and 1, two interviewees in each location (four in total) described tactical N adjustments in relation to canopy management

Recent changes to agronomic management strategies for dealing with season to season climate variability

Most interviewees indicated that the main changes made in recent years to their strategies for dealing with climate variability related to the timing and/or quantity of N applied (Table 20). With respect to timing, this involved a shift from applying all N as pre-drill to applying some of it within-season. In relation to quantity, the application had decreased, with the exception of one case where N had increased in recent years.

The last five changes listed in Table 20 are changes in the assessment of the production system rather than a change in the crop management strategy. Before interviewees were asked questions specifically in relation to Yield Prophet, most identified that Yield Prophet has or could potentially play a role in this change of strategy. Some attributed specific changes to Yield Prophet e.g. changing N, measurement of soil water, increased use of soil testing. These are explored further in later sections of the report.

Table 20. Main changes to strategies for dealing with climate variability in recent years (number of citations by region)

Main change to strategies	Location 3 (n=8)	Location 2 (n=3)	Location 1 (n=5)	Location 4 (n=4)
Vary N (quantity and/or timing)	5	3	5	3
Flexible rotations replaced fixed rotations (including don't plant options)		2		
Dry-sowing replaced waiting for planting rain				1
Cropping program more conservative (lower financial loss)	3			
Changed from conventional to chemical fallow	1			
No till			1	
Volunteered YP as playing a part in the change, or having potential to play a part in change	4	3	4	3
Less reliance on visual inspection for N mgt[10]			1	
Shifted from use of deciles to YP	1			
Measurement of soil water	1			
More soil testing	1			

Approaches used to assess the current season

A wide range of approaches to assessing the current season was reported (Table 21). Stored soil moisture was the most frequently identified means for assessing the season. Location 3 interviewees were the only group that nominated the use of rainfall deciles. Most regions reported the use of seasonal climate forecasts, with Location 1 as the exception.

Table 21. Approaches used to assess the current season

Assessment of season based on	Location 3 (n=8)	Location 2 (n=3)	Location 1 (n=5)	Location 4 (n=4)
Stored soil moisture	8	3	5	4 (c)
Amount of summer rain	1		1	3 (b)
Amount / timing of planting rain ("the break")	1		3	1
Interaction between timing of break and soil moisture (rule of thumb)	1			
Amount &/or timing of rain during season	3	2	3	1
How things are going by September			1	
Climate forecast: long term forecast (e)	2	1(d)	1	4
Climate forecast: SOI	6	1		1
Climate forecast: GESS	4			2
Correlation between May-June and July-Aug rainfall				1
Rainfall deciles	3			
Direction of weather fronts			1	
Comparing current season rainfall with own historical rainfall records		1	3(a)	
Gut feeling	1		4	2
Past performance	1			
Visual crop inspection (e.g. crop growth stage)		1	2	
Leaf tissue testing				2
Ecosystem indicators (e.g. native tree flowering)	2			1

a. one of these was spreadsheet-based modelling relating yield to rainfall;
b. mentioned by 2 as directly impacting on stored moisture
c. one said stored soil moisture only relevant to heavy soil, not sandy soil
d. interviewee explicitly indicated that he did not look at SOI
e. specific climate forecast not offered

Interviewees in all locations expressed doubts about the value of seasonal climate forecasts. The level of knowledge about seasonal climate forecasts varied substantially and is reported for each region.

Location 1

Seasonal climate forecasts were not incorporated into management decisions and all indicated that it was not a major discussion topic with their consultant. One, however, said that if there was a particularly poor long-term outlook, that the "gloom might rub off a bit and make you tighten up the fertiliser regime" but that he would still need to be ready to react for a different seasonal outcome to that predicted by the forecast.

Two appeared to have given very little thought to seasonal climate forecasts, and one of these had an expectation that his consultant keeps on eye on them and feeds it into the advice that he provides. Two other interviewees had given seasonal climate forecasts a greater degree of consideration, but had doubts about their relevance (SOI) to the local area. One said the way a long-term forecast is presented can be uninformative, and doubted the local relevance of seasonal climate forecasts:

> *"No. I try and get some sense out of them [seasonal climate forecasts] and I've been subscribed to a [newsletter from research organisation], which pokes out a lot of information every month, but doesn't make a lot of sense to me. Like it's wet or it's dry. [A] 50% chance of it being above average - well those sort of figures sort of are a bit pie-in-the-skyish for me and I'd probably get a better gut feeling of what's coming. It's nice to have that information there. Yeah. I suppose you know, here it doesn't seem to affect us. Like the El Ninos and all those sort of things, eastern states they… I've got a mate over in [another state mentioned] and he goes by it and it does have a big impact on his weather forecast. Whereas because we've got the [geographical location named] and we just tend to sometimes…. not 100% influenced by it, that's for sure. How much influence it has, I don't know".*

Only one interviewee appeared to be actively seeking opportunities to apply SOI. He had participated in a climate risk workshop presented by CSIRO staff. He has recently come to think that the SOI has more relevance to the local area than he originally believed – this view was influenced by the depiction of yields according to SOI phase in the Yield Prophet reports. However, it is still not currently factored into his management decisions. He is putting effort into learning about SOI and intends to buy a software package called Rainman which is utilized for manipulating and presenting climate data.

Location 2

Two of the three interviewees said that SOI does not influence their management. One said that he had scope to learn more about it, and expected to do so through Yield Prophet, and the other cited that prior interaction with another scientist who "couldn't make the SOI fit to this particular region" confirmed his attitude to SOI. A third interviewee said that he has had difficulty in applying SOI to decisions in the past but is rethinking the value of SOI because Yield Prophet is providing the first opportunity to make comparisons of outcomes in relation to SOI. All interviewees indicated that seasonal climate forecasts were not a focus of discussion with their consultant and that it was discussed only in general terms.

Location 3

Interviewees in this location engaged in the lengthiest reactions to questions about the use of seasonal climate forecasts, but like other regions there was little indication of their value. Only two interviewees indicated that discussion took place about seasonal climate forecasts with their consultant – one of these thought he was still on a "learning curve" to explore their relevance and the other said

he based management decisions on a long term climate forecast, and also indicated that he thinks SOI is unpredictable and not relevant for the region and will follow ESS[11] method instead.

The remaining six interviewees all indicated that they paid attention to what the forecasts said, but not one indicated that they had an impact on management. Comments included:

- seasonal climate forecasts too late to have value
- SOI is vague
- Long term climate forecasts are ambiguous
- Not accurate enough
- One said he would react to a strong signal e.g. rapidly rising SOI, and another said he would take notice of a positive SOI

They varied in their preference to use SOI over the GESS forecast. Two interviewees were interviewed after their participation at a climate forecast workshop and both reported new learning in relation to SOI that has caused them to have a rethink and that they will now pay more attention to SOI.

Location 4

Seasonal climate forecasts are not factored into any interviewees' management decisions, but two had taken an active interest in assessing whether they could be useful, with greatest interest shown in the GESS method. One of the two, who did not discuss them with his consultant, indicated that the difficulty in applying long-term climate forecasts related to their timing:

> *"It's pretty hard because you try and go on the seasonal outlook at the beginning of the year but the problem with their seasonal outlook for [another state named] is it doesn't have – it's not very accurate compared to the seasonal outlooks that they have in the [other states named]. So really the seasonal outlook isn't accurate in [another state named] until really you've started seeding time. And it's not until after seeding time that they start getting a bit more accuracy in the seasonal forecast. It wasn't until after seeding that they could say with confidence that it was going to be a drought year really. So by then it was too late."*

A third interviewee, although indicating that he discussed long-term climate forecasts with his consultant, appeared to have a vague understanding of them. He got the "general drift" but was unable to identify the names of climate forecasts. And a fourth indicated that long-term climate forecasts offered little of value and had not discussed them with a consultant. Like the sentiment expressed in other areas:

"I've got no faith in long term forecasting because it always comes down to 50% chance of above average rains, so it tells you nothing."

Consultants

Three consultants also offered comment on SOI. All were interested, but indicated that SOI has not offered a useful guide for action.

Representation of soil water

All interviewees were asked to describe the soil moisture status of their Yield Prophet paddock (Table 22). Some interviewees did not refer to Yield Prophet when describing soil water, and there were examples of soil water described in terms that were different, but not incompatible, to the representation of soil water in Yield Prophet. For example, soil water was often discussed qualitatively and often as an extrapolation from rainfall figures. A majority of interviewees, with most from

[11] The ENSO Sequence System (ESS) is an experimental system being developed at DAFWA to predict ENSO (El Niño-Southern Oscillation) state with good lead-time. See: http://www.agric.wa.gov.au/servlet/page?_pageid=449&_dad=portal30&_schema=PORTAL30

Location 3, referred to their soil moisture from Yield Prophet (either actual testing or from the report). Location 3 was the only region where soil water was discussed in more sophisticated terms e.g. wilting point, crop lower limits etc.

Table 22. Soil-water descriptions.

Soil water description based on / in terms of	Location 3 (n=8)	Location 2 (n=3)	Location 1 (n=5)	Location 4 (n=4)
mm (depth of wet soil using push probe)		1		
mm (based on YP soil testing or YP report) (b)	7	2	3	
mm rainfall	3	2	2	2
Soil water described in advanced terms e.g. wilting points, crop lower limits etc	3	1		
Description e.g. "Full", "not much" "dry" "good"	1	1	2	2
Soil core - visual assessment			1	2
Monitors other paddocks for SW	3	1(a)		

a. By extrapolation, using moisture probe
b. This included references to the YP report, even if mm wasn't quoted e.g. "I can't remember the exact figure, but it's in my YP report"

Relevant examples of descriptions of soil water are as follows:

1. A qualitative description, informed by amount of rainfall (Location 4)

Facilitator: *How would you describe the current soil moisture status of your Yield Prophet paddock?*

Farmer: *It would be good. There would be some there.*

Facilitator: *And that would be measurements based on--*

Farmer: *Experience. 'Cause I know how much rainfall we had. I know the paddock. And I know that that paddock will finish off regardless of whether we have any more rain or not.*

2. The amount of rainfall used as a proxy for soil water (Location 1)

Facilitator: *How would you describe the current soil moisture of your Yield Prophet paddock?*

Farmer: *Up a week ago it was pretty ordinary, it was extremely dry.*

Facilitator: *Based on?*

Farmer: *We tried to do the core samples and we couldn't extract the soil up with the core, it was that dry it was just falling out the bottom. So it was extremely dry through the profile and just no subsoil moisture.*

Facilitator: *Do you monitor other paddocks other than your Yield Prophet paddock?*

Farmer: *Not to the same extent but I suppose just through years of experience you've got a fair knowledge of how things are going in some of those paddocks.*

Facilitator: *How do you quantify the soil moisture?*

Farmer: *I suppose it's what's stored underneath the root zone, yes.*

Facilitator: *Do you think about it in, say, millimeters?*

Farmer: *Yes, I suppose the easiest way for us to measure it, it's been just millimeters of rain leading up to the optimum sowing time.*

3. A visual assessment of soil water, and one clearly preferred to the use of abstract representations (Location 4)

Facilitator: *How would you describe the current soil moisture status of your Yield Prophet paddock?*

Farmer: *Good, because we've had lots of dribbly bits of rain in September.*

Facilitator: *So that's based on rainfall? Your assessment of …*

Farmer: *No, digging a hole. Honestly, some of the APSIM stuff, I just relax. My agronomist says "let's leave that, let's go out and dig a hole, and look at the next two month forecast. Let's dig a hole". And I go out there and I dig one.*

High tech stuff, digging holes. It means use computer models? No, it means dig a hole, and we dig big holes. We look, and we feel.

All interviewees were asked if they monitored other paddocks for soil water, but only 4 did so. Two (Location 1) said they wish to undertake soil moisture monitoring, another (Location 1) said he was likely to in the future, and another (Location 1) said Yield Prophet gives him an approximation of what soil water would be in other paddocks.

Use of Yield Prophet in 2005: group case studies

The impact of Yield Prophet delivered and used under varying circumstances is explored through group case studies. The variations between them relate to production system location, the nature of the client-consultant relationship, particularly in relation to Yield Prophet use, and degree of previous exposure to Yield Prophet. Each group study is reported below.

Location 1

Five subscribers were interviewed who were clients of the same agronomic consultant, who was also interviewed. The consultant said he has 15 clients who are subscribers, and 6 of them were described as active users. All interviewees were new users of Yield Prophet in 2005 and had about 2-3 months experience with it at the time of interview.

Nature of client-consultant interaction

As well as being involved with group work, the consultant operated with clients on a one-to-one basis, with a major interaction occurring at the start of the year in the form of a crop-planning session for the upcoming season – this includes discussion about N decisions and other agronomic matters. As confirmed by the consultant, all interviewees said that they make most of the farm decisions and used the consultant as a 'sounding board'. Often the discussion about plans for the year started with the interviewees' own ideas. Terms like debate and discussion were used in the description of the interactions taking place with the consultant. One said that the consultant challenges his thinking. Two interviewees said that some decisions (e.g. weed management) were delegated to the consultant – i.e. they accepted recommendations at face value. All interviewees had the same consultant supporting them in the use of Yield Prophet and all said that he plays an important role in introducing other new technologies to them. The interviewees did not use any other consultants for agronomy matters. Two interviewees mentioned they also utilised the services of chemical resellers / fertiliser reps. One of these said his fertiliser sales representative prepared his fertiliser recommendations using "something similar to Yield Prophet", or "maybe even used Yield Prophet." The latter suggestion was checked with the Yield Prophet support team and found to be incorrect.

All interviewees mentioned that the consultant supporting their use of Yield Prophet has organised information and training days and produces newsletters containing Yield Prophet output. The consultant has also had one-on-one discussion with all interviewees, initiated by either the interviewee or the consultant, although the number of interactions appeared to vary between interviewees. Two

interviewees said it was valuable that the consultant is also a farmer – it means that he can use Yield Prophet and assess its value in a practical sense.

Two interviewees mentioned that they used Yield Prophet at least weekly, and for one of these, Yield Prophet was the first electronic and interactive technology that he had used. His son was also doing "what if" management experiments using Yield Prophet.

The quote below from the consultant illustrates the nature of client-consultant interaction:

> *"If you're making a nitrogen decision right now as people are with this moisture, you'd bring it [Yield Prophet] out and put it on the table and say, right let's have a look at this. What's the effect of adding another 50 kilos of urea. Half a tonne increase, an increase in protein of 1% makes the decision very easy and helps us help the grower make that decision very quickly. In terms of the behind the scenes stuff, the big benefit we've found this year with Yield Prophet is it's had a dampening effect on the enthusiasm with which farmers would throw inputs at crops because basically it's predicting lower than average yields I guess and so farmers are going why's that? No stored moisture, hmm, yep, perhaps that's right. Perhaps I won't be quite as gung ho with inputs. So I guess it's still on the table isn't it, saying here's the yield potential, here's your chances of getting a 4 tonne crop, what the hell are you fertilising for a 5 tonne crop for? Like you've got a 10% chance of having a 4½ tonne crop and you want to put on 150 kilos of urea? ….…... So the subliminal effect is to say hang on, I'll start tightening the belt and I'll start minimising some inputs, and I won't go and order a heap of fungicide, and I won't go and buy a new tractor and I'll just sit and see how the season's going. So all that sort of stuff I'm finding it's very important for farmers to recognise when they're in a poor season and hopefully when we have a good one again, you know, the vice versa. We'll be able to say well look hang on, you're just about guaranteed at this stage of getting 3 tonnes. Yep - good idea to get that new header organised or ordered or whatever. So I can see that sort of thing happening."*

Impact of Yield Prophet

Interviewees had about 2-3 month's experience with Yield Prophet when interviewed, and noted that its value was still being assessed. Comments on the value or potential value of Yield Prophet are summarised below:

Nitrogen management

All of the interviewees identified Yield Prophet as being able to support N management decisions, mainly in relation to wheat, but also for barley. Three interviewees provided an elaboration on its application to N management, and, in doing so, also articulated the problematic aspect of their management in 2004 that they could visualise resolving using Yield Prophet.

Example 1

> *"Is this top up N going to be necessary?" ….. "I ran some stuff on the week end and we have now made the decision, with this rain coming Friday/Saturday, we are actually going to finish our nitrogen programme that we pre-planned, let it run for another couple of weeks and then see if it's even worth topping up with some additional nitrogen.*
>
> *Whereas other years we would just go 'Whack' – put it all on at seeding because that was easy, forget about it for the rest of the year, grew tall rank crops that fell over and lodged, couldn't windrow and …you know grow wheat that was up to your chest and with a little pea head on it.*
>
> *So by managing that nitrogen, we'll grow better crops is the expectation. We started last year. That kind of fell over and this year I think it's working because we are just trickling out when we think we need it rather than because it's about to rain we'll go and wack another 50 kilos on.*

So to answer that – we are not changing the inputs as much but we have been more strategic in the way we are using it. And I am quite prepared to leave two silos of nitrogen sitting here ready for next year if I've got to. You know, if the numbers say it's not going to work, well, I'm not going to put it out this year, whereas last year we did all that. We put it all out and all we did was grow screenings".

Example 2

"Perhaps saved in inputs, because I think some of the fertiliser inputs we did, actually damaged our yields, because they actually damaged quality. Yeah, I'd think maybe $30,000 to $40,000.

…. I mean I've got 20/20 hindsight to make that statement I suppose, haven't I, but I think looking back on it, we really tore into it. We had a late start, and things were looking really good. I know we had the really bad hot day that really fried things, but in the end perhaps things weren't quite as good as we thought they were".

Example 3

This interviewee emphasized that he was still making decisions on gut feeling rather than using Yield Prophet until his confidence in the model grew, indicating that *"It's not gospel. It's an influencing tool – to slow you down, speed you up in thinking."* However, he hoped to use Yield Prophet to avoid the type of scenario they ran into last year and is elaborated as follows:

"Well we did a lot of fertiliser spreading this time last year, or August last year. It was an earlier season. Because it was raining, and we didn't really have any idea of what our stored moisture was. And I think if you had a look, there wasn't much there. And as it turned out, the season shut off real quick and real dry, and that fertiliser was wasted. Nearly all of it was wasted that we spread on there 'cause our yields just weren't up there 'cause they just dried out too quick. So that's the sort of scenario we're trying to avoid by using Yield Prophet."

Pre-sowing operations

None of the interviewees reported using Yield Prophet for pre-sowing decisions. This is not surprising as they only set up for Yield Prophet after these decisions were taken. One interviewee expressed an intention to use it to investigate dry sowing options next year – i.e. "What if we did go sowing early with no rain".

Learning about soil water

All interviewees discussed how gut feeling informing their assessment of the system performance, but 3 interviewees reported a learning experience in relation to soil water, which appeared to be reducing their reliance on 'gut feel'. Two provided a clear articulation of their recent shift in thinking about the importance of stored soil moisture and how, through Yield Prophet, they had come to realise that stored soil moisture influenced the seasonal outcome, which facilitated an appreciation of the potential value of Yield Prophet. These interviewees are also quoted in examples 1 and 2 above, and the learning experience of one is reported below.

Two years ago, this interviewee didn't think that soil moisture affected the seasonal outcome, but has come to realise that last year's outcome was totally dependent on it, as illustrated by the following quote:

"We keep thinking we're growing stuff through irrigation, through rainfall, and last year really lit that up badly in the fact that we had had all these little bits of rain and then we had nothing to get us through October 12th [significant hot, dry day]; whereas if we had sub-soil moisture then we would have survived that a lot better than we did. We would also have pulled back on doing a lot of stuff we had done, not knowing that October 12th was coming but

knowing that there wasn't the soil moisture to produce the yields that we were expecting because the top growth looked really good."

Although elaboration was not provided, the quote also suggests that a number of management actions could be influenced by soil water status. This interviewee noted that the soil characterisation process was influential in his learning about soil water.

These two interviewees, when asked to describe the current soil moisture status of their Yield Prophet paddock, were the only 2 who responded with soil water measurements in mm. When asked if they had always described quantity of soil water in mm, both answered that they didn't think about soil water in mm until they started Yield Prophet. Previously, one didn't think about soil moisture at all, because the area had a reliable rainfall, and the other determined soil water by knowing that there was more moisture in clay and also by the sound a fencepost made when pushed into the soil. If the fencepost went 'squoosh' it had a lot of water. He offered the view that most local farmers would not be thinking about stored soil moisture.

There were three comments from interviewees, which explicitly indicated a change, attributable to Yield Prophet, in how production system performance was assessed. One interviewee commented that Yield Prophet was better than visual assessment of soil, another indicated that he could reduce reliance on personal historical experience, and a third comment was that Yield Prophet provided a reality check after rain – i.e. rainfall value must be evaluated in terms of the state of other aspects of the production system which Yield Prophet represents.

Not all interviewees reported such a clear shift in soil water conceptualisation. One interviewee, for example, did not report a Yield Prophet learning experience in relation to soil moisture and did not report soil water with reference to Yield Prophet or in terms of mm of soil moisture. He did however attach importance to soil water in determining the seasonal outcome. He also described his experience of Yield Prophet in more modest terms – that of boosting confidence in his decisions. He did not elaborate on the nature of the increased confidence.

Marketing and finance

Two interviewees identified Yield Prophet's yield predictions as an aid in marketing (1 response) and finance applications (1 response).

Use of information presented as probabilities

The interpretation of probabilistic output did not appear to cause major difficulties. The exception was one interviewee who said that working with probabilities was new for him, and involved "learning another person's language" that he was still "getting the hang of". One interviewee said that his brother, who shares the farm, does not think of crop outcomes in probabilistic terms.

Three interviewees said that they use the 50% chance, or median, as the probability that guided decision making. One said he might raise it to 60% if under financial pressure. Two said that the range of outcomes was important to consider and one said that it was important not to be overly influenced by the chance of making a lot of money at one end of the range. Another said that he also wipes off the top 20% when thinking about the possible outcomes.

Accuracy concerns

All interviewees said they will need to wait until harvest to fully assess Yield Prophet and comment on its credibility, but two said that Yield Prophet seemed credible to date. One wished to do more soil water measurement and leaf testing (for N stress) and compare results with Yield Prophet to boost his confidence in the model. Three interviewees raised concerns regarding the accuracy of soil characterisation data.

One interviewee believed his yields were higher than what Yield Prophet was indicating because he farms in very shallow soils. This suggests that the interviewee may not consider that Yield Prophet has been customised for his farm. Another had concerns about Yield Prophet's treatment of soil mineralisation in the area and had therefore had doubts about the credibility of all information in the Yield Prophet reports. For another interviewee, concerns about within-paddock soil variability reduced his ability to rely on Yield Prophet reports as much as he'd like.

Yield Prophet Discussion

Other than discussions with their consultant, interviewees also discussed Yield Prophet with:

- Members of local farmer groups (2 responses)
- Other Yield Prophet subscribers (3 responses). Another interviewee mentioned that he is not in frequent contact with other subscribers.
- Other non subscribers (1 response)
- Neighbour (1 response)
- Nobody (1 response)

Other comments provided in relation to Yield Prophet discussion included:

- One subscriber said that getting together as a group of subscribers to share experiences is valuable.
- One subscriber said he talks about Yield Prophet with both subscribers & non-subscribers because he is excited about it.
- Two subscribers said they had some reluctance to discuss Yield Prophet because they were protective about a product they've paid for. One elaborated and said that he sees it as competitive advantage – given land prices, he's competing with local farmers for a scarce resource – land.
- One subscriber said his cousins, who are also subscribers, have concerns about Yield Prophet credibility and are not fertilising consistent with Yield Prophet output.
- One suggested that it could be difficult to talk about Yield Prophet with non-subscribers, saying he'll talk about it *"a bit here and there. But if they're not using it they don't know a lot about it. But they'll get there"*.

Location 2.

Three subscribers and their consultant (the same for all interviewees) were interviewed. At the time of interviewing the consultant had 5 Yield Prophet subscribers from his client base of 22 farmers, which he described as the "top 2% of farmers in Australia". The client group is a formal organisation of farmers who own the company that employs the consultant. Two of the clients interviewed were also subscribers in 2004.

Nature of client-consultant interaction

Interviewees indicated frequent individual contact with the consultant, and with each other in the group. The group serviced by this consultant was described as an important information network, and the consultant was viewed as an important source of information about new technology. As confirmed by the consultant, interviewees said that they do not delegate decisions to the consultant (although there was an exception in relation to N management from a new subscriber), but that the consultant plays a very important role in helping them to analyse options. It appeared that the consultant was tightly integrated into the decision-making through such discussion. This was reflected in interviewees' discussions about Yield Prophet.

The consultant described a Yield Prophet interaction:

> *"…. we ran through a few scenarios. We established how much extra nitrogen he needed, which ended up to be only about 25 kilos of N per hectare, which is pretty minimal, and then we were working out when to put it on. It really didn't matter whether we put it on 15 September, 30 September or mid-October – there was going to be no different response in that*

time. That gives us a pretty big window – we have a six week window there to get on 25 units of nitrogen. We can pick a weather front that we think is going to be reliable and get that nitrogen on whenever we think we can. Things like that. The opportunities are starting to open up as we use it [Yield Prophet] more."

The two 2004 Yield Prophet renewers both commented that they were impressed with the accuracy of Yield Prophet in 2004 and that it provided a confidence-building experience that enabled it to be utilised in 2005. Interviewees indicated that Yield Prophet had a direct impact on the N they applied to their crop, and they used Yield Prophet for scenario testing. One interviewee clearly distinguished between the two uses of Yield Prophet – one for tactical N management, and one as a "learning tool". Both described the consultant as playing an important role in Yield Prophet discussion and provided examples. Interaction with the consultant was weekly, which provided opportunities for Yield Prophet discussion. One interviewee described a half-day session that involved looking at reports and designing sets of 'what if experiments'. Both interviewees spoke of Yield Prophet use in terms of enabling scenario analysis. It was noted that the consultant aids the Yield Prophet subscribers to interpret reports and set up teleconferences for discussing Yield Prophet. The consultant was also identified as having a role in managing soil sampling. Both interviewees and consultant were involved in running Yield Prophet simulations.

Yield Prophet reports were also discussed among the consultant's other subscribers. (Yield Prophet was also discussed by one interviewee with a company board of directors and another discussed Yield Prophet with a catchment management authority). According to one interviewee, the group meets about every six weeks, and Yield Prophet is discussed at these meetings. One interviewee, however, indicated that it was difficult to have meaningful discussion about Yield Prophet with non-subscribers, as illustrated in the following quote:

Facilitator: *Do you talk about Yield Prophet with other subscribers?*

Subscriber: *Other ones within [the consultant's client group], yes. We'll discuss that, and those results, at length.*

Facilitator: *With the whole group or the other Yield Prophet subscribers?*

Subscriber: *With the other Yield Prophet members of the group, and to a lesser degree, with the rest of the group who aren't involved, because the ones that aren't involved, don't really understand a lot of what it's about. You don't necessarily have a meaningful discussion with them about it. They don't necessarily understand what it is. They're interested. There's lots of other interested people in it.*

Facilitator: *But they didn't leap on this year?*

Subscriber: *No.*

Both interviewees said that they largely initiated the discussion with the consultant and both interviewees had a history of interaction with scientists/science modelling tools. This was the only region where no accuracy concerns were reported by interviewees or the consultant, and all subscribers renewed their subscription in 2005.

Impact of Yield Prophet

One subscriber described Yield Prophet *"as the first real attempt we've had managing cropping season in relation to the season"*, and:

"The information I've had so far from Yield Prophet has been very beneficial. I had planned to put more nitrogen on a lot of this country, and it's telling me I won't necessarily get an economic return from that. In that case, it's probably saved me $50-$60,000 so far, but that might change as the season progresses. It's been useful in that regard."

He also provided an account of how the value of SOI had been increased through its integration with Yield Prophet:

Interviewee: *As far as the probabilities go, if there's an economic response that you've got a greater than 50% chance of success, then that's when you start to look at it. Then I suppose that's when you look at the comparison between a normal season and a poor season, is to see what, or poor SOI, is to see if the SOI drops and the season starts to drop away, that probability of success of economic success changes. Then it depends on the degree of success then, as to whether you make the decision to go ahead or not.*

You might have potential to make $20, or lose $30. That then starts to impact on whether you proceed or not. So it's not just the probability of having an economic success; it's also the magnitude of that success or failure.

Facilitator: *How valuable is it to have those reliable probabilities of seasonal variation?*

Interviewee: *I find it very comforting, because it's making decisions on the basis of information that we never ever had before.*

The accuracy of that information is still, I mean you've got an SOI that might be predicting one thing, but that doesn't necessarily mean that will happen. It's still just based on probability. But we never had any access to that sort of information in the past. So any decisions that you made, were made without the benefit of any help at all. In that regard, it's very, very useful.

It does give you a certain degree of comfort, that the decisions that you're making have some basis in science, instead of none whatsoever. Otherwise you'll just toss a coin.

The above quote and the one below from another interviewee indicate that both clearly understand probabilities.

Interviewee: *I actually made decisions last year on it, on the probabilities and I am making decisions again on the probabilities.*

Facilitator: *Same types of decisions this year as last year? Is it nitrogen management?*

Interviewee: *Only. Yep. So, it is a probability of yield, yield and return for the cost that you have put on. In the wheat last year the crop had enough nitrogen right at the start to get it all the way through but the season was pretty good so we got to just about halfway through it, we still had plenty of soil moisture underneath so we knew we were going to get through the crop all right and I just thought well, what happens if I threw some more nitrogen on now? Would I actually get a benefit? And for the cost, I had a 50 percent chance of getting half a tonne to the hectare. Now, half a tonne to the hectare, sitting on a substantial amount of wheat but for the cost it was line-ball and given it was only 50/50 I just thought, no, I won't do it.*

Facilitator: *What probability of return, what odds would you need to actually act?*

Interviewee: *Probably 70/30.*

Facilitator: *Right. And that's a 70 percent chance of breaking even?*

Interviewee: *70 percent…no, I'd want a 70 percent chance I was going to make money. So, three years out of ten I would lose but seven years out of ten I would gain. So I would want more than just breaking even.*

Facilitator: *Yep. Okay. What sort of return would you…*

Interviewee: *Well, you obviously want to get more than what you put into it. I think at the time, and it didn't have all this nitrogen profit reports last year, but I think at the time the cost of the fertiliser and the application was worth the extra yield and that was about line-ball.*

Say I had a 70 percent chance of getting one tonne to the hectare increase; I probably would have done it. But given what it told me I just thought, no, it is not worth it.

The quote below illustrates one interviewee's refinement in his conceptualisation of soil water, as a result of Yield Prophet. Yield Prophet has also supported rather than replaced the use of the moisture probe.

Farmer: *And we use … I mean Yield Prophet, I get a bit lazy now I suppose, because I tend to extrapolate that information to other paddocks with similar history, but I'd still be wandering round with a moisture probe, and still using that.*

The measurements that have happened in Yield Prophet give you a bit of a gauge on how to use the moisture probe, that we didn't have before.

Facilitator: *Can you talk me through that a bit?*

Farmer: *The moisture probe really is just a case of pushing a bit of metal into the ground, and when it stops, that's when you run into dry soil. It's not a case of that … it might be moist soil, but it's not necessarily saturated right through the profile.*

That's the first thing we found with the Yield Prophet testing, and actually measuring the moisture in each layer of soil. There was a lot less moisture there than I would have anticipated, given a push probe test, and so it was a case of the testing that was done as part of Yield Prophet program, said okay, well we can push the soil probe into the ground, but that doesn't mean that we've got 200mm of moisture in the soil. It might only be 100mm. So we certainly adjust to the way we look at those sort of tests, and take them with a little bit of a grain of salt.

That makes it easier then. You can go and look, okay well the Yield Prophet has predicted say 100mm of moisture in this paddock here, so you can go and gauge that. This is what soil probe does in this paddock, it's similar in this one next door, so chances are the results will probably be right.

Facilitator: *Okay, so that's what you mean by extrapolating in that case?*

Farmer: *Yep.*

The quote below illustrates a 'what-if' scenario and the learning opportunities provided by counter-intuitive output. In other words, an example of using Yield Prophet for learning, without a decision pending. It also illustrates use of Yield Prophet for a management option other than N.

Farmer: *I've done some reports again on sowing dates, and the effect of sowing date on potential outcome of those crops. I'm somewhat surprised at some of the answers I got. I'm still trying to work out why I got some of those answers. Again, it's giving me something that gives me a potential to learn a lot more about my cropping system.*

Facilitator: *So you used it for pre-season decisions?*

Farmer: *No, we didn't, but it was more after the fact this year, mainly because we didn't get our soil testing done in time. Looking at the effect of planting date this year, I ran several reports with their new variety report, looking really at the same variety, but what would have been the effect of sowing earlier, really in regard to what might happen next season. So okay, if we're in the same position again, or we're better off*

sowing earlier, dry or waited for the rain or whatever, and also looking at when could we have planted to.

I was somewhat surprised at the results. There wasn't as big a difference in yield outcome from planting date as I anticipated. I then have to try and tease out a few more results from that. Is that because of the soil moisture? That if irrigation system's going again, I'll run through all that again and give it heaps of moisture, to see whether my yield has been limited by moisture availability, or whether it's been limited by nitrogen availability, or whether that's just a genetic potential of the crop, given the sowing date.

The interviewee who was subscribing to Yield Prophet for the first time in 2005 was yet to look at a report for his paddock, but participated in a group meeting to look at the outputs of other subscribers' reports. He was attracted to Yield Prophet as an opportunity to "take the guess work out"/"inject precision" into decision making, rather than rely on gut feeling and said he wants to take some of the "hunch" out of farming. This interviewee spoke about soil water differently to the other 2 interviewees, with current soil moisture status described as depth to wet soil using a push probe.

While he was uncertain in pinpointing the expected benefit from Yield Prophet he said the probabilistic information had appeal, as expressed by the following quote:

"Well, just looking at it the other day, the per cent – what I did like about it and as I say, we only had – it's very hard for me to judge, I haven't found anything I don't like, one of the things I did like was it related back to percentages. You had 75% chance of getting increase in yield if you did this. So that was interesting, obviously the closer it gets to 50% the less likely you're to do it, I suppose. So that would be interesting and it just makes you think a bit.

So that's all we hope to get out of it, to give them the hard data and then let them model the data and then they can say, 'Well, if you put on X amount extra,' because there are some trials – you're going to do 40 units, 80 units and 120 units of N post-plant. Then they're going to work out how much money would we make extra on 40 or the 80 or 120. They're the things I'd like to find out, take a bit of the guess work out of it."

This interviewee expressed lack of confidence in his computer skills and clearly indicated that he would need consultant support (both agronomic expertise and computer expertise) to run Yield Prophet – "*he'll (the consultant) be the driver of this"* – but the interviewee also indicated that he would also "play" with it. Like the other interviewees in this location, he said he speaks with the consultant at least weekly, and this would allow plenty of opportunities for discussion of Yield Prophet.

Unlike the other 2 interviewees, this interviewee appeared to delegate the N management decision, which is consistent with his comment that the consultant would be the driver of Yield Prophet:

"So basically we'll soil test the blocks that need soil testing. He'll [the consultant] come back then with a recommendation at planting time. We know what the plant population we want, so that's all right. Basically that's done all here and once the crop's up, then [the consultant] sort of takes over with nutrition issues. The chemical issue is pretty standard; it's a pretty standard brew, through the whole valley. There's a pre-spray and then a post-spray and then that should be it. But then he'll monitor insect pressure. It used to be a visit every week, but now it's probably more like every, I don't know, 10 days……. We'll tell him what we're doing and he'll then give us information we need as far as inputs, fertiliser inputs. The crop will be planted, so he visits us on a regular basis, and he inspects – insect pressure, wheat pressure and then we just go through the season like that and basically the next crop we repeat the same process."

Location 3

Nine interviews were conducted. One agronomic consultant (in his first year of involvement as a Yield Prophet consultant) was interviewed, but none of his clients was available for interview. Two interviewees were farmers who subscribed to Yield Prophet in 2004, but did not renew in 2005. One of these two had a consultant.

Six current subscribers were also interviewed, five of whom had a consultant and all of whom had subscribed in 2004 and/or 2003. Four subscribers had the same consultant, but one of these also had a second consultant, based in another town, who had introduced him to Yield Prophet, and the fifth used a different consultant again.

Nature of client-consultant interaction

Of the four subscribers with the same consultant, discussion about Yield Prophet varied: one said he did not discuss it often, another appeared to let the consultant lead Yield Prophet discussion and interpretation, another had no interaction with Yield Prophet in 2005 at the time of the interview, but was about to start, and another indicated that he initiated discussion about Yield Prophet with the consultant if he had a question, and did so on a frequent basis.

The fifth, who did not share the same consultant as the others, had three discussions about Yield Prophet during the year which covered setting up Yield Prophet and discussing reports. Unlike the other current subscribers interviewed he subscribed in 2003, not in 2004, and renewed in 2005. He reported that a change of consultant had been instrumental in increasing the value he got from Yield Prophet second time around.

The subscriber who did not use a consultant indicated that he did access help from Yield Prophet/BCG staff.

None of the farmer interviewees delegated decisions to consultant, but two interviewees said that they use chemical resellers for weed advice.

Impact of yield prophet

Of the six current year subscribers interviewed, all used it for N management. Three indicated the value was in providing greater confidence in N management, but it was implied or explicitly indicated that Yield Prophet was supplementing existing decision approaches e.g. as indicated by language such as “it’s another tool”, “making sure things were on target”, “probably” let him know things weren’t going to be as good as hoped. One explicitly said he was unclear if he would have made a different decision without it. For N management, 3 interviewees described its value as giving greater confidence to their decision. One said he didn’t feel he would start using it (i.e. valuing it) until a wet season. Similar to comments made by an interviewee in Location 1, one interviewee talked of Yield Prophet restraining his enthusiasm after rain, indicating that visual crop assessment wasn’t always an indicator of likely performance. Another interviewee said that he used Yield Prophet for input management specifically in relation to understanding the performance differences between his paddocks.

Only one interviewee used Yield Prophet for pre-season variety choice and described the simulations as experiments. Two other interviewees identified Yield Prophet’s potential for pre-season use, even thought they hadn’t used it.

Learning

Three interviewees of the eight interviewees reported Yield Prophet impacts in terms of improved soil water and N understanding. A fourth attributed greater interest in in-crop soil water monitoring to Yield Prophet. Some interviewees indicated that the importance of stored soil moisture was understood prior to Yield Prophet becoming available.

The two non-renewers interviewed indicated that they did not use Yield Prophet because the year was dry and that Yield Prophet gave them no more information than what was already needed to make the correct decision. One said that he was not attracted to "study", so Yield Prophet needed to be more than just interesting – it had to support a better decision. Both indicated an interest to use Yield Prophet in wet seasons. Neither had experienced it for pre-season use, but could see potential application. One indicated that the general Yield Prophet report that is based on a small number of sites but is widely circulated in the region was sufficient for their needs in 2005.

Two current subscribers also believed the value of Yield Prophet would increase in a wet year, indicating that the N management decision was already straightforward in a dry year.

These comments regarding wet years are consistent with those made by other interviewees in the 2004 interviews and also highlight the limited impact of Yield Prophet to date for pre-season decisions.

Probabilities

Although one current subscriber did not discuss Yield Prophet output in probabilistic terms, the others appeared to understand Yield Prophet's probabilistic information. There did appear to be one case of misinterpretation of output presented as probabilities. The subscriber described how he interpreted the probability of exceedence curve. He looked at the decile information and used it to identify which part of the probability curve that he would be most likely to experience. For example, if in decile 1 his expectations about the season turned to the lower yielding outcomes in the distribution, with the expectation that they had the greatest chance of occurring. However, this suggested that he wasn't realising that the distribution had already been refined to reflect the decile 1 situation. Had a decile 5 year been experienced to date the entire probability function would have shifted, but instead, on the same logic, the subscriber just would have looked to the median part of the curve. It may be significant that this interviewee did not use a consultant.

Two current subscribers reported that they have found it challenging to understand Yield Prophet's probabilistic information in the past. One offered to the following explanation:

Farmer: *The probabilities and the graph is really good. I really like it, but a lot of people would wonder what the line is, I think.*

Facilitator: *You see probabilities used a lot though, in presentations these days. Are you saying it goes over the head of 70% of the audience?*

Farmer: *I'm saying it used to take me a long time to get my head around it, yeah. [laughs] I understand probabilities now and I like them, so I guess I'm one of the converted sort of thing, but I still struggle to get my head … I've got ask a few questions to get it started.*

I just think about I meet my neighbour at the bus every morning, not now, because the kids drive the car, but we used to talk about, and I couldn't talk about Yield Prophet to him, because he wouldn't understand the concept really. It's a fairly complex thing to get your head around I suppose, yeah.

Facilitator: *Do you know what the bad experience was with your neighbour, with Yield Prophet? Was it an operational thing, or it just wasn't predicting anywhere near right?*

Farmer: *No, I'm not certain. I'm not certain. I'll ask him, if you want to know. I think it would be a yield difference. If you don't understand the probability curve, it doesn't say you're going to get three tonne, it says you've got a good chance of getting three tonne. If you get a 42° day, that's a 100, so it can come right back to the start.*

Then he says, look it said I was going to get three tonne, and I only got a tonne, well Yield Prophet gets the blame.

Facilitator: *That's a bit like climate forecasting, isn't it? People don't see the probabilities in that either.*

Farmer: *Yeah, and I mean that's basically [it] to me, I think that's understanding probabilities properly. That's what a lot of people miss.*

When asked about the probabilities that would warrant action on an N management decision, four described a 2:1 decision rule (i.e. the profit from N had to be twice its cost), with three indicating a minimum probability of getting this ranging from 50 – 75%, and the fourth not indicating the probability of getting this. A fifth interviewee said a 50% chance of getting any return was reasonable.

Accuracy concerns

Four had concerns about the accuracy of soil data. One had concerns about variety comparisons. Two indicated that the report output which provides information about economic returns from nitrogen application was not helpful.

One interviewee offered a view on accuracy required:

Facilitator: *How close has it got to be, to be useful?*

Farmer: *There's got to be some variance, because like you say, I mean you can't allow for those days in October. I suppose what I'm inferring is that last year, all year, it basically said that it wasn't going to be a good year. Yet we chose to ignore it [Yield Prophet].*

I'm saying that perhaps we should have hung our hat on it a bit more and tapered off. This year it's saying it's average, so if we come in our average year, which around here is probably 2.8 to a bit over 3 tonne to the hectare in cereals. Over a long term period, we'd like to think it's better than that, but if you can look at it over the last 20 years, that's what it's been. If it comes in close, reasonably close to that, I'll certainly run with it.

I suppose what we're looking at is to indicate whether is it a year when we have a go at it. Is it a year when we sort of go cautiously, or is it one of those good years, where we've really got to have a crack at it?

I suppose when we're looking at Yield Prophet, not so much being within 2.2 of a tonne to the hectare, but is it a 2 tonne to the hectare year? Is it a 3 tonne to the hectare year? Or is it a corker year?

This quote indicates that precision isn't demanded, rather, the expected performance in more general terms is what is of interest. However, what the discussion also highlights is that despite Yield Prophet providing probabilities, the probability range is still summed up as 'bad' or 'average'. Given that a probability distribution could encompass bad, average and good outcomes, of interest is what part of the probability curve is being used to assess the season? For this particular interviewee, it was not clear, although he indicated that yield was expected to be between the (narrow) range 3.5 and 3.8 tonne.

Several other interviewees, although giving indications of understanding probabilities, frequently indicated that Yield Prophet was "telling them" an expected seasonal outcome. It was not clear how the probability distribution was summarised into a seasonal outcome, particular for probability distributions with a wide tonnage range. (In contrast, in Location 4 in 2005, the graph plotting possible yield outcomes was close to vertical from Sept meaning Yield Prophet had locked in the season type. Similarly in Location 1 in 2004, Yield Prophet locked in early to a poor season. There are circumstances where the seasonal outcome can be predicted early, mainly when water supply becomes irrelevant either because other factors are limiting (N) or because there is enough soil water to complete the crop).

Another interviewee, to contrast the response quoted above, offered the view that 10% accuracy was required for Yield Prophet to taken seriously.

Other Yield Prophet discussion

One interview suggested that Yield Prophet is difficult to discuss with other subscribers:

Facilitator: *Is this knowledge and this support of Yield Prophet staying within the people that are paying to use it, or is it getting out there into the wider community too? Is Yield Prophet talked about?*

Subscriber: *No, I think it's pretty well in the users. …..…..I think Yield Prophet is fairly complex. It's probably taken me three years, and I probably still don't understand it properly, but it's sort of developing as it goes too. It's pretty hard to talk about. I show my reports to [other subscribers named] and a few of those sort of guys, but nobody else, because I don't think they'd understand.*

Location 4

The consultant interviewed in this location indicated that he facilitates the use of Yield Prophet for 11 farmers as part of a research project with a farmer group. He is herein referred to as the facilitator to avoid confusion with subscribers' private consultants. Each of the 11 farmers has a paddock in Yield Prophet, but 'technically' they are not individual subscribers and have not personally paid for their subscription. Four of the eleven farmers were interviewed. The facilitator identified himself as a subscriber on behalf of the eleven farmers and is also a private consultant to some members of this farmer group.

Although the facilitator supported interviewees' involvement with Yield Prophet, it was not clear if the consultant interviewed in this location was the private agronomic consultant for any interviewees. None of the interviewees offered to name their consultant.

Nature of client-consultant interaction

Three of the four used agronomic consultants. All said they do not delegate decisions, with the exception of two who will delegate herbicide recommendations. One said he doesn't rely on his consultant for being introduced to new technology.

Two interviewees became aware of Yield Prophet through the farmer group referred to above, with one approached to host a trial site, another one cited APSRU researchers and the fourth said a researcher, who champions one the alternative N management tools in the research project in which Yield Prophet plays a part, provided the introduction of Yield Prophet.

The facilitator said that subscribers generally instigated Yield Prophet discussions, although he took the initiative in ensuring subscribers had Yield Prophet set up on their computers. He reported that some individuals have been active users, but that he generated most of the reports (approximately ¾ of the simulations) and helped them to get set up with Yield Prophet. He was motivated to generate runs because he needed the outputs for the bulletin that he puts together on a monthly basis through the growing season. The bulletin was being produced as part of the research project and contains Yield Prophet results. The facilitator also indicated that he sometimes initiated contact with subscribers:

> *" I suppose with some of them … I must admit, if they haven't entered their rainfall, because I've got this responsibility to get a report out once a month, then I'm pestering them for rainfall, and some of them will just never return the fax. You've got to physically ring them and say "how much rain have you had on which days?" That I suppose, gives them the chance to ask you a few questions."*

"Half the people would have rung at various times, saying I'm trying to generate a report, I can't do it. What am I doing wrong? How do I enter the rainfall? I kept entering it and it disappears, because they haven't saved it. All those sorts of things. So we've provided that support."

Two of the four interviewees said that they ran their own reports. One ran reports up until June, but decided to trust his own judgement rather Yield Prophet from July onwards. The other indicated that reports were run regularly in July, but not from August onwards, explaining that Yield Prophet is "probably very important at the end of July" but that beyond this point all the key management actions would be taken and Yield Prophet less important. The same interviewees also noted that his simulations would supplement the general Yield Prophet information that was produced for the group.

A third said that his brother often generated reports, at least once every 3 weeks (his brother was more involved with the business side of the operation, while he was more involved with the physical farm management work). The fourth did not run any reports and only received what was produced for him.

Yield Prophet Discussion

Two interviewees discussed Yield Prophet with a family member. The only other discussion that appeared to take place was the through workshops at the farmer meetings. Two said that Yield Prophet doesn't receive much discussion in at the farmer group meetings, and a third said it wasn't the only thing discussed.

One interviewee said that more help would be appreciated, but indicated that it would be provided if he asked for it. He's not confident that he's using it properly, and would be interested in one-on-one help to understand it better. He thinks that only 50% of the farmers in the farmer group really understand it. He has found it a difficult concept to get his head around. One difficult aspect is that it's not combined with tissue tests:

"You've got a model, and out there is a paddock, and that paddock is telling me something, straight away, with nitrogen. It's telling me something through a tissue test. If you ignore that in Yield Prophet, then you're talking about the profitability of lifting a yield by applying nitrogen at this price, and whatever. Nowhere do you put in what nitrogen … it's only what you think. You do … PYCAL comes in to say what it should be, but what is out there, is a nitrogen test. I don't see any part of Yield Prophet, that puts that into the equation."

Of concern to this interviewee was that the local fertiliser agronomist who does nothing but think about fertiliser hasn't fully come to grips with the model – and, according to the interviewee, this says something significant about Yield Prophet. His advice was that it should be ensured that fertiliser company agronomists can come to grips with it for him to get benefit out of Yield Prophet.

Of the three interviewees who had consultants, it is clear that consultants are not an integral part of the Yield Prophet use for two: one said he did not discuss Yield Prophet with his consultant, another said his consultant doesn't think much of Yield Prophet. The third indicated that his consultant is aware of and interested in Yield Prophet, but, when asked, he answered that discussion took place with the consultant, but didn't elaborate on nature or frequency of discussion.

For all interviewees there was limited discussion, but this was not a predictor of dissatisfaction with Yield Prophet – e.g. the interviewee who appeared to have most enthusiasm for Yield Prophet did not discuss Yield Prophet with consultant and did not run it himself (his brother did). On the other hand an interviewee with a much higher degree of hands-on involvement with Yield Prophet reported less value because of accuracy concerns and lack of understanding.

Impact of yield prophet

Two interviewees indicated that Yield Prophet has not offered value. For one, who has been farming 30 years, it was because Yield Prophet 'doesn't tell me anything I don't know". He indicated he already knows the probabilities presented in the Yield Prophet report through experience. This interviewee had a Yield Prophet trial on his paddock, but had not generated any Yield Prophet reports by himself. The other interviewee, who, in contrast, has a history of seeking and using scientific outputs/models to guide management, had self-generated Yield Prophet reports, but rejected Yield Prophet because of concerns that APSIM does not accurately model the production system. Such concerns were also shared with this interviewee's agronomist (not interviewed). This interviewee also placed more credibility on tangible rather than abstract measures of farming systems performance.

A third interviewee reported reassurance value from Yield Prophet – i.e. it confirms existing practice is "on the right track", but did not appear to change from his existing approach to N management because of Yield Prophet – i.e. he said he applied N according to an optimistic outlook. The N decision still appeared to be grounded in a historical approach to N management.

> *"I'm still a great believer farmers have got a gut feeling, so this is another tool which gives you confidence". The key benefit he reported from Yield Prophet was that he had learnt " hell of a lot about soil types, and how soils react, and it's been a very positive experience for us."*

When asked about how he acted on the use of Yield Prophet probabilities he implied it was straightforward because the range was very narrow – "a vertical line" indicating a highly restricted range of yield outcomes.

A fourth interviewee clearly articulated a changed approach to N management. He based his N management decision directly on Yield Prophet output, but did qualify that the decision based on Yield Prophet was consistent with the rate that would be applied in the absence of Yield Prophet, but he was doing what the model 'tells him' for the purpose of evaluation in relation to the Yield Prophet N trials on his paddock. When this was explored further in the interview, he explained that acted on the median of yield outcomes, but found the range 'interesting'. This interviewee, who has a degree in agriculture, indicated that use of APSIM is supplemented by digging holes, taking soil profiles, and tissue tests.

The other three interviewees did not report any difficulties with probabilities, and there was no evidence of misinterpretation. Two interviewees commented on the straight line, indicating that the range of yield outcomes was very close.

The only interviewee not to express accuracy concerns was the interviewee who was not generating reports.

In this location, none of the interviewees provided descriptions of current soil water status in mm, and there was no explicit mention by any interviewee of changed conceptualisation of soil water, except the learning quoted above.

Other information subscriptions (all regions)

Interviewees were asked what other information they purchased. Prompts provided by interviewers included soil tests, marketing information, association membership, publications and weather information.

Most interviewees did not provide an itemised breakdown of the money spent. The total amount spent on this information per interviewee ranged from hundreds of dollars through to $3,000, with one exception of $10 000 being spent ($2k of which was spent on magazines). Most interviewees said that

they did not pay for weather or climate information, although all accessed free weather information via the internet – e.g. Weatherzone, Bureau of Meterology.

Without prompting from interviewers, 3 subscribers offered a view on the cost of Yield Prophet as an additional information subscription. One (Location 1) mentioned that although $500 is a "drop" compared to the annual amount spend on nitrogen, in the order of $100 000, he still "wrestles" with its value and another member of his family business doesn't think it is worth it. One interviewee (Location 3) thought Yield Prophet offered value because he only needed to save one tonne of urea for Yield Prophet to have paid for itself. Another (Location 2) said that he couldn't quantify the benefits of Yield Prophet but felt that it was worth the money.

Consultant interviews

Value of Yield Prophet

All consultants indicated that they thought Yield Prophet could offer value to clients, although two of the four consultants (Location 3 and 4) stated that Yield Prophet was still under evaluation by them until some credibility concerns had been resolved (discussed further below). Two consultants also indicated that Yield Prophet is of less value in some production environments e.g. in reliable rainfall zones (Location 4) and in dry seasons (Location 3) when the appropriate decision to make is clear.

All consultants nominated nitrogen fertiliser management as a decision that could benefit from Yield Prophet, and this was the only decision for which they said they had experience in using Yield Prophet. Three consultants specified that the value of Yield Prophet in relation to N management related to the in-season, top-dressing decision, and the fourth (Location 3) made the more general comment "backing up our thoughts and our other tools that we use to make particularly nitrogen decisions". Three consultants thought Yield Prophet could deliver value for pre-season planning such as variety choice and timing, and whether or not to plant, with one noting that Yield Prophet could have value for the planting decision that he believed can be clouded by emotions (Location 4). One consultant (Location 3) did not believe Yield Prophet was suitable for pre-season planning because a) it was not accurate enough, b) there were other satisfactory approaches for pre-season planning and c) that the decision was often highly constrained in reality by the practicalities of pre-season planning (e.g. associated with grain storage arrangements, growers can't switch varieties easily). Two consultants also suggested that Yield Prophet could aid management of other crops (canola, pulses, sorghum).

There were suggestions from consultants that they were direct beneficiaries of Yield Prophet, not just farmers. Two (Location 3 and 4) identified that Yield Prophet could be a tool to support consultants' thinking i.e. to help them better understand the likelihoods of possible outcomes. This, in turn, could be incorporated in advice they provide to clients. One consultant (Location 3) said he was unsure whether he would use Yield Prophet directly with clients. Rather, he visualised use of Yield Prophet to inform his own thinking, which may or may not be conveyed to clients through Yield Prophet reports. The same two consultants expressed the view that farmers generally prefer to rely on agronomists rather than a model for decision making and that only some farmers will take to direct model use. One believed that such farmers could make improvements to their management through exposure to general principles without the use of Yield Prophet.

One consultant who appeared to have had a higher degree of interaction with clients around Yield Prophet (Location 1), believed that few farmers would adopt Yield Prophet without consultant support, which he thought was essential for delivery to farmers. He also said that further expansion of Yield Prophet use would require more consultants supporting the service, which in turn would require further resource and support of the Yield Prophet team (BCG / CSIRO).

Use of probabilities in Yield Prophet output

Yield Prophet outputs are presented in the form of probabilities and three consultants indicated that they discussed Yield Prophet outcomes using the outcome with a 50% chance of occurring – i.e. the

median outcome. All consultants thought that subscribers were comfortable in interpreting information presented as probabilities. One consultant (Location 2) noted that growers act on probabilities differently e.g. some will take action in relation to an outcome that has a 30% chance of occurring, because they may be able to accommodate the financial risk and/or are comfortable with risk, whereas others may require a 50% chance before taking action. Another consultant indicated that although the 50% probability outcome was not representative of what could happen in practice, it was still useful information for subscribers.

One consultant's (Location 3) quote illustrates communication that has taken place with subscribers in relation to interpretation of probabilistic output. The quote deals with Yield Prophet not providing a definitive in-season yield prediction:

> *"You could never be spot on, we understand that, so it's all about probabilities, and I explained that to them [clients]. One day the probability that it says we're going to get 4 tonnes to the hectare, and it's only a 10% probability, it will happen because of that one rain event that occurs when we've got enough nitrogen there to drive it.*

Accuracy issues

Three consultants spoke of concerns with Yield Prophet. For one (Location 3) it was serious enough to withhold discussion from clients because he had already received unfavourable feedback from 2 clients who rejected Yield Prophet. This consultant offered a means to address this problem:

> *"It's probably more time spent by me showing them and I suppose proving to them that it does work and it has got some logical outcomes, etc. But I guess because I'm nervous about it as well, it's just difficult for me to promote it.*

For two consultants (locations 1 and 3) their concerns related only to inaccurate soil characterisation data, rather than to the model itself. Accurate soil data were regarded as critical to building confidence in model output (see quote below). One said that the soils were 40% characterised in his area, but it would take at least another 2-3 years to complete.

> *"So while we've got 15 on the books we've probably got 5 effective users because we've only got the 5 soil types characterised at the moment. The other 10 aren't confident with the soil description. Extremely time consuming to obtain soil characterisation data. Those 10 who have not got soil types properly characterised are "sitting back using someone else's soil profile and feeling that perhaps they're not quite getting the value out of it just yet.*

> *"And I think with the work we've done so far, how we're using it so far with our clients, the work we've done so far is that we've recognised there is huge variation in soil types and soil depths and those sorts of things, and once we get that done and can allow agronomists I guess to help their growers construct a decent profile, that we'll be able to use this more intelligently and with better results, because that is a big limitation with it at the moment."*

The third consultant's (Location 4) concerns related to discrepancies between Yield Prophet and other N decision tools, and performance on some soil types.

The consultant who did not register any concerns with Yield Prophet (Location 2) was a consultant to three subscribers in 2004, who all renewed. He summarised the client reaction to Yield Prophet in 2004:

> *"Most people were pretty happy with the accuracy of it last year and that is why they are doing it again this year. If it came down to it that it wasn't accurate then there is no point in doing it. If the yield predictions aren't there then there is no point. You are best to walk into*

the paddock, have a look yourself and make the decision while you are standing in the paddock."

His impressions and use of Yield Prophet in 2004:

> *"Last year I was pretty impressed with the way it predicted the yield. We ran a few scenarios and didn't really use the top dressing part of it because by the time it had come up, the situation came up, we had already applied nitrogen and the crop was in basically, so all the decisions were made. But in terms of yield prediction and crop reaction and things like that, it was pretty good."*

He offered a view on how accurate Yield Prophet needs to be to be useful for subscribers:

> *"Some guys might be happy with that and they might accept a 10% error in yield but 10% error in yield, potentially if you are putting extra nitrogen on and you are not getting that extra 10% yield back, that can cost you $20 or $30 per hectare. They won't tolerate that too often."*

Constraints to wider use of Yield Prophet

Price

Different views were offered on whether the price of Yield Prophet subscription would constrain adoption. One thought that cost would not be a deterrent, whereas two thought it would, particularly in the current environment of poor seasons. One of these suggested offering a cheaper price for the purchase of simulations for just one paddock, rather than the current 3-paddock package on offer. The same consultant also mentioned that the current price could be an irritation for some current subscribers because they are contributing to a technology development process.

Difficulties in visualising benefits

One consultant (Location 2) indicated that an adoption challenge for Yield Prophet is that not all farmers are able to visualise the practical use of Yield Prophet because they think there are few top-dressing opportunities, although the quote from the consultant below highlights a changing attitude to this.

> "*Some guys like the fact that they can put all their nitrogen on up front, put a broadleaf spray on it and walk away until harvest sort of thing. But people are now, because of cost price squeeze most people are getting to the point where they're having to say 'I couldn't live with the risk through the crop."*

Time and effort

The time and effort required from subscribers to use Yield Prophet was suggested as a potential constraint to growth in Yield Prophet use (Location 2).

> *"Time is another one. Time it takes to sit down, run the reports, sit there and analyse the reports. That's one of the issues. We have guys with over 2,000 hectares that they are trying to suit two or three people, so they are fairly pushed, so they haven't got time to sit down and just do that type of thing cause they have got their marketing and all sorts of other things going on. Sitting in front of a computer doesn't turn them on that much.*

The demands of Yield Prophet on consultants' time was mentioned by 2 consultants (locations 1 and 3), and specifically in relation to obtaining soil characterisation data. One consultant said he was interested in being involved if an opportunity arose to characterise soils in the region, but said he couldn't give it much time. When prompted by interviewer, said he'd be willing to collect crop lower

limits[12] at the end of the season. He did say that people in private business are not going to have time or inclination to collect soils data.

Redundancy of Yield Prophet after a learning experience and use of regional predictions

One consultant (Location 1) suggested the possibility that subscribers will learn from Yield Prophet and then discard it, particularly if they can still access Yield Prophet reports relevant to their region (although not customised) e.g. through newsletters. The following quotes from this consultant elaborates:

> *I think even the guys that are subscribing - are going to say after a few years and having dug a few holes and got a feel for the model and how it works and those sorts of things, they're going to say well you just keep running it and we'll go and dig a few holes and just see how much moisture's down there. And after a while they'll develop a feel as to how much stored moisture they've got, despite using those soil probes, banging in the hole and going, hmm well it's dry or it's wet and making decisions from that.*

> *"You know, we punch out newsletters and we'll just have the yield Prophet curves for [four sites mentioned]. And so they'll have a look at the yield potential in that zone and make a decision as to what they'll do based on the fact that their neighbour 10 miles away who's still doing it and who's information is published in the newsletter is provided with a bit of a rough and ready model anyway. So I don't see that every farmer in [the state] will be subscribing to Yield Prophet. They won't. I think what'll happen is through farming systems groups, through consultants, there'll be a number of people that use it and that information will get shared and published and there'll be a bit of a rough and ready sort of model that's predicted [yields] for regions.*

[12] Crop lower limit measures the extent to which a particular crop can extract water from a particular soil type.

Discussion of Results: Stage 2

All interviewees make tactical adjustments to crop management to accommodate seasonal climate variability. The adjustments are made using various combinations of rules, analysis tools, and experience. Yield Prophet provides information that is relevant to the main strategies identified by interviewees for managing climate variability. All interviewees said that a key strategy for dealing with climate variability was managing N input according to the season. When combined with historical climate records and seasonal climate forecasts, Yield Prophet's combination of pre-season soil-water and nutrient testing, and simulations of alternative management options in relation to crop type/variety and nitrogen provides information that directly informed N management and a range of other strategies for managing climate variability. The interview findings, as summarised in Table 23, however, indicate that not all interviewees got the same value from Yield Prophet. 'Value' took on three aspects: tactical N management, learning, and, to a far lesser extent, accountability (e.g. in relation to finance applications and communicating the rationale for management decisions externally). These are 3 of the 4 uses of DSS put forward by McCown (2002). Issues that account for the variation in value obtained from Yield Prophet are summarised and implications for future delivery discussed.

Table 23. Value of Yield Prophet as indicated by interviewees, with nature of consultant interaction and subscriber learning also reported

	Location 3 (n=8)	Location 2 (n=3)	Location 1 (n=5)	Location 4 (n=4)
Clear articulation of value or potential value	5	2	2	0
Lukewarm articulation of value / value uncertain / value not clearly established	1	1	3	2
No / low benefit	2	0	0	2
Nature of consultant interaction	Ranged from minimal to high interaction	High interaction	Mostly high interaction	Low interaction
Reports of a reconceptualisation of production system	3	1	3	1

How compatible is Yield Prophet with the way farmers currently see their farming environment, i.e. does Yield Prophet make sense?

The question of interest is whether a reconceptualisation of the way farmers currently understand their production system is required before Yield Prophet's scientific concepts can be viewed as meaningful and relevant. In other words, is a learning experience in relation to these scientific concepts a pre-requisite before Yield Prophet can be seen as relevant to the management decision? The interview route was designed to explore how interviewees currently mentally represent their farming system in relation to describing seasons, assessing seasonal outlook and describing soil water status.

There was variation in the way the production system was conceptualised. Using the soil water example, some described it qualitatively, informed by visual assessment, some used rainfall as a proxy for soil water, through to discussion of plant available soil moisture based on direct measurement. Some interviewees used a combination of concepts, e.g. visual assessment of crops and soil water, ecosystem indicators and objective measurement. Some interviewees clearly articulated a change in conceptualisation of their production systems that was a result of and facilitated their appreciation of Yield Prophet. Experienced Yield Prophet users and those who provided a clear description of a

valuable Yield Prophet experience rarely talked in terms such as 'gut feeling' and typically discussed the production system using objective, scientific measures.

Appreciation and understanding of seasonal climate forecasts appeared to be low overall, with some variation among interviewees, but this did not appear to be a pre-requisite for interviewees valuing Yield Prophet. Interviewees appeared to separate seasonal climate forecasts from Yield Prophet, such that low appreciation was not associated with low appreciation of Yield Prophet.

While there were no conceptual representations of the production system among interviewees that were fundamentally incompatible with Yield Prophet's representation of the production system, some interviewees had experienced a shift in how they measured various states of the production system.

These shifts and differences in production system representation amongst farmers can be helpfully elaborated using Hammond's (1996) two forms of cognition: *analysis* and *intuition*, and Zuboff's (1988) distinction between 2 cognitive approaches to management based on *intellective skill* and *action-centred skill*, which may here be viewed as ends of a continuum rather than an either/or dichotomy. Hammond's two forms of cognition are explained:

"The meaning of analysis or analytical thought in ordinary language is clear; it signifies a step-by - step, cautious, logically defensible process. The ordinary meaning of intuition signifies the opposite - a cognitive process that somehow produces answer, solution, or idea without the use of a conscious, logically defensible, step-by-step process. Analysis has always had the advantage over intuition with respect to the clarity of its definition for two reasons: (1) its meaning could be explicated by the overt reference to a logical and/or mathematical argument, and (2) analytical thought forms the basis of rationality, because rational argument calls for an overt, step-by-step, defensible process. Thus, analytical thought and explicit, overt definition are part of the same system of thought. Not so intuition; throughout its history it has acquired powerful claims to efficacy despite its ineffable, undefinable character". (Hammond, 1996, p60.)

Zuboff's (1988) distinction between 2 cognitive approaches to management complements Hammond's, with *analysis* aligning with *intellective skill*, and *intuition* aligning to *action-centred skill*.

Intellective skill involves working with an environment represented in abstract terms through a data interface. Such skills are required for Yield Prophet use. To elaborate, the simulation model behind Yield Prophet (APSIM) represents the features and states of paddocks, weather and management events using mathematical models. This means that for Yield Prophet to make sense to farmers they must, to some degree, appreciate the logic (i.e. conceptual constructs, though not the mathematical representation) used by APSIM. In addition, to participate in setting up a simulation of a crop and to discuss simulation outputs, familiarity with quantitative measures is often necessary.

Action-centred skill, in contrast, is based on sentient information and developed in and reactive to the performance of the physical environment e.g. making assessments of crop performance using visual cues, or the sense of touch (e.g. in relation to soil moisture). For a farmer, such skill is associated with knowledge of the farm that is experience-based and highly context dependent i.e. specific to the farm, and implicit to the farmer. This is in contrast to intellective knowledge, which is explicit and based on transparent logic. The use of the term "gut feeling" as a management approach can be closely associated with an action-centred approach.

Variation in the intellective skills of farmers was evident. Those who provided the clearest articulation of Yield Prophet value displayed high existing intellective skills – e.g. described their farms using the quantitative terms of Yield Prophet and some indicated their interest in modelling, or had recently acquired and valued new scientific understanding of their production system. They showed competence in interpreting and visualising the value of Yield Prophet output. These individuals often had a history of interactions with researchers and, for some, other DSS.

Use of Yield Prophet requires, and can be used to develop, intellective skill in representing the production system through a data interface. There were no accounts of the logic of Yield Prophet being incomprehensible, even among those who indicated it was of limited value. For some interviewees, familiarity with quantitative measures was acquired through experiencing Yield Prophet. There was evidence that interviewees used Yield Prophet's new quantitative measures to complement their existing, quantitative measures of system performance, or even replaced the use of sentient evaluations of the production system (e.g. using Yield Prophet to estimate soil water and crop growth rather than visual assessments). In relation to the use of Yield Prophet to augment existing approaches to management, there were two accounts of interviewees indicating that they developed an understanding of how Yield Prophet measurements related to existing approaches for soil water estimation, allowing them to extrapolate measurements from the Yield Prophet paddock to other parts of the farm. On the other hand, there were accounts of Yield Prophet being perceived as incompatible with their existing system representation (e.g. leaf tissue testing), or superfluous to existing representations of the system (e.g. with respect to digging holes for soil moisture assessment, or as having nothing to add over gut feeling). There were clear examples of those with action-centred skills (i.e. gut feeling) that were preferred over Yield Prophet. These people were giving action centred skills primacy and the value of Yield Prophet was confirming that their way was working.

An advantage of Yield Prophet recognised several times from interviewees is that it provides ongoing information about what is below the ground (namely soil water and soil nitrogen) that cannot be readily observed in the paddock, which can be used to reshape expectations about outcomes. This is the point being made when Yield Prophet was referred to as able to temper an 'emotional reaction' to apply inputs in response to a visual assessment of a crop and is a recognition that action-centred skill could let them down.

While we did not collect data about interviewees' level of education, intellective skills can be expected to relate to formal learning about production systems using scientific concepts and measurements. Comments by two interviewees, in different regions, who had at least 2 years' experience and a high level of familiarity with and appreciation of Yield Prophet suggest that some new concept appreciation does take place through Yield Prophet use that isn't easy to discuss with a non-subscriber unless they have also had a similar learning experience. This provides a tighter framing of the chasm of relevance introduced in Chapter 4 – i.e. those who have and haven't a learning experience associated with differences in levels of intellective skills in areas relevant to Yield Prophet.

The interview findings suggest that improving the intellective skill of farmers has facilitated an appreciation of Yield Prophet. The questions for a Yield Prophet marketing strategy are therefore:

1. How to improve the intellective skill of farmers cost-effectively?
2. Can someone else - e.g. a consultant - act as proxy for farmer in intellective analysis? In other words, consultants use Yield Prophet to provide recommendations to farmers on "what should they do". This, in turn, raises the questions:
    - Do farmers delegate such decisions in a way that would conform to this strategy?
    - Do consultants want to operate in such a way?
    - Do consultants find APSIM crucial to the support they give clients?

Role of consultant in marketing Yield Prophet

The nature of the client-consultant relationship was explored through subscriber and consultant interviews and the results indicated that clients generally do not delegate crop management decisions in the Yield Prophet domain to consultants, although there were some exceptions in relation to N management. Many subscriber-interviewees, however, viewed the consultant as an important way to introduce new technologies to them. Descriptions of the relationship which included language such as 'a sounding board', 'challenging my thinking', 'debate' and 'discussion', 'starting with my own ideas' highlighted the interactivity. In two locations, the consultant appeared to be very well-integrated into interviewees' farm management, i.e. that although they do not always delegate decisions to the consultant, the consultant plays a very important role in helping them to analyse options.

Such a relationship points to the role of consultants as playing a role or having the potential to act as a support for farmer and provide conditions for a farmer to gain new intellective skills in Yield Prophet's domain.

To varying degrees, interviews revealed consultants' abilities to compensate for farmer deficiency in intellective skills and facilitate farmer learning at the data interface in the key steps of:

- soil characterisation and monitoring of soil water and nutrients
- conduct APSIM runs
- interpreting crops yields in relation to water and nutrient supply
- interprets output for farmer action
- probabilistic expectations

Two consultants provided clear examples as acting as a partner for Yield Prophet discussion, and stimulating farmers to think critically (from a different perspective) about their farms, with interactions resembling the original FARMSCAPE sessions. The consultants also played an important role in establishing model credibility for interviewees. Consultant confidence in Yield Prophet was at times influential in subscribers appreciation of Yield Prophet. The results also showed that establishing credibility with consultants is critical otherwise consultants won't promote the technology. It was demonstrated that consultants also require a sizeable time period to evaluate the technology.

In Location 1 the consultant appeared to be an influential factor in facilitating interviewees appreciation of Yield Prophet. In contrast, in Location 4, there was limited discussion of Yield Prophet with consultants, and limited new learning reported. There were exceptions, however, where interviewees reported value from Yield Prophet (including learning) but reported limited discussion with the consultant.

An alternative model of delivery takes the emphasis away from farmer learning and treats Yield Prophet as an information product on offer, requiring subscribers to trust Yield Prophet without necessarily having an underlying understanding of how things work in Yield Prophet. By ruling out the learning side of Yield Prophet, it leaves yield prediction as the only use of Yield Prophet. A consultant operating in this mode of delivery is essentially delegated the task of dealing with the underlying complexity represented in the model, and would shield the farmer from the data interface. Such a relationship would involve the consultant playing the role as proxy for farmer in intellective analysis.

The majority of farmers interviewed did not delegate such decisions in a way that would conform to this strategy, and two of the consultants (Location 1 and 2) explicitly indicated that they did not wish to operate in this mode. However, the other two consultants (Location 3 and 4) suggested they could operate in this way because they saw themselves as a potential beneficiary of Yield Prophet, indicating that Yield Prophet could be a tool to support consultants' thinking and the advice they provide farmers, rather than for direct use by farmers. This indicates a market for Yield Prophet which includes consultants, not just farmers. As one consultant explained, he is unsure whether he would use Yield Prophet directly with clients, rather it could be that he would use Yield Prophet to inform his own thinking rather than have farmers running it themselves and may or may not take reports to clients. Of note is that both consultants expressing an interest in this mode believed that only some (progressive) farmers will take to direct model use, most will prefer to rely on agronomists for decisions, also expressed the greatest concerns about model accuracy and value.

Social networks facilitate cost effective delivery (but not without professional facilitation)

Social networks greatly facilitated consultant delivery and aided the establishment of potential relevance. Most interviewees from the Stage 2 round of interviews had been introduced to Yield Prophet through a professionally-facilitated farming network (in the cases explored, the networks at

influence were the client groups of consultants (Locations 1 and 2), and farmer groups (Locations 3 and 4). The networks, through consultant-coordinated group activities, provided the means of delivering formal information sessions about Yield Prophet (including presentations by researchers) and coordinating some of the processes involved in setting up subscribers. Given the high cost of doing these on an individual-subscriber basis, targeting established networks appears to be a highly effective way of introducing these technologies and providing user support.

As raised in Chapter 4, there were indications of limited discussion about Yield Prophet outside subscriber circles, and no indication that interviewees could discuss Yield Prophet in a way that could convey the concepts other than in a superficial form. While social networks can establish potential relevance, the consultant was often needed to facilitate appreciation sufficient for Yield Prophet to be valued.

Does yield prophet offer significant value?

Returning to the framework introduced in the section of this report outining Stage 1 for describing the process of adoption using the categories: potentially relevant, relevant, and significant, the final category focuses the remainder of this discussion. Is Yield Prophet significant, i.e. do the benefits sufficiently outweigh the costs?

Moore (1999) claims that great products need a "unique and compelling application" to be commercially successful. Stone and Hochman (2004) similarly argue that DSS are most likely to be useful for delivery of information to farmers if they provide information with evident, defined, high and capturable value, and are demonstrably the best and preferably the only method for imparting that information.

Yield Prophet's value is the provision of a versatile tool for managing climatic uncertainty in relation numerous management issues. It does this by two main avenues: *ex ante* evaluation of management change (arguably the main focus of its historical use in FARMSCAPE) and forecasting of production outcomes in relation to contemplated tactical management alternatives (the main focus of Yield Prophet). Farmers have found both applications useful, neither has proved to be the unique and compelling application that is the marketer's dream, which is discussed further below.

In the case of *ex ante* evaluation of management innovations, even when cases of 'unique and compelling applications' have occurred, they have not been sustained because they are used in the planning stage of infrequent events. Major change events, e.g. shift to dryland cotton, occur only a very few times in the life history of an individual farmer.

In the case of the other application, the forecasting of production outcomes to primarily guide tactical management, demand for such an application would be expected on a more continuous basis. Whether Yield Prophet will be valued sufficiently to result in use on a continuous basis requires consideration of a number of issues outlined below.

While APSIM has the flexibility to simulate a wide range of problematic situations and to help clients explore features of situations and management options and to learn about the system, its use is currently restricted to tactical in-season N management for most interviewees. There was little pre-season use of Yield Prophet in relation to variety choice and sowing date, despite interviewees frequently identifying such options as another means to deal with climate variability and acknowledging that Yield Prophet could play a role here. Low use of pre-season Yield Prophet largely reflects the fact that subscribers were not set up early enough for such use and that consultants had not facilitated an appreciation of Yield Prophet for this use – a situation which, again, highlights the importance of the consultant in facilitating Yield Prophet use.

Is the use of Yield Prophet solely for tactical N management going to generate enough value to warrant ongoing use by subscribers? N is an important management decision – it is a costly but

necessary input, and the only in-season management option identified for dealing with climate variability. Significantly, the in-season application is a new N management approach for many interviewees. If Yield Prophet is valued primarily as a learning tool in relation to N management, this raises the question of whether some interviewees will learn from Yield Prophet, form new management heuristics, and abandon Yield Prophet. One consultant interviewed expressed this possibility.

If experimentation to explore new management options or better understand production system performance (use in line with traditional FARMSCAPE) is not performed on an ongoing basis, the value that would lead subscribers to use Yield Prophet on an ongoing basis would need to come from its generation of yield forecasts. As a tool to forecast production outcomes that combines a seasonal climate forecast, Yield Prophet suffers the handicap of the forecast not providing certainty for action in the coming season. In contrast, in strategic evaluations of long-term implications of a change, the inability to predict the coming season is not a problem in that it is the frequency distribution itself that is of interest.

The degree to which farmers' experience and judgment was augmented by explicitly probabilistic output varied: this ranged from one report provided by an interviewee who clearly indicated that Yield Prophet had nothing to offer above his own estimation of the range of seasonal forecasts, others reported of the consistency of the information with their own estimations – with Yield Prophet frequently spoken of as able to "back up" or "reassure" an existing management approach. Such responses indicate that Yield Prophet was not the only method for informing the N management decision. While such expressions of value seem marginal, some offered the view that it was still sufficient to warrant ongoing subscription. However, Yield Prophet's failure to identify a better decision than the one already being made in relation to N management was the reason provided for the 2 non-renewals investigated. Although the production environment was described as reliable by a number of interviewees across three locations, such a comment did not correspond with expressions of low Yield Prophet value.

The clearest and most convincing articulation of the value of Yield Prophet's probabilistic yield forecasts came from subscribers who previously had no way of making structured comparisons between yield outcomes under different seasonal climate forecasts. While this points to a 'unique and compelling value' for Yield Prophet, there was poor understanding and/or trust in confidence in seasonal climate forecasts to guide tactical management decisions. This presents a challenge for Yield Prophet, but not a barrier given that interviewees clearly viewed seasonal climate forecasts as a component that could be separated from the rest of Yield Prophet.

Can Yield Prophet be regarded as cost competitive with other information subscriptions? The cost components of Yield Prophet include the subscription cost ($500 for 3 paddocks at the time of interview) as well as costs associated with the collection of soil characterisation data and allocating time to run Yield Prophet simulations and interpret reports. The cost of the latter 2 can vary significantly, depending on the degree of engagement of both the consultant and subscriber, and the allocation of effort between the two. There was no clear indication provided through the interviews of the significance of cost in relation to Yield Prophet's adoption potential. Likewise, it was difficult to gauge how competitive Yield Prophet was with other information subscriptions. All interviewees spent at least in the order of hundreds of dollars, and often thousands, on information, but were generally unable to readily define what aspect of the information makes it a value proposition. This is not to say that these subscriptions had no value, but indicates the difficulty in eliciting such information from interviewees through the interviewing approach taken – an issue also relevant to the evaluation of Yield Prophet. While interviews were timed to coincide with the likely timing of Yield Prophet's use for nitrogen top-dressing decisions, the interview team reflected on the difficulties of investigating the decision making of farmers in an interview situation removed from actual decision-making context.

Yield Prophet 2005 subscriber survey

Survey findings

Respondent profile

A total of 21 surveys were returned (Q1). This represents approximately 20% of the 104 registered Yield Prophet participants who, in total, had 338 paddock subscriptions. Most returned surveys were from Victoria (ten responses), followed by New South Wales (six responses), Western Australia (three responses) and South Australia (two responses). The majority (two-thirds) of respondents were in their first year of subscription (Q2). Results are summarized below and a detailed presentation of results appears in Appendix D.

Usefulness of Yield Prophet

Most respondents (14) nominated their Yield Prophet experience in 2005 as moderately useful from a management perspective (Q3), with only four describing their experience as being of no or limited usefulness. Issues affecting the usefulness of Yield Prophet (Q4) included lack of trust in Yield Prophet predictions (four responses); failure of Yield Prophet to provide new knowledge (one response); the use of generic soil characteristics (one response) and one respondent indicated that the conservative management of his or her Yield Prophet paddock compared to other paddocks resulted in a poorer yield and protein outcome.

Respondents scored the usefulness of Yield Prophet for a range of management decisions (Q5). Based on an average score, Yield Prophet was regarded most useful for determining nitrogen application date and rate, with nearly half the respondents assigning this one of the top two scores indicative of high value. In contrast, most respondents assigning Yield Prophet one of the bottom two scores indicative of low usefulness for selecting sowing date and variety. Similarly, responses concerning the use of Yield Prophet for calculating yield potential for insurance purposes, and marketing, were skewed to the lower scores for usefulness, however, there were some strong indications of usefulness in both cases. One respondent added another use for Yield Prophet – “crop growth and water use” to which a ‘not useful at all’ score was applied. Another respondent added a “whether to spray rust” as another use and assigned it a mid-way score.

Responses to the usefulness of the SOI roughly followed a normal distribution, with some tendency towards the lower usefulness categories. Most responses to the value of the GESS seasonal climate forecasts in Yield Prophet fell between the mid-way and the ‘not useful at all’ scores, with the remaining four responses allocated to the second-highest score for usefulness.

Factors limiting use of Yield Prophet

A majority of respondents indicated that their use of Yield Prophet was not limited (Q7) by internet line speed; their PC not working; difficulties with computer use in general; lack of support or instruction. This was similarly the case for factors including: Yield Prophet site not working; difficulties understanding how the web site worked; difficulties understanding what Yield Prophet output meant; and lack of interest; but this also included responses which indicated relatively minor limitations were experienced.

With the exception of inaccurate soil characterisation data, there were few responses indicating significant (bottom two scores) limitations associated with any factors. Based on an average score, lack of time was the second most significant limiting factor.

Yield Prophet interactions

The majority of interviewees discussed their reports with an agronomic consultant and almost half discussed their reports with other growers who are not subscribers (Q8). Other categories mentioned to a lesser extent were other subscribers, government extension officers (five responses for each); partners (two responses) and Yield Prophet staff (one response). No respondents indicated that they do not discuss their reports with anyone. Just over half of the respondents ran Yield Prophet by themselves (Q9), five ran it in conjunction with a consultant and two respondents indicated that a consultant always or nearly always ran Yield Prophet. Respondents were asked to nominate how often Yield Prophet was run for their paddock in 2005 (Q10). Results are presented in this report, however, it appears that question was misinterpreted such that all possible answer categories referred to runs per month.

Simulation accuracy

Respondents were asked to comment on how happy there were with Yield Prophet's simulation accuracy for their paddock in relation to yield, protein and growth stage (Q11). Responses were spread across all scores ranging form very happy (1) to very unhappy (5) for protein, and from one to four for yield and protein, with responses concentrated around the mid-way score. Respondents were also asked to comment on how happy they were with Yield Prophet's simulation accuracy for their paddock in relation to yield and protein for all subscribers (Q12), as outlined in the annual results summary sent to all subscribers, and, again responses were concentrated around the mid-way score.

The majority of respondents (18) indicated the level of error that is acceptable from the Yield Prophet yield predictions is +/- 0.5t/ha or less (Q13), with six of these expecting that it should be +/-0.25 t/ha. The majority of respondents (18) indicated the level of error that is acceptable from the Yield Prophet protein predictions is +/- 1% or less (Q14), with five of these expecting that it should be +/-0.5 %.

Value for money

Ten respondents indicated that Yield Prophet offers value for money and one respondent indicated that it didn't (Q15). A large proportion of respondents (10 respondents) did not answer the question, but nine of these added comments indicating that they were unsure or still deciding.

General comments and suggestions

Respondents supplied a range of comments (Q16) and suggestions for Yield Prophet (Q17). Some of the comments raised were in relation to accuracy concerns, the value and importance attached to soil characterisation and the role of Yield Prophet to facilitate learning.

Discussion

Comparison with interview findings

Subscriber survey responses presented a picture of Yield Prophet use that was consistent with the interview findings. Responses to the usefulness of Yield Prophet for a range of management decisions covered the same range as those provided in the interviews and also confirmed that Yield Prophet's value was most closely associated with nitrogen management. Similarly, the responses to the value of seasonal climate forecasts, with only a small proportion indicating these to be of high value, were consistent with the interviews.

The interviews highlighted different levels of support and instruction experienced by subscribers, which could be associated with limitations to the value obtained from Yield Prophet use. Varying levels of ease in interpreting Yield Prophet output were also identified. Both of these situations were confirmed by the survey responses. Likewise, the survey data reinforced the concerns raised by interviewees about the importance of accurate soil characterisation data. As for the interviews, the levels of satisfaction with simulation accuracy varied among survey respondents.

To provide background to the interpretation of comments made by interviewees and survey respondents in relation to soil characterization data, in 2005 Yield Prophet expanded from 57 to 236 growers and that this necessitate having many subscribers relying on best bet soil characterization while the data was being gathered for their soil type. This was a big factor in less than satisfactory performance of Yield Prophet for a significant number of users in 2005. A lesson/recommendation from that is that a period of consolidation is required in 2006 to ensure that re-subscribers experience a more reliable Yield Prophet experience this year. There has been a very high re-subscription rate (~90%) in 2006, which provides a second chance to turn these growers to a positive reference for Yield Prophet.

The significant proportion of survey respondents who did not provide a yes or no answer to the question of whether Yield Prophet offered value for money is not surprising given that two thirds of respondents had experienced Yield Prophet for the first time in 2005. Also, interviewed subscribers often pointed out the long time frames they required to be able to fully evaluate it. General comments provided by survey respondents confirmed interview findings that Yield Prophet can play a role in supporting learning, and is not restricted to use for supporting tactical crop management decisions.

Survey limitations

This survey had a 10% response rate and represents a small sample of total subscribers. Tests of statistical significance were not performed and the results cannot be generalised beyond this sample. An additional limitation to the survey is that while intended for grower-subscribers, a consultant also completed the questionnaire. Future surveys will need to clearly distinguish between subscribers and consultants.

Implications

This study explored discontinuous technology adoption through case studies focused largely on the use of cropping systems simulation technology by farmers. The insights generated are relevant to other developers of technologies such as computerised DSS to help avoid marketing failures associated with their limited use among farmers.

For a small group of technologies, the study investigated whether there are two distinct market segments for discontinuous technologies separated by a 'chasm' that has the potential to prevent technology diffusion to the mainstream market. While the existence of a chasm in social referencing cannot be dismissed, the findings revealed that social processes (i.e. farmer-to-farmer social referencing) alone are not a sufficient mechanism for facilitating farmers' appreciation of the significance of these technologies to their farm management practice. The finding that farmers' appreciation of the relevance of cropping systems simulation can be greatly facilitated by a learning experience that influences their conceptualisation of their farming system, points to the importance of cognitive processes in the adoption process.

The study found variation in the way farmers conceptualised their farming system, which could be represented along a continuum between two forms of cognition – analysis and intuition. The former, analytical thought, is concerned with scientific representations of the production system, and is a requirement for use of cropping systems simulation by farmers. The study revealed consultants' abilities to compensate for farmer deficiency in analytical understanding of the production system and facilitate farmer learning. Given the high cost of providing facilitation on an individual basis, social networks (e.g. farmer groups) were found to be an effective way of introducing these technologies and providing user support.

Appendix A. Yield Prophet

Yield Prophet information accessed from http://www.bcg.org.au

What is Yield Prophet?

Yield Prophet® is a web interface for the crop production model APSIM (http://www.apsim.info/). It simulates crop growth based on paddock-specific inputs of soil type, pre-sowing soil water and nitrogen, rainfall, irrigation and nitrogen fertiliser applications, and climate data.

Yield Prophet was developed by BCG (Birchip Cropping Group) in collaboration with CSIRO as a risk management tool for dryland farming systems in the Victorian Wimmera and Mallee, with an emphasis on decision support for nitrogen fertiliser inputs. It was first used for wheat at BCG trial sites in 2002, and its early predictions of the failure of that season generated sufficient interest and credibility to allow a commercial release to BCG members in 2003 as a monthly fax-out service. Continuing demand resulted in the development of the Yield Prophet web-interface, which allowed a larger number of subscribers to receive up-to-date crop information and forecasts in 2004.

2005 was the first year of general commercial release of the service, and 338 paddocks were subscribed to the service from all over Australia and over 6800 reports were generated during the season. Subscriptions grew in 2006 to include 540 paddocks, and over 9000 simulations were generated.

How does Yield Prophet® work?

Subscription

Farmers or consultants subscribe to the service in late summer and autumn and provide the Yield Prophet team with their paddock names, locations (used to determine soil type and closest Bureau of Meteorology weather stations) and planned crops and varieties.

Subscribers are then given a user name and password allowing them to log onto the Yield Prophet website. Growers are also able to nominate a consultant with whom they wish to access Yield Prophet, and this consultant is also given access to data on that grower's paddocks.

Soil sampling

During autumn, subscribers sample their Yield Prophet paddocks' soil at different depth intervals down to the maximum rooting depth of their crop (e.g. 0-10, 10-40, 40-70, 70-100 cm). These samples are analysed for water content, nitrate concentration, organic carbon, electrical conductivity, chloride concentration and pH. These data are entered by growers into the Yield Prophet web interface, and are also used by the grower and Yield Prophet team to select a suitable soil characterisation.

Soil characterisation

An appropriately measured soil characterisation is an essential input for Yield Prophet to simulate crop growth, yield and protein accurately.

The plant available water capacity (PAWC) and bulk density of a specific soil type determine how much of the measured water and nitrogen is available to the crop for growth during the season. PAWC is determined by a soil's 'drained upper limit' (DUL, or field capacity) and its 'crop lower limit' (CLL, similar to permanent wilting point).

The Yield Prophet team have a 'library' of soil characterisations measured for many of the major cropping soil types found throughout Australia. However, many subscribers have soil types for which there are no available measured characterisation data. In these circumstances, a soil characterisation is estimated by the Yield Prophet team based on soil type and previous rainfall and crop yields provided by the growers, and any information available from existing soil surveys. An estimated characterisation is less likely to produce accurate results in comparison to a measured characterisation,

and it is recommended that potential subscribers to Yield Prophet consider characterising their soil if no appropriate data exist. For more information, please contact Neal Dalgliesh on 07 46881376, mobile 0427 725955 or e-mail.

Crop growth simulation

During the season, subscribers enter paddock management details (sowing date, crop type, variety, nitrogen fertiliser and irrigation) and rainfall. When growers wish to find out how much water and nitrogen is currently available to a crop, the likely yield of their crop, or what the likely impact of management events will be, they generate a report.

When a report is generated, Yield Prophet simulates daily crop growth from sowing up to the present using the paddock specific rainfall and management data entered by the subscriber, and climate data (maximum and minimum temperature, radiation, evaporation and vapour pressure) from the nominated BOM weather station.

At every daily time step Yield Prophet calculates the amount of water and nitrogen available to the crop, and the water and nitrogen demand of the crop. This is used to determine if the crop is suffering stress from lack of either of these resources, and any subsequent reduction in growth and yield potential. This information is then presented to subscribers in reports returned to the subscribers' account (Figure 1).

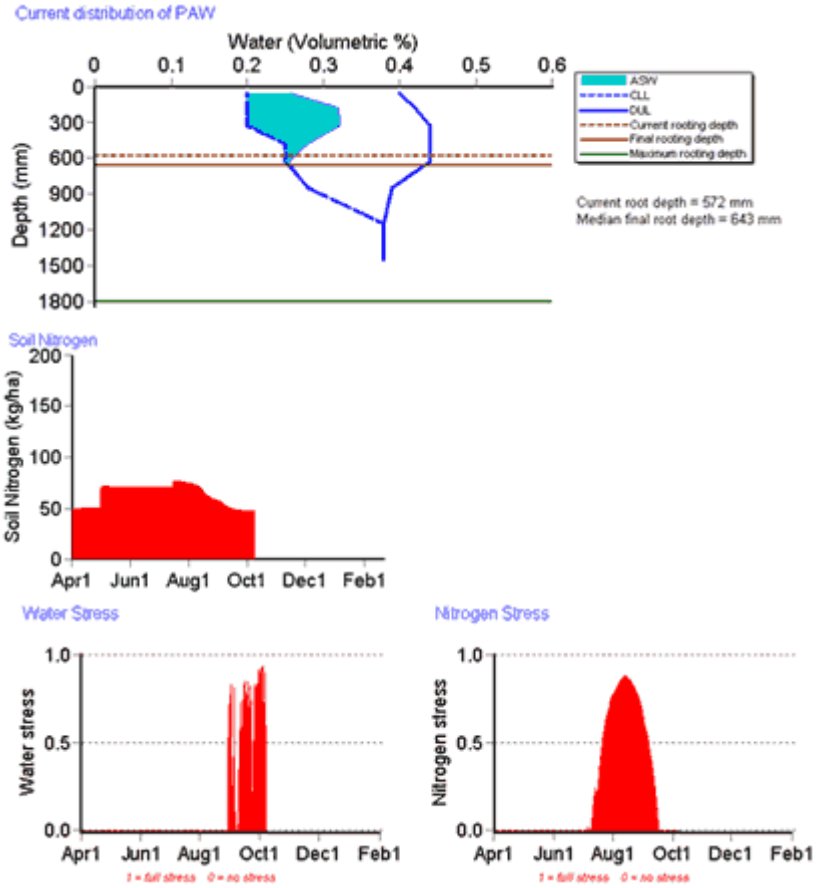

Figure 1. *Output from Yield Prophet® indicating the amounts of water and nitrogen available to the crop during the season. The stress graphs indicate loss of potential growth and carbon fixation, i.e. on a day when the graph is at 0.5, the crop is growing and photosynthesising at half its potential rate.*

Yield prediction

In order to make predictions about crop yield, Yield Prophet uses the last one hundred years of climate data taken from the nearest Bureau of Meteorology weather station to continue the simulation from the

date of report generation to the end of the season. The model simulates one hundred different crop yields and proteins, based on the current season up until the day the report is generated, and on the season finishes of the past one hundred years. These yields are then plotted as a probability curve (Figure 2), which provides growers with an estimate of the probabilities of obtaining different yields. This range of probabilities narrows as the season progresses and components of yield become more certain.

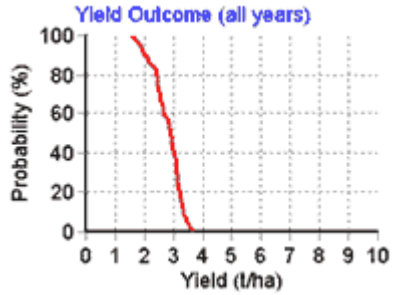

Figure 2. *A yield probability curve, the main output from Yield Prophet.*

This is the main output of Yield Prophet, and its value is increased by incorporating seasonal forecasts, such as the Southern Oscillation Index (SOI) phase system. In this case, instead of using season finishes for the last one hundred years, Yield Prophet selects the years in which the SOI phase was the same as in the current year, and runs the future part of the simulation using only the finishes from those years. This creates another probability curve which growers can use if the SOI phase is strongly indicating wet or dry conditions (Figure 3).

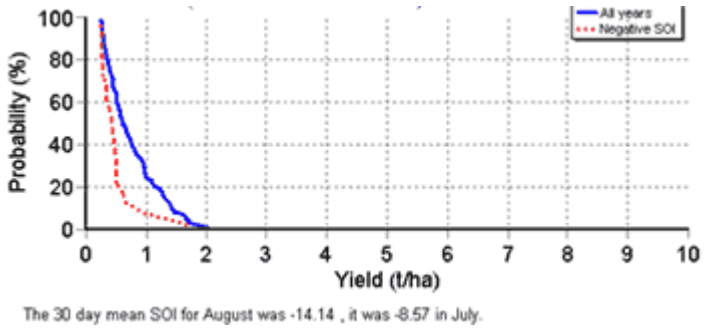

Figure 3. *Yield probability curve generated using season finishes for the last hundred years of climate data (solid blue line), and only those years in which the SOI phase was the same as the current phase at the time the report was generated. In the above example, this is the years with a negative SOI phase in July-August; the report was generated for a paddock near Birchip on 1 September 2006.*

Scenario predictions

The likely impact of different sowing dates, varieties and irrigation and nitrogen applications can then be determined by simulating different ‘scenarios’. Yield Prophet calculates a probability curve for each scenario, and subscribers use this to determine the probability of achieving a yield or protein response from the addition or water or nitrogen (Figures 4 and 5), or from different sowing dates and varieties (Figure 6). Yield Prophet can also calculate a nitrogen gross margin based on likely grain quality and price (Figure 7).

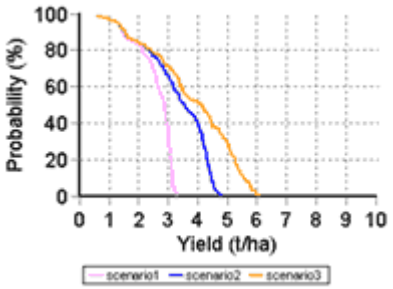

Figure 4. *Yield probability curves for three different nitrogen top-dressing scenarios generated for a dry land wheat crop on 1 August 2005. Scenario 1 (pink line) is the yield probability adding no further nitrogen, Scenario 2 (blue line) is the yield probability with 35 kg/ha of nitrogen top-dressed on 15 August, Scenario 3 is the yield probability with 70 kg/ha of nitrogen top-dressed on 15 August 2005. There is an 80% chance of achieving a yield response with topdressing, and about a 50% chance of achieving a 1 t/ha yield response from 35 kg/ha of nitrogen.*

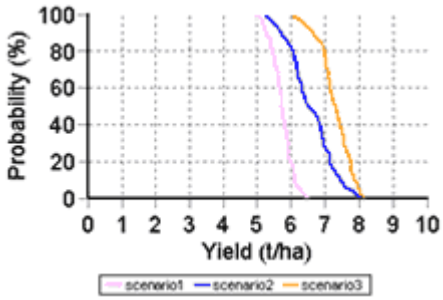

Figure 5. *Yield probability curves for three different nitrogen and irrigation scenarios generated for an irrigated wheat crop on 3 October 2005. Scenario 1 (pink line) is the yield probability adding no further water or nitrogen, Scenario 2 (blue line) is the yield probability with an additional 50 kg/ha of nitrogen top-dressed on 3 October, Scenario 3 is the yield probability with 50 kg/ha of nitrogen top-dressed on 3 October and two additional 25 mm irrigations on 3 and 17 October.*

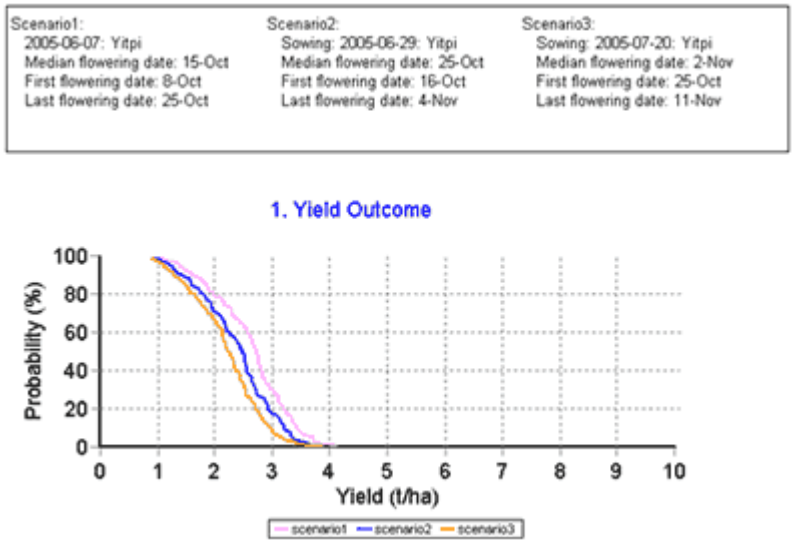

Figure 6. *Yield probability curves for three different sowing date scenarios (sowing dates are shown above the graph) generated for a wheat at Birchip crop on 21 June 2005.*

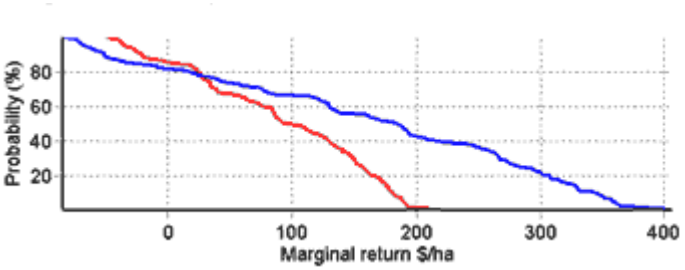

Figure 7. *Nitrogen profit curves for the same two nitrogen application scenarios shown in Figure 4. Each line is calculated as the return from grain (determined by yield and protein minus cost of fertiliser and spreading) for Scenarios 2 (solid red line, 35 kg/ha of nitrogen) and 3 (solid blue line, 70 kg/ha of nitrogen) from Figure 8, minus the return from Scenario 1 (adding no further nitrogen). This shows the difference in return between applying nitrogen of specified amounts, and not applying nitrogen. In this case it assumed the cost of fertiliser as $0.95 per kg of nitrogen, cost of spreading as $5 per ha and that the wheat price would be APW at $160 per tonne, with a $2 per 0.5% protein bonus.*

Irrigation scheduling

Because Yield Prophet calculates the amount of water available to a crop, and average evaporation and transpiration based on 100 years of data, it has the potential to be a very effective tool for irrigation scheduling.

Figure 8 shows the Irrigation Scheduling report from Yield Prophet. The graph shows the PAWC of the soil that is being accessed by the crop as roots grow, and the amount of PAW calculated from initial measured soil water plus rainfall and irrigation, subtract evaporation and transpiration. The red section of the line is a projection of PAW over the future two weeks assuming no rain, and growers can use this to determine when to water, and how much water to apply. The impact of any irrigation can be calculated from the probability curves in the irrigation comparison report described above (Figure 9).

This output is also very useful for dry-land crop management, as it provides an indication of the amount of water that is available to a crop at any point in the season.

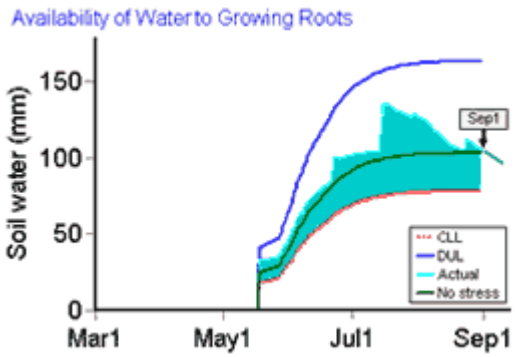

Figure 8. *The graphic display of soil water from the Irrigation Scheduling Report in Yield Prophet.*

Appendix B. Example Interview Protocol for Stage 1 interviews

"Targeting pragmatist farmers"
Case Study: WA Livestock Group November 2003

Questions about computer usage

Do you own a computer?

- No?
  - why not?
- Yes?
  - When did you buy your first PC?
  - Do you remember what made you buy a PC?
  - What do you use it for?
  - Are you on the internet?
  - When did you get connected?
  - What do you use internet for?
-

Questions about estimating PGR using satellite technology

- What experience have you had with the use of satellite technology to estimate PGR?
- Are you the main user?
- How and why did you become interested in using satellite PGR images to aid farm management?
- What have been your experiences so far from it e.g. has the software helped you make decisions, and if so, in what way? (Or if early days, what do you expect to gain from it?)
- (if hasn't helped decision making) What have been the difficulties / reasons for not using it?
- Are you interested in continuing to use satellite technology to estimate PGR? Why or why not?

Questions about Precision Agriculture

- Do you use any precision agriculture technologies? E.g. yield maps, other forms of remote sensing, EM, digitial elevation data, management zones, spatially variable input management, tram lining using GPS etc
- (if applicable) What do you think about the results?
- Do you see a role for PA technologies on your farm in the future? What do you expect to gain from them?

Questions about knowledge of cropping systems simulation (if producer has mixed crop-livestock enterprise)

- What do you know about computer simulation of crop production systems?
- Have you heard of APSIM?
- (If applicable) How and why did you become interested in using cropping system simulation to aid farm management?
- (If applicable) What have been your experiences so far from it? What do you expect to gain from it?

- (If applicable) Are you interest in learning more about cropping systems simulation? Why or why not?

Open Questions

- Do you use any other computer based DSS software for livestock or cropping enterprises?
- What other high-tech innovations do you have on the farm? E.g. machinery or innovative processes
- Where / to whom do you look for information before adopting the technologies that we've been talking about?

Self Assessment:

We'd like to ask how you describe your approach technology adoption.

For the technologies we discussed earlier, where would you place yourself in terms of when you prefer to adopt a technology? (For example, would you describe yourself as an early adopter e.g. in first 15% to adopt, or would you tend to be more among the majority of farmers who adopt after others have taken up the technology?)

Could you say a few words on what influences the timing of technology adoption for you? E.g. Why do adopt when you do?

Do you require evidence that other producers are finding the technology useful before you invest in it? In other words, need to hear feedback from other farmers before making a decision?

(If applicable) You mentioned that other farmers influenced your decision to adopt – how would you describe their approach to adoption using these categories?

Appendix C. Example Interview Protocols for Stage 2 interviews

A. Interview questions for consultants

Q1: How do you operate with your clients on matters related to decisions on crop planting in relation to weather and soil conditions and related agronomy?

(Prompts: Explore whole client base, and Yield Prophet clients specifically: What proportion of your clients essentially delegate the decision to you? What proportion of your clients expect advice for action with well set out reasons? What proportion of your clients expect advice for action *without* any justification? What proportion of your clients count on you to provide information only? Do you provide any with soil water information?)

Q2: How many of your clients subscribe to Yield Prophet?

Q3: What do you see as the potential applications of Yield Prophet in your clients' farm management?

Q4: How are you planning to use / or have been using Yield Prophet with clients in 2005?

(Prompts: For example, explore if they see themselves using it to provide recommendations to farmers? Or do they see themselves supporting farmers to learn about their system? Will Yield Prophet play a behind the scenes role or be the focal point of their discussions with farmers?)

Q5: Do you feel confident in assisting clients to interpret Yield Prophet results based on your current understanding of / experience with Yield Prophet?

Q6: What do you see as the main constraint to more farmers subscribing to Yield Prophet? (Note if they volunteer the cost or effort involved in soil sampling? (If they don't follow up with a prompt).

Q7: Given that accurate determination of soil moisture is critical to Yield Prophet accuracy, how much error would their clients tolerate if simpler, less accurate estimates were made?

Getting their views on the long-term feasibility of data collection – will it be practical and affordable?

Q8: Did you have clients in Yield Prophet in 2004?

Q9: Did you discuss Yield Prophet with those clients? (Prompts: how often, who initiated, what was discussed)

Q10: What were your impressions of Yield Prophet in 2004 (accuracy of predictions, usefulness in management, usefulness in their interactions with their clients, practicality of information supply for simulations)

B. Interview questions for new Yield Prophet interviewees (new to Yield Prophet in 2005)

Q: What are your current strategies to deal with climate variability (season-to-season differences)?

Q: How have these strategies changed over recent years? What are the main 'knobs' which you can turn in such strategies?

Q: How would you describe different seasons? (look for subtlety in categorisation c.f. good average, poor. What do you mean by….)

Q: How do you adjust your management to different seasonal conditions? (look for specific agronomic and marketing, financial, and personal (e.g. holidays) adjustments and when a decision is make)

Q: How do you decide how the season is likely to turn out? When do you make these estimates? How often do you revise them?

Q: Do you use any climate forecasting tools? Which one? How do you use it?

Q: Do you discuss climate forecasts with your consultant? In what context? Does it influence any decisions-plans you make?

Q: How do you factor paddock history into your estimation of likely seasonal outcome?

Q: How much do you believe that stored soil moisture can influence your seasonal outcome?

Q: How would you describe the current soil moisture status of your Yield Prophet paddock? Based on what? Monitoring of other paddocks apart from Yield Prophet? (if response is in mm of stored moisture of fraction of full profile ask how they used to describe soil moisture before involvement with Yield Prophet)

Q: What can you tell me about Yield Prophet?

Q: What do you hope to get out of Yield Prophet?

Q: What have been your experiences with Yield Prophet this year? (How did Yield Prophet predictions compare with your expectations at the start of the season?) How much / when did you use it / what for this year? Useability constraints? What can be done to improve Yield Prophet?

Q: How valuable is it to have reliable probabilities of seasonal variation? Is trusting them a problem or rather acting on them?

Q: Take N profit report. What probability of return is required for you to act on a particular strategy?

(prompts: e.g. if you had a 60% chance making a return from N, would you act on this? Vs say 90%. Do you factor in residual N into this decision? Or the other inputs etc that may compete for $ (opportunity cost)?)

Q: Do you use other consultants?

Q: Please describe the relationship you have with your consultant with respect to the following activities:
Fallow management and weed control, Crop choice, Variety, Time of sowing, Pre-drill N: timing, source and amount
Topdressing N: yes/no, source, timing and amount. Control of pests and diseases. Financial, Marketing

For each of the above we want to explore role of consultant: does (s)he provide information, does (s)he put pros and cons for various alternatives, does (s)he make a strong case for a particular course of action (i.e. a recommendation), do you delegate that decision to her (him).)

Q: What role does your consultant have in making you aware of new technologies?

Q: Who else do you rely on to keep you abreast of new technologies, new information, R&D?

Q: Have you discussed Yield Prophet with your consultant this year?

Q: Who initiated those discussions?

Q: What aspects of Yield Prophet did you discuss?

Q: How would you describe the support your consultant provided you?

(Help in learning how to run Yield Prophet? Help in interpreting output? Help in interpreting implications for management decisions?)

Q: how did you first hear about Yield Prophet? (Prompts: Where / Who / When did they first hear about it?)

Q: Who influenced your decision to subscribe to Yield Prophet?

Q: Do you talk about Yield Prophet with other subscribers?
(Prompt: Have others had similar experiences to you with Yield Prophet?)

Q: Are you a member of a farmer group?
(Prompts: which groups, how regularly do you participate in group activities, positions of responsibility).

Q: How often does your group get together?

Q: Is Yield Prophet a focus for discussion in your group?

Q: Do you talk about yield prophet with anyone else (additionally to consultant and group)?

Q: Do you discuss Yield Prophet with members of your family (partner, parents, siblings, children)?

Q: do you have past experience with DSS? If so, what is your reaction?

Q: What other information do you subscribe to? (Prompts: soil tests, probabilistic marketing information, weather information).

Q: Roughly how much would you spend on each of these?

Q: What influence do they have on your farm management?

Q: What do you require in such systems for them to ‘pay their way’?

Appendix D. Yield Prophet Subscriber Survey Results

1. Please tick the box that best describes your location

State	Region	Number of Respondents
Victoria	Wimmera/Mallee	7
	Other	3
New South Wales	North	3
	South	3
South Australia	Yorke Peninsular	0
	Other	2
Western Australia	Nothern Grainbelt	1
	Southern Grainbelt	2
Queensland		0

2. Was 2005 your first year of subscription to Yield Prophet?

	Number of Respondents
Yes	14
No	7

3. Overall, how would you describe your Yield Prophet experience in 2005?

	Number of Respondents
a. Very useful from a management perspective	3
b. Moderately useful from a management perspective	14
c. Of limited usefulness from a management perspective	3
d. Not useful from a management perspective	1

4. If you didn't find Yield Prophet useful from a management perspective, please elaborate:

NOTE: There were only 7 responses to this question

	Number of Respondents
a. Yield Prophet output not relevant to management decisions	0
b. I didn't trust the Yield Prophet predictions	4
c. Yield Prophet didn't tell me anything I didn't already know	1
d. Other:	2
"YP paddocks were managed more conservatively for N topdressing than non YP paddocks and missed out on increased yield & protein due to better than expected Spring rainfall."	
"Only used generic soil characteristics"	

5. How useful was Yield Prophet for the following management decisions in 2005?

(1=very useful, 5=not useful at all)

		Number of responses in each category					
		1	**2**	**3**	**4**	**5**	**Mean**
a. Selecting sowing date and variety		2	2	3	3	8	3.7
b. Determining nitrogen application date and rate		2	8	5	4	2	2.8
c. Calculating yield potential for insurance purposes		1	0	7	5	5	3.7
d. Calculating yield potential for marketing purposes		1	3	6	5	4	3.4
e. Other 1 (please list)	"Crop growth and water use"	0	0	0	0	1	5.0
f. Other 2 (please list)	"Whether to spray rust"	0	0	1	0	0	3.0

6. How useful did you find the seasonal climate forecasts in Yield Prophet?

(1=very useful, 5=not at all useful)

	Number of responses in each category					
	1	**2**	**3**	**4**	**5**	**Mean**
a. SOI	1	4	7	6	2	3.2
b. David Stephens DAWA	0	4	9	5	1	3.2

7. Did you feel that your use of Yield Prophet was restricted or limited by any of the following factors?

(1= Not limited to 5=very limited)

	Number of responses in each category					
	1	**2**	**3**	**4**	**5**	**Mean**
a. Your internet connection line-speed	15	2	1	1	1	1.6
b. Your own PC not working	18	2	0	0	0	1.1
c. Yield Prophet web-site not working	9	8	3	0	0	1.7
d. Difficulties in understanding how the web site worked	11	6	3	1	0	1.7
e. Difficulties in understanding what Yield Prophet output meant	10	6	2	2	0	1.8
f. Difficulties with computer use in general	16	3	0	1	0	1.3
g. Lack of time	10	3	5	1	1	2.0
h. Lack of interest	12	6	2	0	0	1.5
i. Lack of support or instruction	14	3	2	0	0	1.4
j. Inaccurate soil characterisation data	1	3	5	9	3	3.5
k. Other (please list)	0	0	0	0	0	0

If you did have difficulty understanding what Yield Prophet output meant, please elaborate:

"Protein increment not self evident: was $ per 0.5%, not $ per 0.1 or 1.0%"

8. Did you discuss your Yield Prophet reports with anyone?

	Number of Respondents
a. No	0
b. Yes, other subscribers	5
c. Yes, other growers who are not subscribers	9
d. Yes, government extension officer	5
e. Yes, agronomic consultant	14
f. Other: "Partners"	2
"JAMES" (Yield Prophet Co-ordinator)	1

9. Who ran Yield Prophet for your paddocks in 2005?

	Number of Respondents
a. A consultant always, or nearly always, ran Yield Prophet for me	2
b. Both a consultant and I ran Yield Prophet	5
c. I ran Yield Prophet myself	13

10. How often did you (including your consultant) run Yield Prophet for your paddocks in 2005?

	Number of Respondents
a. Regularly (several runs per month)	6
b. Often (15-30 runs)	3
c. Occasionally (5-10 runs)	10
d. Rarely (less than 5 times)	2
e. Never	0
f. Other	0

NOTE: There may have been some confusion with this question and respondents assumed that all run numbers were per month.

11. How happy were you with the level of simulation accuracy for your paddock in 2005? (1= very happy, 5=very unhappy)

	Number of responses in each category					
	1	**2**	**3**	**4**	**5**	**Mean**
a. Yield	1	5	9	6	0	3.0
b. Protein	1	3	9	3	3	3.2
c. Growth Stage	3	5	10	3	0	2.6

12. How happy were you with the general level of simulation accuracy for all subscribers in 2005, as outlined in the results summary? (1= very happy, 5=very unhappy)

	Number of responses in each category					
	1	**2**	**3**	**4**	**5**	**Mean**
a. Yield	1	6	10	1	0	2.6
b. Protein	1	3	11	3	0	2.9

13. What is your expectation of the level of error that is acceptable from the Yield Prophet for yield predictions?

	Number of Respondents
a. ± 0.25 t/ha	6
b. ± 0.5 t/ha	12
c. ± 0.75 t/ha	2
d. ± 1 t/ha	1

14. What is your expectation of the level of error that is acceptable from the Yield Prophet for protein predictions?

	Number of Responses
a. ± 0.5%	5
b. ± 1%	13
c. ± 2%	2
d. Other:	1
	"protein is notoriously difficult to model/predict and is not worth trying to manage in our area." (respondent from WA - Southern Grainbelt)

15. Does Yield Prophet offer value for money?

	Number of Responses
a. Yes	10
b. No	1
Other comments	9
	"Hard to say with the results l got , but it was a free service anyway"
	"It is questionable as to wether it is worth the cost"
	"Unsure, it was used more as a discussion tool for a group of farmers"
	"better ask growers - they will be paying"
	"Needs further evaluation and better data inputs in 2006"
	"Undecided at this stage"
	"not sure how accurate it is in our climate of highly variable springs" (NSW – Northern)
	"Give it time"
	"Can't say yet. Need to better characterise the soils in the Esperance region of WA and get some more useful results first."

16. Do you have any general comments regarding Yield Prophet in 2005?

"was generally disappointed with results"

"I havent seen or have mislaid the 2005 summary. Please resend. Some things about the Web Site a bit awkward. Protein responses to N were always quite positive even when yield response was large: normally there is a reverse relationship between these two as moisture changes."

"It was difficult to guage the accuracy of yield prophet in our situation. Our soil analysys data was very suspect and therefore we could not rely on the information"

"I used it in a research and evaluation mode as a 'consultant' with growers. There was a range of interest with some growers keen, others only just interested."

"Found yield prophet a good learning/educational exercise to understand the soil-plant moisture relationship. The soil characterisation was critical and a useful exercise to learn about your soil. The nitrogen model was also a useful comparison with how we assess N."

"It is a good learning tool and should in time lead to better management decisions. I need to improve my knowledge of our soil characterisations and how PAWC is calculated to gain more benefit from the program. There is still a lot I do not understand properly."

"Last year was a screwed up season and probably plant growth was abnormal" (NSW – Northern)

"Keep it up fellas! It's an excellent system, representative of the technological advances we're seeing pushing through Agriculture today. It will take time for many to catch on; especially given the lack of computer knowledge throughout the Ag. Sector. The system is good, but people using it must take interest and ownership of the data (i.e. responsibility for inputing data and obtaining useful results)."

"soil testing was an issue"

17. Do you have any suggestions for Yield Prophet in 2006?

"Suggest that anybody using the Yield Prophet organise their own deep soil N tests through their fertiliser companies and pay for it. We found that the level of interest and input from [agribusiness company named] was nothing short of dismal; many tests that had been lined up were simply not undertaken owing to the simple fact that no fertiliser sale followed."

"Changes made so far have been positive"

"May be interested again if results came out with more realistic figures"

"Make the Website friendlier"

"I am concerned that if we take it 120 km NE from Esperance, there will not be a good set of weather data to run it. - simpler systems will be just as good. I would like to see scaling on the cumulative yield distribution X axis so lower yielding areas can read the graphs a bit easier."

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