Risk management strategies and decision support tools

for dryland farmers in southwest Queensland, Australia

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by

NAM CAO NGUYEN

(BAgrEcon: National Economics University, Vietnam

MAgrbus: The University of Adelaide, Australia)

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School of Natural and Rural Systems Management

Statement of Originality

I hereby certify that the work presented in this thesis is, to the best of my knowledge and belief, original and my own work, except as acknowledged in the text.

I also declare that the material of this thesis has not been submitted, either in whole or in part, for a degree at this or any other university.

Author   Principal Advisor

Nam Nguyen   Dr Malcolm Wegener

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Finally and most importantly, to my family and friends, I sincerely thank all of you for your faith and support. Especially, my wife (Vinh Nguyen) and two daughters (Hoa Nguyen and Chau Nguyen), you are everything to me!

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Abstract

The aim of this study was to evaluate risk management strategies and decision support tools that might be useful to dryland farmers in southwest Queensland to improve their decision making. This topic was chosen because there has been little previous work done to examine the sources of risk faced by farmers in that area, the practical risk management strategies employed by these farmers, or their interests in and attitudes towards risk management.

This study adopted an action-learning approach to present farmers with opportunities to use various tools that might help to manage the range of risks affecting their farm management. The study was designed to test farmers' interests in existing tools, or the potential for developing new tools, to assist dryland farmers in southwest Queensland improve their risk management.

The thesis is presented in three parts including an introduction to the study and an extensive review of the relevant literature on decision making and risk management (Part I), an overview of the area in southwest Queensland where this study was focused and the various research methods used in this study (Part II). Part III comprises four chapters reporting results and presents the conclusions from the study.

The thesis also reviews the advantages and disadvantages mentioned in the literature about decision support systems (DSS) in Australian agriculture and examines some programming and simulation models that can be applied to risk management in agriculture.

The research methods used in this study included a literature review, interviews, focus group discussions, an 'expert' survey, training workshops for farmers, and evaluation techniques.

The observations and reflections from the preliminary inquiries identified soil moisture management and crop choice as the critical issues concerning dryland farmers in southwest Queensland when dealing with crop production risks. Those discussions suggested possibilities for developing a decision support tool to help farmers in the study area assess their planting options. In developing the options for a decision support tool for planting

decisions, a series of workshops was conducted with farmers in the study area, while some observations of farmers who attended similar workshops in adjacent areas are also reported. These workshops provided the opportunity for participants to experience some existing risk management and decision support tools. They were also designed to collect inputs to develop an appropriate decision support tool for crop planting decisions.

A 'Key to dryland planting decisions' for farmers in southwest Queensland was developed and the personal experiences and lessons that the author has learnt through the course of this research are reported.

The thesis enhances the understanding of farmers' attitudes to risk, contemporary risk management strategies, and decision supports tools used in agriculture. This research has contributed to knowledge in the following ways. It has presented a methodological framework for doing research of this type. This study has identified the different sources of risk faced by dryland farmers in southwest Queensland and the practical risk management strategies they employ. The research has introduced those farmers to some existing risk management and decision support tools. The research has contributed more specifically to improving their management decisions by developing a decision support tool that could help dryland farmers in southwest Queensland make better informed and more appropriate planting decisions in the very uncertain and risky conditions with which they have to cope.

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List of Abbreviations

AAEA	American Agricultural Economics Association
AAFC	Agriculture and Agri-Food Canada
AARES	Australian Agricultural and Resource Economics Society
ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
AFFA	Agriculture, Fisheries and Forestry Australia
APEN	Australasia-Pacific Extension Network
APSIM	Agricultural Production Systems Simulator
APSRU	Agricultural Production Systems Research Unit
CBIT	Centre for Biological Information Technology
CIAT	Centro Internacional de Agricultura Tropical
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CVAP	Climate Variability in Agriculture Program
DAFWA	Department of Agriculture and Food Western Australia
DEST	Department of Education, Science and Training
DPIE	Department of Primary Industries and Energy
DSS	Decision Support Systems
ECADG	European Commission Agriculture Directorate-General
ENSO	El Niño-Southern Oscillation
EU	European Union
GRDC	Grains Research and Development Corporation
IAAE	International Association of Agricultural Economists
ILRI	International Livestock Research Institute
IPRS	International Postgraduate Research Scholarship
LWA	Land and Water Australia
LWRRDC	Land and Water Resources Research and Development Corporation
MJO	Maiden-Julian Oscillation
NSW	New South Wales
NSWDA	New South Wales Department of Agriculture
OECD	Organisation for Economic Co-operation and Development
QDNR&M	Queensland Department of Natural Resources and Mines
QDPI&F	Queensland Department of Primary Industries and Fisheries

QLD	Queensland
R&D	Research and Development
RM	Risk Management
RMA	Risk Management Agency
SA	South Australia
SARDI	South Australian Research and Development Institute
SOI	Southern Oscillation Index
UK	United Kingdom
UQ	The University of Queensland
USA	United States of America
USDA	United States Department of Agriculture
UWA	The University of Western Australia
WA	Western Australia
WFS	Western Farming Systems

Part I: Introduction and Literature review

Part I sets the scene for this study. Chapter 1 provides the conceptual framework, identifies the main issues, formulates the objectives, and reports on the appropriate methods to be used to handle the problems identified for appropriate risk management and decision support tools for dryland farmers in southwest Queensland. The review of relevant literature is then covered in the following three chapters.

Chapter 1: Introduction and research overview

1.1   Introduction

Chapter 1 presents a broad overview of this thesis. The chapter is divided into seven sections. After the introductory section, Section 1.2 explains why it is important to study risk management and decision support tools for dryland farmers in southwest Queensland. Section 1.3 outlines the research questions that were identified, while Section 1.4 formulates the aims and objectives of the study. Section 1.5 describes the research methods used in this study. Section 1.6 then presents an outline of the thesis. Lastly, Section 1.7 summarises the chapter and sets the scene for the review of literature in the following three chapters.

1.2   Justification for the research

The Chinese maxim says: 'Plans are man's, but the odds are God's'. We live in a world of uncertainty. We always try to make our plans with great consideration and anticipation of all likely events happening. However, we still face risk regularly (Nguyen, 2002).

Eminent economist and Nobel Prize winner, Joseph Stiglitz[1], said: "Risk is like love: we all know what it is, but we don't know how to define it". Giles and Stansfield (1990) noted that reaching agreement on definitions, in any subject, can be difficult – a hair-splitting and time-consuming business. It usually requires compromise by everybody involved and often produces results that please nobody. Defining risk is no exception and the definition of risk will be addressed later, in Section 2.2 of Chapter 2.

Whatever definition of risk might be used, it is important to remember that risk is an inevitable part of life, and most certainly of farming life. Generations of Australian farmers have lived with risk since farming began in Australia after the arrival of European settlers.

Australian farmers (and those in Queensland in particular) believe they operate in one of the most risky environments in the world. They farm an island continent where the climatic inputs to production are variable and the conditions for farming are much more unreliable

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[1]: Joseph Stiglitz: the American economist receiving the Nobel prize in 2001

than those to which many of their competitors are accustomed. For example, the 2002 drought, one of the worst droughts in Australia, had a major impact on farmers and the wider Australian community. The drought was reported to have cut agricultural income by 58 percent in 2002-03 (Potter, 2003). The situation in 2006 was even worse than 2002, with agricultural income forecast to fall to $2.6 billion in 2006-07, a fall of 72.4 percent from 2005-06 levels of $9.3 billion (ABS, 2006a).

In addition to climatic variability, most farmers face significant price uncertainty. With up to 80 percent of some Australian agricultural products destined for international markets (Clark and Brinkley, 2001), where prices fluctuate widely for a number of reasons, producers of most major commodities experience considerable variability in prices for their products. The variability and uncertainty associated with these two risks (climatic variability and price fluctuations), in addition to the other risks that farmers face (*e.g.* financial and institutional risks as well as health and personal risks), establish the basic business environment in which Australian farmers operate and form judgments, plan strategies, and position their businesses to capture the benefits of future scenarios.

Moreover, most farms in Australia are family-owned and operated, rather than company-owned. The risks associated with farm operations are therefore shared among a limited number of individuals in farm-owning families, rather than spread across a larger number of shareholders. This has implications for portfolio diversification and the management of risk (Marchant, 2003).

As we confront the realities of risk management in the present and the future, it is reasonable to look back at what we have learnt regarding agricultural risk management and to consider where our risk management research efforts would be most productively utilised in coming years. In recognition of this need, this section briefly addresses the background to agricultural risk management. A comprehensive review of literature will be presented in the following three chapters of this thesis (Chapters 2 – 4).

There is an extensive literature on risk and risk management in general as well as risk in agriculture in particular. There has been some previous work of particular interest to risk and risk management in Queensland agriculture.

The strategies used to manage price and marketing risks in agriculture have been described widely in the literature, for example, Trapp (1989), Duncan *et al.* (1991), Cooke (1997), Faruqee *et al.* (1997), Hanson and Pederson (1998), Lubulwa and Beare (1998), Williams and Schroder (1999), Sarris (2000), Kingwell (2000), Meuwissen (2001b), Peterson and Tomek (2001),Wilson and Wagner (2002), Wynter and Cooper (2004), and Adam *et al.* (2006). Similarly, strategies related to managing risk in agricultural production have been discussed in various publications, *e.g.* Hammer *et al.*(1996), Gaynor (1998), Robinson (1999), Williams (1999), Truscott and Egan (2000), Meinke *et al.* (2001), Makki *et al.* (2001), Dawson (2001), Ferreyra *et al.* (2001), Phillips *et al.* (2002), Cooper *et al.* (2003), Marra *et al.* (2003), Robertson *et al.* (2003), and Ritchie *et al.* (2004).

Nevertheless, little previous work that examines the sources of risk faced by farmers in southwest Queensland, the practical risk management strategies that they employed, or their interests in and attitudes towards risk management, has been reported in the literature. Moreover, there has been little investigation so far into the need for risk management and decision support tools useful to Queensland dryland farmers or how these needs might be met.

Accordingly, this study has identified the opportunities for farmers in this area to use various tools to manage the range of risks affecting their farm management. Thus sources of risk, current strategies, interests and attitudes of farmers to risk management were investigated and described. Once these were understood, the feasibility of developing a risk management improvement program or a decision support tool for Queensland dryland farmers was examined.

1.3   Research problem and questions

The title of this thesis expresses the major research problem being addressed:

> *What are the appropriate risk management strategies and decision support tools for dryland farmers in southwest Queensland?*

This problem has been divided into four well-defined and fundamental questions. The four fundamental questions being asked were:

1. ***Research question 1****: What are the current trends in the theory and practice of risk management in general and in agriculture in particular, with a focus on Queensland agriculture?*

2. ***Research question 2****: What are the sources of risk that dryland farmers in southwest Queensland have to deal with? How do they perceive and rank these risks?*

3. ***Research question 3****: How do dryland farmers in southwest Queensland manage farming risks?*

4. ***Research question 4****: What decision support tools or models can be used to help southwest Queensland dryland farmers make better decisions under risky conditions?*

These questions will be developed within the context of the literature review and restated again in Section 4.7 of the thesis.

1.4   Aims and objectives of the study

In addressing the questions identified in Section 1.3, this study aims to evaluate current risk management strategies of dryland farmers in southwest Queensland and improve their risk management capacity, possibly by developing decision support tools. The main objectives of the study were:

- to review the current trends in the theory and practice of risk management in general and in agriculture in particular;

- to identify the sources of risk that dryland farmers in southwest Queensland have to face as well as document their perceptions of these risks;

- to investigate the risk management strategies currently employed by farmers in that area and understand their interests in and attitudes towards risk management; and

- to help dryland farmers cope better with the risks they face, to assist them to make good decisions under risky conditions, and encourage them to apply appropriate risk management and decision support tools in their farming businesses.

1.5 Research methods and the data

Qualitative methods are identified and used in this study to answer specific issues and questions from the proposed objectives. The methodological framework chosen is action research (Costello, 2003). This approach involves six main methods:

- Literature review to examine what has been done in the field of study and to define the research questions (Chapters 2 – 4);
- Semi-structured interviews with researchers in the field of study to refine the research questions (Chapter 7);
- Preliminary interviews and focus group discussions with farmers in the study area to find out what sources of risk they face, what risk management strategies they are using, and what tools might be worth developing to help them make better decisions under risky conditions (Chapter 7);
- A survey of experts to seek guidelines and advice in regard to designing a decision support tool for farmers (Chapter 7);
- A series of workshops to involve farmers in an educational process to improve their decision-making ability. These workshops were also designed as part of the consultation process and interaction with farmers to identify the information needed for the design of a decision support tool that would be applicable and relevant to their conditions (Chapter 8); and
- The design and development of a simple decision support tool to assist dryland farmers in southwest Queensland with their planting decisions (Chapter 9).

For the purpose of carrying out these proposed investigations, two types of data were utilised: primary data collected from interviews with various advisers, researchers, and farmers; and secondary data collected from various published sources. Other sources of data included surveys and statistics from ABS, APSRU, QDPI&F, etc in order to relate findings to the general farming population. The specific sources of data will be referred to in the relevant chapters of Parts II and III of the thesis.

1.6 Thesis outline

To address the main issues and objectives of the study systematically, the thesis is organised into three parts. Figure 1.1 highlights these parts and shows the linkages between them.

Part I sets the scene and describes the background for this study. It consists of four chapters. Chapter 1 outlines the main issues and provides a brief synopsis of the thesis. Chapter 2 contains a review of risk management, decision making, and decision theory literature. Chapter 3 covers the major issues of risk management in agricultural literature. Chapter 4 includes a review of the literature about decision support systems and describes some models and tools applied to risk management.
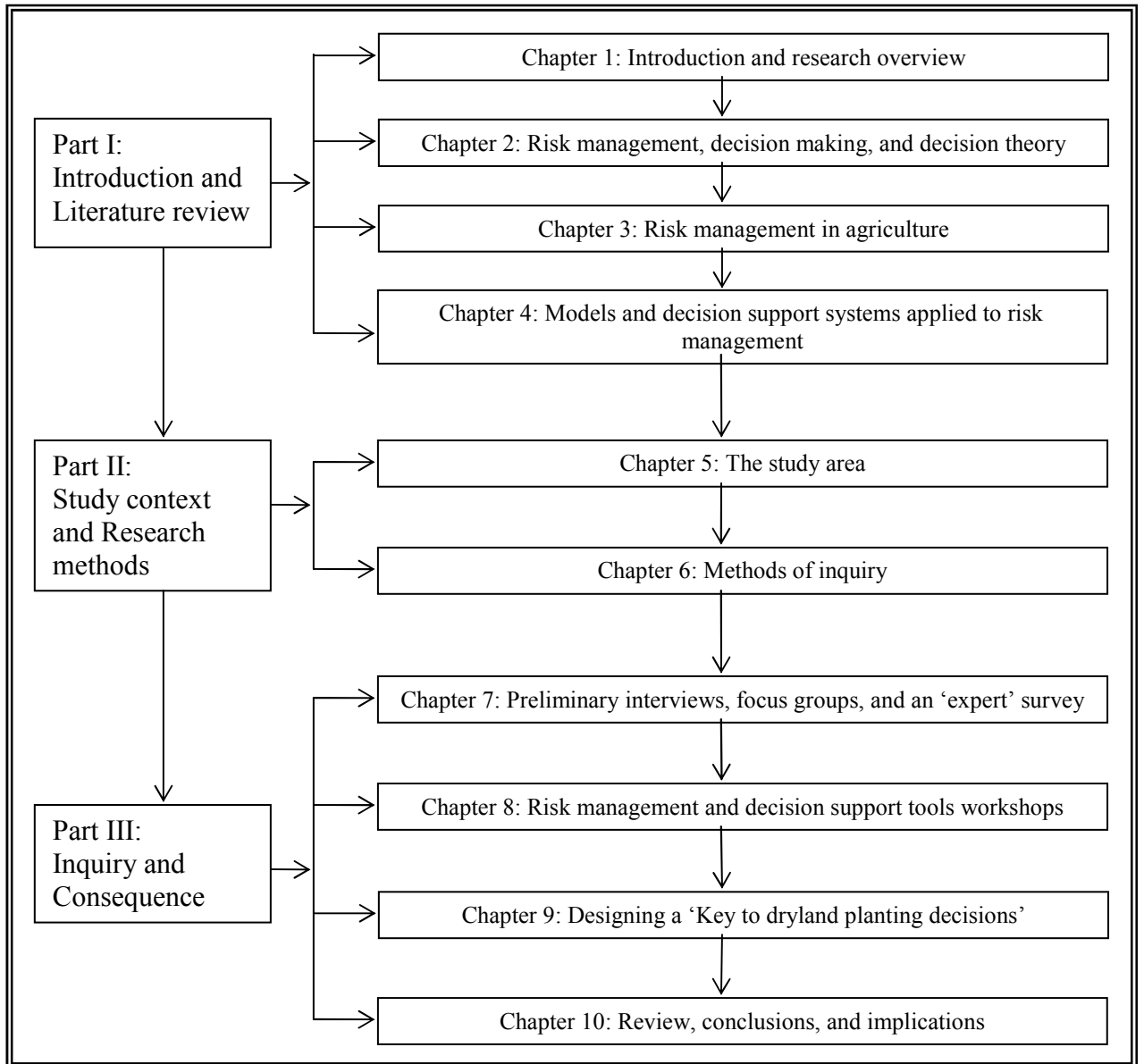
Figure 1.1: Structure of the thesis

Part II describes the study context and research methods. It consists of two chapters. Chapter 5 presents an overview of the area in which the study was conducted. Chapter 6 discusses various methods used in the inquiry.

Part III details the research methods used to find answers for the research questions. It consists of four chapters. Chapter 7 discusses the results of some preliminary interviews conducted with researchers in the field of study and farmers in the study area during the first year of research. This chapter also describes the focus group discussions and an 'expert' survey. Chapter 8 describes a series of training workshops organised for a small group of farmers from southwest Queensland and discusses their results. Chapter 9 includes the design and testing of a decision support tool for dryland farmers. Finally, Chapter 10 draws the study to a conclusion and suggests some implications for further research.

1.7   Chapter summary

This chapter has laid the foundations for the rest of the thesis. It has identified the main issues that gave rise to the research questions. Justification for the research has been given, aims and objectives have been formulated, and the research methods chosen have been briefly described. The next three chapters in Part I will examine in detail the available literature in this field of study.

Chapter 2: Risk management, decision making, and decision theory

2.1   Introduction

This chapter consists of four sections and reviews relevant theory, empirical research, and other literature addressing the issues of risk management, decision making, and decision theory. After this introductory section, Section 2.2 presents an overview of risk management, ranging from perceptions of risk, to the risk management process, principles of risk management, risk assessment, and risk mapping. Section 2.3 canvasses the major issues involved in research into decision making. It includes a description of the categories of decision making (normative, descriptive, and prescriptive) and the contribution of relevant decision theories to decision making (utility theory, prospect theory, reason-based choice, heuristics, and biases). Lastly, Section 2.4 presents a summary of the chapter.

2.2   Risk management

2.2.1   Definition of important terms

In attempting to answer the research questions posed previously in Section 1.3 of the thesis, it is first necessary to define what is meant by 'uncertainty', 'risk', and 'risk management'.

Uncertainty

The two terms risk and uncertainty, in fact, are often used interchangeably in many publications. Yet they do have different meanings. Therefore, it is useful to define them in order to avoid ambiguity.

Williams and Schroder (1999) stated that few things in nature are certain. The weather and human competitive forces are constantly changing, thus causing predictions about the future to be always uncertain. Tversky and Kahneman (2002) proposed that uncertainty is an unavoidable aspect of human activity.

Uncertainty arises from our lack of perfect knowledge. In some cases, we can reduce uncertainty by obtaining better information, but this may not always be possible.

Uncertainty implies that decision makers might make non-optimal choices because they may expect one outcome, but something quite different might actually occur (Thompson, 2002).

Uncertainty covers all things that could happen but which the decision maker would never expect to happen (Krause, 1995). Cooper *et al.* (1993) and Mishra (1996) described uncertainty as situations where one cannot attach probabilities to the occurrence of events because the likelihood of such occurrence is not known. Similarly, Just *et al.* (2003) linked uncertainty to situations where the objective probability distribution of outcomes is unknown by the decision-maker. Briefly, uncertainty is considered as imperfect knowledge of the future (Hardaker *et al.*, 1997; ECADG, 2001).

Wherever mentioned within the context of this thesis, *uncertainty is characterised by imperfect knowledge of a future situation where we cannot attach objective probabilities to the possible outcomes or we do not know the outcomes*.

Risk

Risk is often used as a very loose term in agriculture. For example, some people think risk relates mainly to fluctuations in commodity prices, while others view it as variations in weather and the effect on yield. Generally speaking, risk is a term in everyday use, but it is difficult to define in practice due to the complex relationships between its components.

Williams and Schroder (1999) claimed that risk is a very broad subject because everything we do has an element of risk. It is a complex concept, which does not easily lend itself to a neat, one line definition (Cross, 2000). Understandably, there are many different definitions of risk.

Fleisher (1990) suggested that although there is no universally accepted definition of risk, several working definitions are commonly used. He went further to indicate risk as a situation in which the resolution of uncertainty will affect the well-being of a firm or decision maker and which involves the chance of gain or loss. Krause (1995) defined risk as the estimated measure, or probability, of something happening. According to Cooper *et al.* (1993) and Williams and Schroder (1999), a state of risk is considered to exist whenever knowledge of the situation enables the likelihood of the various possible events to be assessed in advance.

Risk is used by some authors to describe situations where one can attach probabilities to the occurrence of events influencing the outcome of a decision (Mishra, 1996). Likewise, Just *et al.* (2003) referred to risk as situations in which the objective probability distribution of outcomes is known by the decision-maker. In other words, risk is considered as uncertainty with consequences (Blackburn *et al.*, 1994; Hardaker *et al.*, 1997; Cross, 2000). Risk occurs when there is a chance of something happening that will have an impact upon objectives. It is measured in terms of consequences (Australian/New Zealand Standards, 2004).

In the context of this thesis, *risk is characterized by an inability to predict the future but where it is possible, at least in principle, to determine objective probabilities about possible outcomes*.

Risk management

Kloman (1990) argued that it is only recently that risk management has risen to prominence in management theory and practice and that the different risk areas have been brought into a total risk management philosophy and methodology. What then is risk management?

Hardaker *et al.* (1997) considered risk management as the systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring risk. Similarly, the Australian/New Zealand Standards (1999) described risk management as the logical and systematic method of establishing the context, identifying, analysing, evaluating, treating, monitoring and communicating risks associated with any activity, function or process in a way that will enable organisations to minimise losses and maximise opportunities.

There are some short definitions of risk management. For example, Beer and Foran (2000) identified risk management as a formalised method of dealing with uncertainty, while Pritchard (2000) viewed risk management as the process of implementing decisions about accepting or altering risks. Risk management was described as the process used to avoid, reduce, or control risks (Queensland Government, 2003).

The term *risk management* used in this thesis *is defined as the process of identifying, assessing, treating, and implementing actions to reduce risks and enable*

farmers/managers to strike a balance between possible losses and opportunities. This definition is not necessarily better than others but it is stated here to provide consistency with the definition of risk presented above, as well as relating to the objectives of this study.

2.2.2   The importance of managing risks

Risk needs to be managed to increase or stabilise the prospective returns to owners or shareholders from a particular enterprise (Stulz, 2003). A recent publication from the Queensland Government (2003) notes that any business manager who ignores the risks which apply to their business activities or the events that they have planned could face many adverse outcomes.

The objectives to be achieved in managing risk require that the risks be identified and evaluated so that managers can be informed about which risks to hedge or to mitigate, and which risks to transfer or to sell. Thieke (2000) said that these activities are both offensive and defensive, in that good risk management is able to promote a business person's risk capacity (in this case, a farmer), as well as defend the business (farm) from unwanted risk.

Cross (2000) suggested that there are perhaps three reasons for the increased emphasis on risk management in current business planning. One is the increased pace of change. Basing decisions on past experience has become increasingly unreliable. Decisions now need to take account of a range of possible futures and to optimize opportunities and minimize losses in an uncertain and changing environment. The second reason why risk management has increased in prominence is the apparently increasing number of major disasters that (retrospectively) could have been avoided or better managed (Clement, 1989). Disasters have a significant impact outside the immediate areas affected because of the complexity and inter-connections of modern society. The third reason is that the frequency of major disasters has made public liability insurance more expensive and changes to liability laws mean Company Directors and Chief Executive Officers may now be held directly, legally, and personally responsible for losses resulting from poor decisions and poor control of risks by an organization. Senior managers need all managers throughout the organization to think about the risks involved with their decisions and to ensure that appropriate actions are taken to keep risks under control.

The following parts of this section will therefore review the various aspects of risk and risk management.

2.2.3   Perceptions of risk

Risk perception is concerned with the psychological and emotional factors that have been shown to have an enormous impact on behaviour. In a set of path-breaking studies begun in the 1970s, Paul Slovic, Baruch Fischhoff, and other psychologists began measuring lay persons' concerns about different types of risks (Kunreuther, 2002). Recently, another significant contribution about perceptions of risk has been published by Kahneman and Tversky (2000a).

Abadi (2003) observed that individuals differ widely in their characteristics, especially when they have to make decisions under uncertain conditions. These characteristics might include management style, perceptions and beliefs and how long they take to revise them, attitudes towards risk, competence with different enterprises, communication skills, partnership structure and leadership styles, physical resources available to them (*e.g.* credit, land, and labour), social circles of influence, and response to social pressures and competition.

Consequently, it is necessary to include a wider review of perceptions of risk before moving on to the description of the multi-faceted aspects of risk management.

Research concerning perceptions of risk

Important contributions to current understanding of risk perceptions have come from geography, sociology, political science, anthropology, and psychology (Slovic, 2000b). For example, geographical research focused originally on understanding human behaviour in the face of natural hazards, but it has since been broadened to include technological hazards as well (Burton *et al.*, 1978). Sociological studies (Short, 1984) and anthropological research (Douglas and Wildarsky, 1982) have shown that perception and acceptance of risk have their roots in social and cultural factors. Short (1984) argued that response to hazards is mediated by social influences transmitted by friends, family, fellow workers, and respected public officials. In many cases, risk perceptions may form afterwards, as part of the *ex-post* rationale for one's own behaviour. Douglas and

Wildavsky (1982) asserted that people, acting within social groups, downplay certain risks and emphasize others as a means of maintaining and controlling the group.

Fenton-O'Creevy and Soane (2001) proposed four important influences on perceptions of risk by individuals including how an individual understands risk, how the individual perceives losses and gains, cognitive biases, and personality. Generally speaking, people's perceptions of risk can be categorised into three types as discussed in the following paragraphs.

Risk attitude/risk profile

In some people's mind, the relationship between risks and benefits is negative (*i.e.* high risk equates with low benefit). In aggregate, the real risk-benefit relationship in the external environment is positive (*i.e.* high risk is associated with high benefit).

Personal attitudes and past experiences mould the risk profile of each individual person. People have different risk profiles and each individual has a different attitude towards risky behaviour. Also, each individual perceives the same risk differently (Williams and Schroder, 1999). In addition, the way people process information on the costs and benefits of reducing risk plays an important role in their decision on whether or not to take protective action to manage risk.

There is also a growing body of evidence, *e.g.* Slovic (2000a) and Loewenstein *et al.* (2001), that affection and emotions play an important role in people's decision-making processes. Furthermore, rather than basing one's choices simply on the likelihood and consequences of different events, as normative models of decision making suggest, individuals are also influenced in their choices by emotional factors such as fear, worry, and love (Kunreuther, 2002).

In economics, the conventional way to discuss risk attitude has been to classify decision makers as risk-averse, risk-seeking, or risk-neutral, according to the shape of their individual utility functions (Marchant, 2003). Risk-averse people can be defined as those who wish to avoid risk and are willing to sacrifice expected profit to do so (for example, a farmer who sells grain at a spot price, but also buys a future contract to avoid the risk of price falling). In other words, someone who is risk-averse is willing to accept a lower average return to reduce the uncertainty, with the trade-off depending on the person's level

of risk aversion. Kahneman and Tversky (2000b) believed that a risk-averse person would value a protective action which reduces the probability of harm from one percent to zero more highly than an action that reduces the probability of the same harm from two percent to one percent.

In contrast to risk-averse people, risk seekers can be defined as people who view risk as an opportunity to make a profit and are prepared to accept losses in doing so (for example, a trader who purchases grain and stores it in the hope of a price increase). Tversky and Fox (1995) stated that risk-seeking is exhibited if a risky prospect is preferred to a sure outcome with equal or greater expected value.

Between the two extremes are risk-neutral individuals. Risk neutrality is often assumed if the decision maker can eliminate the risk, *e.g.* by being able to diversify his or her portfolio totally (Gustafsson, 2000). It is represented as a description of an investor who purposely overlooks risk when deciding between investments. A risk neutral investor is completely indifferent to the risk involved in an investment and is only concerned about expected return.

Generally, people tend to choose the risk-free option, even at the cost of a lower expected utility value. In the real world, however, it is extremely difficult to present 'zero risk' as a viable option (Nakayachi, 2000). There is usually a need to strike a balance between risk and reward and an example from accumulating retirement benefits could serve as an example:

> "Most experts agree that you should not take too much risk with your pension accumulation. On the other hand, if you don't take enough risk, you might not build sufficient assets for a comfortable retirement. So you need to find a risk-reward balance that is comfortable and appropriate for you" (Hertzler, 1997, p.71).

Generally, the same principle operates in most decisions where uncertainty is involved.

In terms of the decision-tree diagram (Figure 2.1), a risk-averse decision maker may prefer the sure outcome (1) to the risky outcome (2 or 3), even though the risky action could have a higher expected return than the sure action, because such an action avoids the risk of a low outcome (3).
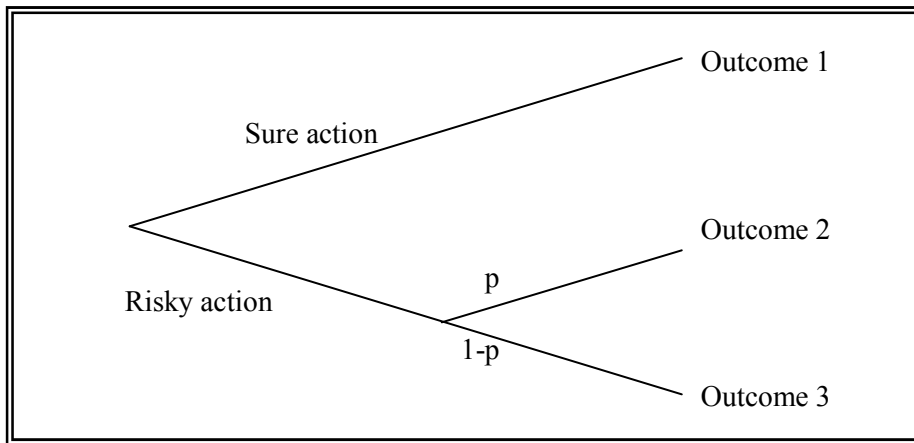
Figure 2.1: Representation of a risky choice by a decision-tree

Source: Parton and Pandey (1991, p.28), cited in Wegener (1994, p.48)

Vlahos (2001) noted that traditional decision analysis usually attempts to model risk preferences on the basis of utility functions that map monetary outcomes to a measure of attractiveness. Figure 2.2 shows three differently shaped utility curves corresponding to risk-averse behaviour, risk-neutral behaviour, and risk-seeking behaviour.
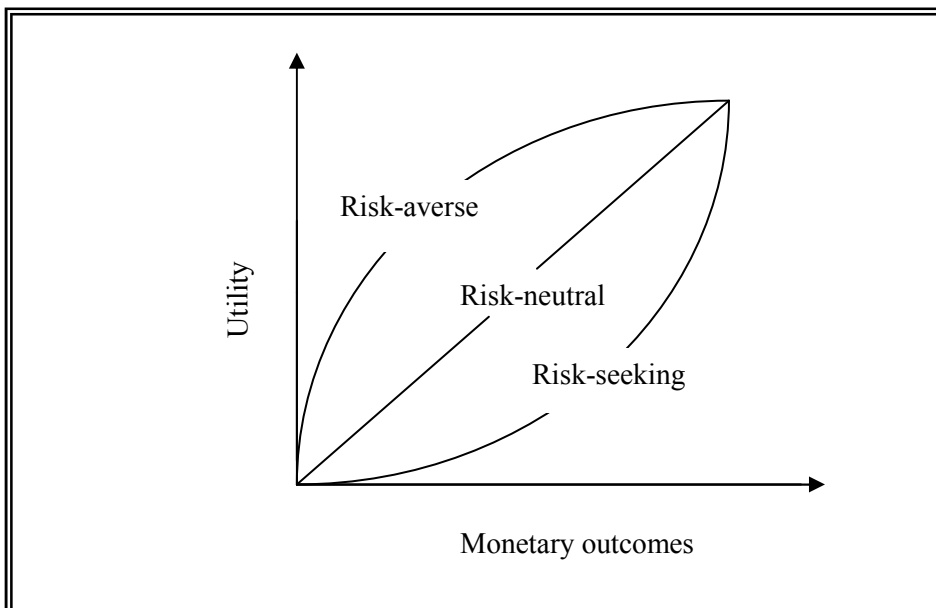
Figure 2.2: Utility functions

Source: Adapted from Vlahos (2001, p.51)

In all three cases, greater wealth corresponds to greater utility but the risk-averse curve is concave, because as wealth increases, the incremental attractiveness of the same amount of money becomes smaller. Vlahos (2001, p.50) said: "This is intuitive: Bill Gates did not get the same kick out of making his fifth billion as he did from making his first". The risk-

neutral curve is a straight line and a risk-seeking curve is convex (in technical terms, the second derivative is positive). In contrast, the second derivative of utility is negative for the risk-averse curve, and is zero for the risk-neutral curve.

2.2.4 Risk management process

Effective risk management involves anticipating outcomes and planning a strategy in advance given the likelihood and consequences of events. It involves much more than reacting to those events after they occur. A number of authors have suggested that the risk management process can be divided into a number of steps, namely risk identification, risk analysis, risk evaluation, and risk treatment (Hardaker *et al.*, 1997; Noell and Odening, 1997; Green, 2000). These steps can be performed in a routine and cyclical way by most individuals and organisations.

Management of risk is an integral part of the overall business management process. Risk management is a multi-faceted process and its main elements are illustrated in Figure 2.3. For the sake of brevity, only a brief description of these elements will be discussed in the next paragraphs. Details of the risk management process are reported in the Australian/New Zealand Standards (2004).
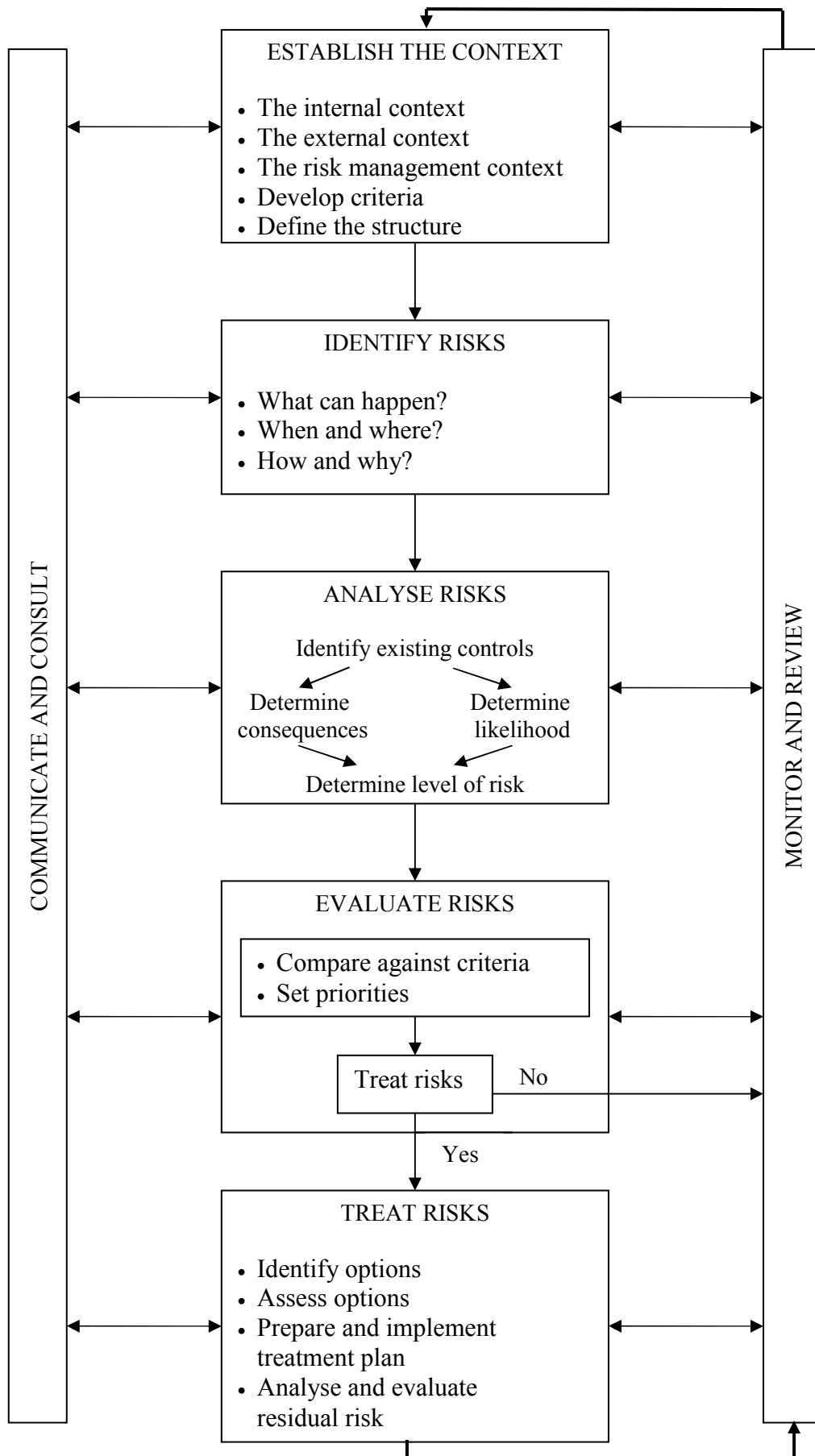
Figure 2.3: Risk management process

Source: Adapted from the Australian/New Zealand Standards (2004, p.13)

Establishing context

The first step in the process of risk management is defining the context. This step recognises that it is not effective to try to identify future scenarios and estimate potential losses and opportunities before one has thought about what one is trying to achieve and why (Cross, 2000).

Clark and Brinkley (2001) emphasised that the 'context' used here refers to specific aspects of the environment, risk, and organization to which risk management is being applied. Context is usually established early because this exercise is critical to the success or failure of the process. 'Setting the context' will ensure that the other stages in the process are more targeted and efficient, and it will avoid wasted time and resources. It is necessary to understand the organization and its capabilities, as well as its goals and objectives and the strategies that are in place to achieve them. Information about the context helps to design a suitable risk management process. This task is usually carried out early in risk management, but it can also be modified throughout the remaining stages.

The context needs to be established to define the basic parameters within which risks must be managed and to provide guidance for decisions within more detailed risk management studies. This sets the scope for the rest of the risk management process.

Identifying risks

The next step is to identify the risks that are relevant. This is often said very glibly. It is, however, the most difficult step of the process.

In identifying the risks to be managed, a systematic approach is important to ensure that important types of risk are not overlooked. The list of all possible risks is obviously endless, so the aim in risk identification is to make a list of the events that may have an important effect on the performance of the organisation. It is a matter of considering what might happen, why, and how (Hardaker *et al.*, 1997). Having identified a list of events, it is necessary to consider possible causes and scenarios. There are many ways an event can be initiated. It is important that no significant causes are omitted.

Risk identification narrows the task in risk management down to considering a specific set of threats, given the values, policies, and organizational context in which the individual or business is operating. The risk identification process develops preliminary information

about a broad set of risk factors. These factors may be narrowed either through iterations of this process, or through a more complete risk analysis (Clark and Brinkley, 2001).

Analysing risks

Once risks have been identified, the next step is to analyse them. The aim is to try to estimate how big the consequences of these risks are and to find the factors that affect their magnitude so that negative impacts can be traded off. Most of the discussion about risk is focussed on down-side risk, but it is worthwhile considering whether managers can take advantage of up-side risk.

Analysis or risks may be qualitative, semi-quantitative or quantitative, or a combination of these depending on the circumstances. In the risk analysis step, facts, predictions, calculations, and reasoned judgements about the risk and its magnitude are considered alongside political considerations, values, criteria, constraints, and prejudices so that a decision can be made.

Evaluating risks

The purpose of risk evaluation is to make decisions, based on the outcomes of risk analysis, about which risks need treatment and treatment priorities. Risk evaluation involves comparing the outcomes from particular events identified during the analysis process with risk evaluation criteria established when the context was considered. In some circumstances, risk evaluation may lead to a decision to ignore the risk, accept the risk, or even to postpone the decision and undertake further analysis.

Making a decision

Decision making, or treating risks, is the process of selecting and implementing appropriate options to deal with risk. It involves evaluating alternative options and selecting among them. Options can be assessed on the basis of the extent to which risk will be reduced, and the extent of any additional benefits or opportunities created. A number of options may be considered and applied either individually or in combination. The options should consider how risk is perceived by affected parties and the most appropriate ways to communicate the effects to those parties.

Ideally, responsibility for decision making in risky situations should be borne by those best able to control the risk. Responsibilities should be agreed between the parties at the earliest

possible time. The successful implementation of the risk management plan requires an effective management system which specifies the methods chosen, assigns responsibilities and individual accountabilities for actions, and monitors them against specified criteria.

Monitoring and communicating risk

The risks themselves, and each step of the risk management process, require monitoring. Risks change as circumstances change. New risks arise and new information becomes available to help analyse the magnitude of their outcomes. Once the risk management program is put in place, data can be generated which can improve the management process. Once a risk management cycle is complete and risks are reduced, criteria can be strengthened to make a continuous improvement in risk management. In spite of a risk management program being in place, losses can still occur. It is therefore important to monitor the outcomes from decisions and learn from poor ones (Cross, 2000).

Furthermore, Clark and Brinkley (2001) claimed that because risk management is based on information, communication is a foundation of the process, and many criticisms of applied risk management processes have attributed failures to poor communication. Risk management processes that are viewed as 'successful' are often highly communicative with rich and easily accessible information available at all stages.

2.2.5 Principles of risk management

The Australian/New Zealand Standards (1999) outlines some general strategies for risk management as well as a generic process for preparing risk management plans. A plan might contain part or all of the following individual strategies, and it might not be confined to one single approach. These strategies include:

- risk reduction which lowers the frequency of occurrence of events with adverse outcomes and subsequently the potential impact of these risks;
- impact reduction (mitigation) which can be used when there is no practical way of influencing the frequency of a risk;
- risk transfer involves sharing part or the whole of the impact of the risk with a third party;
- avoiding risk involves a decision to take no action, and usually occurs when the impact of a risk is negligible; and

- retaining the risk involves accepting the impact as a normal part of the operating context and occurs when other strategies are not possible or more costly.

2.2.6 Risk assessment and risk mapping

In a rational world, the objective of a risk assessment should be to identify all the pertinent risks, analyse them carefully, and mitigate the down-side impact of those risks as far as it is possible and economic to do so. The remaining risks need to be monitored and controlled as much as possible, and contingency plans put in place, should the risk event occur (Lewin, 2000).

A detailed discussion of methods of risk assessment is beyond the scope of this study. However, there are some common methods in use. Marchant (2003) quoted Barry (1984) who claimed that mean-variance (E-V) analysis (implemented through quadratic programming), minimization of total absolute deviations (MOTAD), and simulation analysis are some of the methods used to develop farm plans with outcomes that are acceptable to decision makers with various levels of risk tolerance. Methods of applying models to risk management will be explored further in Chapter 4 of this thesis.

Hanley (2001) suggested that risk mapping is a commonly used tool in risk assessment. It analyses a manager's/farmer's portfolio of risks in a way that clarifies the links between, and impacts of, the risks on each other. Risk mapping clarifies a manager's or farmer's risk attitude, and enables risks to be formally identified and given a priority rating, so that critical risks can be mitigated or managed in timely fashion. This list of priorities will reflect the manager's/farmer's risk attitude (Hanley, 2001).

According to Hanley (2001), each risk can be placed on a risk map once each has been identified and quantified. Typically, a risk map is a matrix with four quadrants, or a graph with two axes, representing severity of consequences and levels of frequency. Each quadrant refers to a different category of risk, which needs to be handled differently (see Figure 2.4).

	Insure		**Self-insure**
High	• Buy insurance • Mitigate – reduce severity • Use non-traditional funding methods		• Mitigate – reduce frequency and severity • Recover in pricing
	Self-insure		**Self-insure**
	• Mitigate only – risk mitigation and financing are not cost effective		• Mitigate – reduce frequency
Low			

(Severity on vertical axis: High to Low; Frequency on horizontal axis: Low to High)

Figure 2.4: Risk map – the classical approach

Source: Adapted from Hanley (2001, p. 55)

2.2.7 Section conclusion

Risk management is not always easy or straightforward, and this reflects the very nature of most risk-based problems. Experience also indicates that there is no universal approach and that each specific situation requires a different mix of tools and instruments. Moreover, risk management implies different things to different people, depending on their attitudes towards risk, their financial situation, and the opportunities available to them. In some cases, managing risk may involve minimizing the extent of variability for a given level of expected output or revenue. In other cases, it may involve keeping variability within acceptable bounds while seeking higher expected returns. More generally, the goal of risk management is to obtain the best available combination of expected income and income certainty, given the individual's resources and risk preferences.

In conclusion, the research issue that arises from this review of risk and risk management literature, and which is appropriate to this study, is:

- ***How can the tools of risk assessment and the recorded knowledge about perceptions of risk be linked to develop appropriate risk management strategies that are likely to be implemented successfully by southwest Queensland dryland farmers?***

This research issue will be developed into several formal research questions in Chapter 4, Section 4.7 of the thesis.

2.3   Decision making and decision theory

2.3.1   Introduction

This section explores the current state of knowledge with respect to decision making processes and describes the theoretical basis for several decision making methods. The review of literature in this section is used to reflect the changes in understanding in the last twenty years of how people actually make decisions. This review is deliberately selective in using current approaches focussed on behavioural economics, an area not well recognised or pursued by agricultural economics.

Johnson *et al.* (1961) rated decision making among the five managerial functions of observing, analysing, decision making, acting, and bearing responsibility, to which they later added problem definition. Current risk management practices are outlined in Section 2.2, and because of the close association between decision making and risk management, some topics discussed in Section 2.2 will be expanded in this section.

Willock *et al.* (1999) emphasised that farms are businesses where many decisions are made and implemented by a single person and, as in other businesses, these decisions are predominantly focussed on production and profit (although at certain stages in the farmers' lives, they may need to address other serious issues such as intergenerational transfer of assets). Willock *et al.* (1999) also mentioned the importance of psychological theory in understanding farmers' decision making processes. Shrapnel and Davie (2000) noted that farmers must have the necessary psychological resources to bring about change, want to change, have the knowledge required to make change, and the necessary material resources to make changes in the operation of their farms, or even to cease farming altogether.

2.3.2   Categories of decision making

In their book, titled 'Decision Making', Bell *et al.* (1988a) presented the following taxonomy of decision making under uncertainty:

- Normative – logically consistent decision making procedures, or how people should decide what to do;

- Descriptive – decisions people make, and how people go about deciding what to do; and

- Prescriptive – how to help people to make good decisions and how to train people to make better decisions.

This sub-section (2.3.2) is based largely on the introduction of 'Decision Making' (Bell *et al.*, 1988a), and is devoted to a discussion of this taxonomy.

Normative decision making

Normative decision making describes the way that people ought to make decisions. Fishburn (1988) reviewed the traditional theory of von Neumann and Morgenstern (1944) and surveyed attempts to adapt this theory to accommodate the mounting evidence that many authors were finding the theory too restrictive. Bell and Raiffa (1988b) set themselves the goal of 'explaining' the axioms of von Neumann and Morgenstern in such a way as to leave all readers lifelong devotees of expected utility theory.

Shafer (1988) made a substantial contribution to understanding when he presented a constructive procedure for making decisions. His complaint about subjective expected utility theory was that it was doomed to fail as a prescriptive tool because it required inputs such as probabilities and an understanding of utility which were not natural to a decision maker. He built a theory around goals rather than values, and beliefs rather than probabilities which, even if aesthetically less pleasing to purists, had the prospect of achieving more success in practice (Bell *et al.*, 1988c). Shafer and Tversky (1988) explained the belief function approach more thoroughly. They stated quite clearly that their work was intended neither as a description nor as a prescription. Rather, they investigated the normative implications of their ideas (Bell *et al.*, 1988c).

Dempster (1988) examined the various roles possible for a quantitative theory of evidence by distinguishing between a truthful theory and a truthful application of the theory. He argued that one normative theory should not be expected to be useful in all situations, and that normative theorists would do well to supply a range of tools for applied use.

Bell (1988), in a similar way to Schelling (1988), took as a premise that people suffer from being disappointed (in a way that they would be prepared to pay to avoid). People are disappointed when the outcome of a decision made under uncertainty is lower than their

expectations. His paper showed how a normative model may be constructed to take account of the detrimental (and positive) effects of disappointment and used the model to derive implications for human behaviour (Bell *et al.*, 1988c).

Bell and Raiffa (1988a) considered whether the traditional concepts of diminishing marginal economic value and risk aversion are really equivalent, as it is often assumed. They argued that the usual measure of risk aversion confounds two concepts, decreasing marginal value, and 'intrinsic risk aversion'. While a person's value curve may quite properly vary with the commodity over which it is measured (thus altering the measure of risk aversion), these authors hypothesized that a person's intrinsic aversion to risk (dislike of uncertainty) remains constant across situations. Regret and disappointment were two ideas that arose from considering factors that might contribute to intrinsic risk aversion (Bell *et al.*, 1988c).

Descriptive decision making

Descriptive decision making addresses the issue of how people actually make decisions. Tversky and Kahneman (1988), McNeil *et al.* (1988), and Slovic *et al.* (1988) all produced sound evidence that suggests people may arrive at opposite conclusions when data are presented in different, but mathematically equivalent, ways. Such behaviour is strictly ruled out by normative models, so these results are of tremendous significance to those who try to understand how people think (description) and to those who try to apply normative principles in the face of such potential distortions (prescription) (Bell *et al.*, 1988c).

Many scholars have questioned whether the traditional normative paradigms really capture the essence of what is important in making a decision (Bell *et al.*, 1988c). March (1988) drew attention to the dynamic nature of the world, especially to a decision maker's uncertainty about his/her own future preferences. He explained apparent anomalies from the normative approach by the need for people to be resilient in the real world. Simon (1988) discussed his famous premise that people aim to achieve satisfactory rather than optimal results from their decisions. Einhorn and Hogarth (1988) gave a comprehensive review of critiques of traditional normative paradigms. They concluded with implications for prescriptive work

Schelling (1988) cited evidence that suggests people may derive pleasure that they will pay for from experiences in which the brain (temporarily) suspends logical analysis. He said that we may cry when a movie character dies even though logic tells us the actor is still alive and that the script is fiction. This and other examples led him to question 'who is in charge?' If the mind is the ultimate consumer of our actions, should we be trying to frustrate its desires via logical thinking?

Argyris (1988) looked at the impediments, created by social upbringing, to the identification by decision makers and decision scientists alike of non-traditional (and optimal) solutions to problems. He argued that, when decision makers dislike the outcome of a decision, they infer that something was wrong about their decision and ignore the possibility that there might be something wrong about the values and process that produced their decision. While the aim of Argyris was to improve the chances of helping people to make better decisions (prescriptive decision making), the majority of his article was descriptive in illustrating how people think (Bell *et al.*, 1988c).

Prescriptive decision making

In the classification of decision making developed by Bell *et al.* (1988a), prescriptive decision making addressed the issue of how to help people make good decisions and how to train people to make better decisions. Edwards *et al.* (1988) described an application in which multiple objective analysis was used to rank research projects. Along the way they told many of the lessons they had learned over years of using decision analysis in the field (Bell *et al.*, 1988c). Keeney (1988) suggested that people would do well to analyse their value systems as a means of identifying decisions that could be made. However, he noted the reverse is more usually the case: a decision situation leads to an analysis of values. By pursuing value-focused thinking, Keeney argued, a person may derive greater incremental benefit from opportunities for decisions.

Fischhoff *et al.* (1988) described a number of difficulties that stand in the way of any analyst who attempts to measure the values of a decision maker. While alerting the reader to the potential pitfalls, they argued it may be mistaken as a premise, both in reality and as a practical matter, to assume that people have values that await quantification. Decision aids might be developed that exploit the insights to be gleaned from the inherent instability of values (Bell *et al.*, 1988c).

Hershey *et al.* (1988) identified five sources of distortion in the assessment of utility functions. This was a descriptive contribution to a normative theory with prescriptive implications (Bell *et al.*, 1988c). Fong *et al.* (1988) questioned whether formal statistical training would help people to avoid common reasoning errors in everyday life. While their results do support such a conclusion, it is somewhat alarming to see how often even trained people fall into such traps. The difficulty of the task ahead of those wishing to make prescriptive contributions was clearly underlined by this study (Bell *et al.*, 1988c). Since then, prescriptive theory has been used and applied in much empirical work (Motiwalla, 1991; Sarma, 1993; Huber *et al.*, 2002; Meacham, 2004).

2.3.3   Decision making theories

Models of decision making

In order to unravel how people make decisions, some researchers have used formal modelling approaches, traditionally employed in economics, management science, and decision research, which characteristically associate a numerical value with each alternative, and describe the choice made, as the maximization of that value (Marchant, 2003). Normative models such as expected utility theory (von Neumann and Morgenstern, 1944) and descriptive models such as prospect theory (Kahneman and Tversky, 1979) illustrate this value-based approach.

In the disciplines of law, history, and business, an alternative tradition of informal, reason-based analysis has been used to describe decisions. This methodology identifies reasons and arguments that are claimed to be part of, and influences on decisions. A decision is reached by balancing reasons for and against a number of alternatives (Marchant, 2003). According to Shafir *et al.* (1993), reason-based analyses are commonly used to interpret case studies in the areas of business and law, especially where value-based models are difficult to apply. Indeed, the formal, model-based, and the informal reason-based processes of decision making are not mutually exclusive, as reason-based decisions may be explained in terms of a formal model, and vice versa (Marchant, 2003).

Another approach to the study of judgment under uncertainty involves the consideration of heuristics and biases. The core idea of this approach is that judgment under uncertainty is often based on a limited number of simplifying heuristics rather than more formal and

extensive algorithmic processing. These heuristics typically yield accurate judgments but can give rise to systematic error (Gilovich and Griffin, 2002).

The models and theories that have been used as the basis for explaining decision making will be explored in more detail in the following paragraphs.

Utility theory

The initial description of utility theory was advanced by Daniel Bernoulli in 1738 when he proposed a method of defining the value or attractiveness of different outcomes (based on his observations of gamblers). According to Bernoulli, the consequences of different outcomes, when making decisions, can often outweigh the probabilities that each will occur. That means that the perceived magnitude of the risk will vary, depending on the assessment different people have of the consequences of that risk (Bernstein, 2001).

Following Bernoulli's initial proposition, the standard expected utility theory of von Neumann and Morgenstern was formulated as an adjunct to their theory of games (Fishburn, 1988). Essentially, game theory pointed out the distinction between a theoretical economy where people act alone, and control all the variables, and real life, where people interact in a social economy and decisions are made by intense interaction among all the players (people in the natural course of their lives). Thus the source of a great deal of uncertainty in life lies not only with nature and other unknowns but with the actions of other people. In the context of game theory, an investment does not necessarily have a theoretical value arrived at by calculation, but a value based on what someone else (a competitor, customer) is willing to pay for it (Bernstein, 2001).

The application of expected utility theory to choices between prospects is based on the following three tenets:
- The overall utility of a prospect, denoted by U, is the expected utility of its outcomes;
- A prospect is acceptable if the utility resulting from integrating the prospect with one's assets exceeds the utility of those assets alone; and
- Risk aversion: u (the utility function) is concave ($u^{''} < 0$) (Kahneman and Tversky, 1979).

Expected utility theory reigned for several decades as the dominant normative and descriptive model of decision making under uncertainty (Kahneman and Tversky, 1992). They quoted Keeney and Raiffa (1976) who described expected utility as a normative model of rational choice and noted that authors such as Friedman and Savage (1948) and Arrow (1971) reported it as being widely applied as a descriptive model of economic behaviour. Thus, Kahneman and Tversky reported that it was assumed that all reasonable people would wish to obey the axioms of the theory as described by von Neumann and Morgenstern (1944) and Savage (1954), and that most people actually do follow these principles, most of the time (Kahneman and Tversky, 1979).

There now seems to be general agreement that expected utility theory does not provide an adequate description of individual choice. There has been a substantial body of evidence that shows that decision makers systematically violate its basic tenets. For example:

- In expected utility theory, the utilities of outcomes are weighted by their probabilities. However, Kahneman and Tversky (1979) showed that people overweight outcomes that are considered certain, relative to outcomes which are merely probable – a phenomenon which they labelled the certainty effect.

- The best known counter-example to expected utility theory which exploits the certainty effect was introduced by the French economist Maurice Allais in 1953 (Kahneman and Tversky, 1979). Allais demonstrated the Allais Paradox by showing that the difference between probabilities of .99 and 1.00 has more impact on the preferences than the difference between 0.10 and 0.11 (Kahneman and Tversky, 1992).

- Under both risk and uncertainty, losses loom larger that gains. This asymmetry cannot be explained by income effects or decreased risk aversion (Tversky and Kahneman, 1991).

- People often prefer a small probability of winning a large prize over the expected value of that prospect, and risk-seeking is prevalent when people must choose between a sure loss and a substantial probability of a larger loss (Kahneman and Tversky, 1992).

- Utility theory does not describe how people actually make decisions, but rather how a rational person should make decisions (Dillon, 1979a; Anderson *et al.*, 1985).

Consequently, many alternative models have been proposed in response to this empirical challenge (Kahneman and Tversky, 1979; Machina, 1987; Fishburn, 1988; Camerer, 1989; Kahneman and Tversky, 1992). The descriptive, empirically-based, and most appealing model, called 'prospect theory', proposed by Kahneman and Tversky will be discussed next.

Prospect theory

Kahneman and Tversky (1979) described several classes of choice problems in which preferences systematically violate the axioms of expected utility theory. In the light of these observations, they argued that utility theory, as it is commonly interpreted and applied, is not an adequate descriptive model and they developed an alternative account of choice under risk, called prospect theory. Prospect theory was proposed as a more representative, descriptive model of decision choices in conditions of uncertainty.

Bell *et al.* (1988b) noted that three systematic differences between prospect theory and expected utility theory are demonstrated convincingly. First of all, people think of consequences as increments (or decrements) to current wealth and have aversion to losses. Secondly, they do not distinguish adequately between large numbers. Thirdly, people give unlikely events more weight than they deserve, and give correspondingly less weight to very likely events.

Prospect theory distinguishes two phases in the choice process: an early phase of framing, and a subsequent phase of evaluation. The framing phase consists of a preliminary analysis of the offered prospects, which often yields a simple representation of these prospects. Basically, the function of the framing phase is to organise and reformulate the options so as to simplify subsequent evaluation and choice. Framing consists of the application of several operations that transform the outcomes and probabilities associated with the offered prospects. Following the framing phase, the decision maker is assumed to evaluate each of the edited prospects, and to choose the prospect of highest value (Kahneman and Tversky, 1979). These two phases partly cover the risk management process described previously in Section 2.2, in which the framing phase would embrace establishing context, identifying risk, and analysing risk and the valuation phase would include making the decision and monitoring and communicating risk.

Kahneman and Tversky (1992) reviewed the key elements of prospect theory. They listed these as:

- A value function that is concave for gains, convex for losses, and steeper for losses than for gains;
- A nonlinear transformation of the probability scale, which overweights small probabilities and underweights moderate and high probabilities.

An essential feature of this theory is that the carriers of value are changes in wealth or welfare, rather than final assets. The value function represents gains and losses relative to a neutral reference point. The reference point usually corresponds to the current asset position in which case gains/losses coincide with the actual amounts received or paid out (Kahneman and Tversky, 1979). In other words, people normally perceive outcomes as gains or losses from their current standpoint or reference point, not in terms of their final asset position. In theory, the reference point can be any point along the curve (see Figure 2.5) implying that when a change takes place, a new reference point is established at the new asset position (Marchant, 2003).
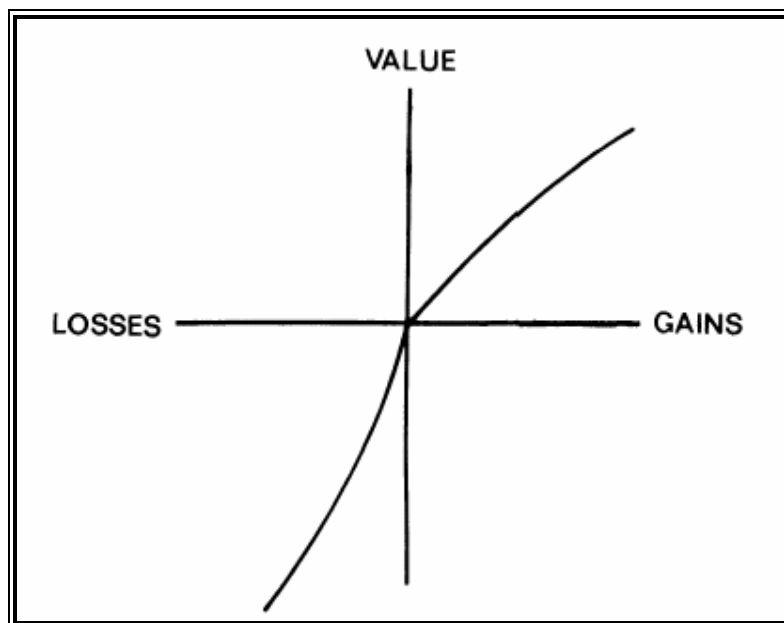
Figure 2.5: A hypothetical value function

Source: Kahneman and Tversky (1979, p.279)

In prospect theory, the reference point from which various prospects are evaluated is critical (Kahneman and Tversky, 1979). A change in reference point alters the preference for prospects, since the impact of a change diminishes with the distance from the reference

point. This is implied by the principle of loss aversion, according to which losses loom larger than corresponding gains (Tversky and Kahneman, 1991).

In prospect theory, the value of each outcome is multiplied by a decision weight which is inferred from choices between prospects (Kahneman and Tversky, 1979). The decision weight associated with an event will depend primarily on the perceived likelihood of that event, which could be subject to major biases (Tversky and Kahneman, 1974). In addition, decision weights may be affected by other considerations, such as ambiguity or vagueness. Kahneman and Tversky noted that the work of Ellsberg (1961) and Fellner (1961) implies that vagueness reduces decision weights. Consequently, sub-certainty should be more pronounced for vague than for clear probabilities (Kahneman and Tversky, 1979).

According to prospect theory, the value function and the weighting function (Figure 2.6) exhibit diminishing sensitivity with distance from the reference point. Thus diminishing sensitivity gives rise to an S-shaped value function that is concave for gains and convex for losses (see Figure 2.5).
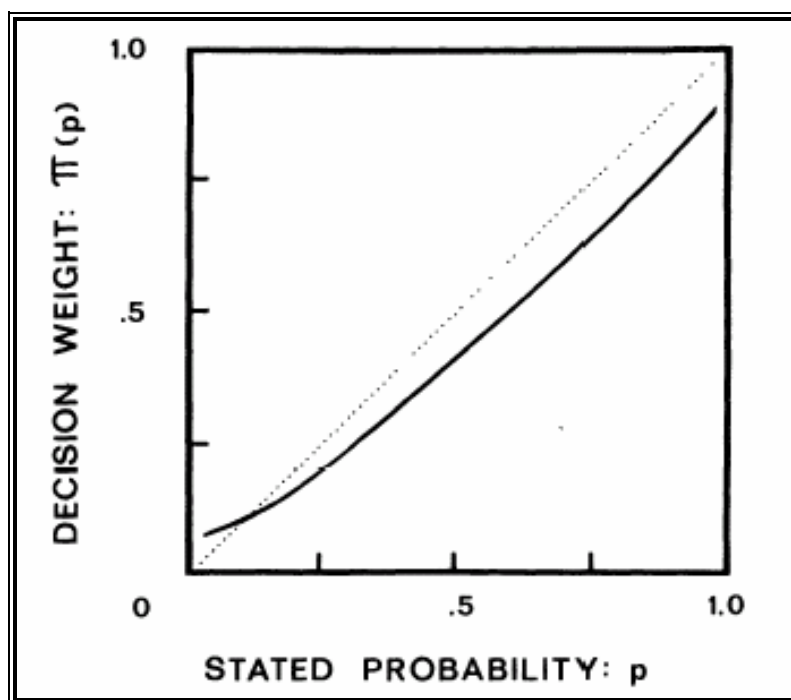
Figure 2.6: A hypothetical weighting function

Source: Kahneman and Tversky (1979, p.283)

However, it can be seen from Figure 2.5 that the S-shape of the value function is not very obvious. Kahneman and Tversky (1979) explained that is because people are limited in

their ability to comprehend and evaluate extreme probabilities, highly unlikely events are either ignored or overweighted, and the difference between high probability and certainty is either neglected or exaggerate. Consequently, the value function is not well-behaved near the end-points.

The end-points of this scale correspond to certainty and impossibility, such that diminishing sensitivity implies that increasing the probability of wining by 0.1 has more impact when increasing that probability from 0.9 to 1.0, or from 0.0 to 0.1, than changing the probability from 0.4 to 0.5. The weighting function is concave near 0 and convex near 1 and this is labelled as the certainty effect (Kahneman and Tversky, 1979).

Kahneman and Tversky (1979) also found that the preference between negative prospects is the mirror of the preference between positive prospects. Thus, the reflection of prospects around 0 reverses the preference order. They called this pattern the reflection effect.

The reflection effect implies that risk aversion in the positive domain is accompanied by risk seeking in the negative domain. In the positive domain, the certainty effect contributes to a risk-averse preference for a sure gain over a larger gain that is merely probable. In the negative domain, the same effect leads to a risk-seeking preference for a loss that is merely probable over a smaller loss that is certain. The same psychological principle – the overweighting of certainty – favours risk aversion in the domain of gains and risk seeking in the domain of losses (Kahneman and Tversky, 1979).

To examine people's attitudes towards risk, it is very important to consider the joint use of the value function and the weighting function, rather than solely the utility function. Kahneman and Tversky (1979, p.285) stated in the discussion section of their paper that:

> "In prospect theory, attitudes towards risk are determined jointly by the value function (v) and the weighting function (π), and not solely by the utility function. It is therefore instructive to examine the conditions under which risk aversion or risk seeking are expected to occur. Consider the choice between the gamble (x, p) and its expected value (px). If $x > 0$, risk seeking is implied whenever $\pi(p) > v(px)/v(x)$, which is greater than p if the value function for gains is concave. Hence, overweighting $(\pi(p) > p)$ is necessary but not sufficient for risk seeking in the domain of gains. Precisely the same condition is necessary but not sufficient for risk aversion when $x < 0$. This analysis restricts risk seeking in the domain of gains

and risk aversion in the domain of losses to small probabilities, where overweighting is expected to hold".

Cumulative prospect theory

In 1992, Kahneman and Tversky developed a new version of prospect theory that employs cumulative rather than separable decision weights and extended the theory in several respects. This version, called cumulative prospect theory, applies to uncertain as well as to risky prospects with any number of outcomes, and it allows different weighting functions for gains and for losses. Two principles, diminishing sensitivity and loss aversion, are invoked to explain the characteristic curvature of the value function and the weighting functions. A review of the experimental evidence and the results of a new experiment that they conducted confirmed a distinctive fourfold pattern of risk attitudes: risk aversion for gains and risk seeking for losses of high probability; risk seeking for gains and risk aversion for losses of low probability (Kahneman and Tversky, 1992).

Comparison of neoclassical and prospect theory

List (2004) reviewed several experimental studies (Knetsch, 1989; Kahneman *et al.*, 1990; Bateman *et al.*, 1997), which have shown that preferences are not independent of current entitlements. Numerous theories have been advanced to explain this behavioural pattern, but the most accepted conjecture invokes psychological effects, and comes broadly under the term 'prospect theory' (Kahneman and Tversky, 1979) – which has been introduced in the previous discussion.

Even though considerable laboratory evidence in favour of prospect theory has accumulated, List (2004) indicated that some economists, *e.g.* Knez *et al.* (1985), Coursey *et al.* (1987), and Shogren *et al.* (1994), believe in the endowment effect (a hypothesis that people value a good or service more once their property right to it has been established). This effect was first described by Thaler (1980) as merely the result of a mistake by inexperienced consumers, and through time these consumers will learn, and their behaviour will match predictions from neoclassical models more closely. More recent field experimental evidence supports the notion that the endowment effect can be attenuated with market experience (List, 2003).

According to List (2004), the endowment effect anomaly is not universal, and consumers who have significant market experience do not exhibit behaviour consistent with prospect

theory. Rather, their behaviour is in line with neoclassical predictions. Moreover, under individual or group choice, neoclassical theory and prospect theory have sharp and disparate predictions about behaviour across the various endowment points (List, 2004).

In his study, List (2004) examined trading patterns for everyday consumables and reported several insights:

- First, prospect theory is found to have strong predictive power for inexperienced consumers;
- Second, for experienced consumers, neoclassical theory predicts reasonably well.

This result is consistent with the notion that agents will have learned to treat goods leaving their endowment as an opportunity cost rather than a loss from their previous market interaction and arbitrage opportunities (List, 2004). Thus, while psychological effects have been extremely popular in explaining the anomaly that has been called the endowment effect, the data from List's study suggest that psychological effects may also help to explain the attenuation of the anomaly.

Reason-based choice

Slovic (1995) postulated that people follow a choice mechanism that is easy to explain and justify. Thus people resolve the conflict of a choice by selecting the alternative that is superior when judged according to the most important criterion, which gives them a powerful reason for their choice, rather than choosing randomly, or for any other casual reason. On making such a decision, the result will depend on the weights that are given to the reasons for and against each option. People will thus focus on the reasons for selecting to choose (or reject) an option on the basis of the positive (or negative) features of the option, depending on whether they are intending to accept (or reject) the option. This situation will prevail especially where it is difficult to assign a value to the options in the choice problem (Slovic, 1995).

Shafir *et al.* (1993) noted that one of the basic tenets of the rational theory of choice is the principle of procedural invariance, that is, strategically equivalent methods of elicitation will yield identical preferences. According to Shafir *et al.* (1993), the choose-reject methodology of reason-based choice is a failure of procedural invariance, and is at odds with the idea of maximizing utility (a formal normative model), but it is readily understood in the context of reason-based choice. Reasons for choosing are more convincing when

participants actively choose than when they reject, but reasons for rejecting are more convincing when participants are actively rejecting than choosing. Thus, when using reason-based choice, the reasons for actively choosing or actively rejecting an option are as important as the outcome (Marchant, 2003).

Heuristics

In the late1960s and early 1970s, a series of papers by Amos Tversky and Daniel Kahneman revolutionized academic research on human judgment. The central idea of the 'heuristics and biases' program – that judgement under uncertainty often rests on a limited number of simplifying heuristics rather than extensive algorithmic processing – soon spread beyond academic psychology, affecting theory and research across a range of disciplines including economics, law, medicine, and political science. The message was revolutionary in that it simultaneously questioned the descriptive adequacy of ideal models of judgment and offered a cognitive alternative that explained human error without invoking motivated irrationality (Gilovich and Griffin, 2002).

In understanding everyday judgment, Tversky and Kahneman (1974) suggested that people use a number of 'rules of thumb' or simplifying tactics in making decisions. These simplifying tactics, called heuristics, are standard rules that inherently direct decision maker's judgment and help decision makers contend with the complexities surrounding their decision-making processes (Bazerman, 1998).

People do not normally analyse daily events into exhaustive lists of possibilities or evaluate compound probabilities by aggregating elementary ones. Instead, they commonly use a limited number of heuristics. Tversky and Kahneman (1974; 1982) identified three heuristics that are employed in making judgments under uncertainty:

- Representativeness, which is usually employed when people are asked to judge the probability that an object or event A belongs to class or process B;
- Availability of instances or scenarios, which is often employed when people are asked to assess the frequency of a class or the plausibility of a particular development; and
- Adjustment from an anchor, which is usually employed in numerical prediction when a relevant value is available.

One characteristic of the use of heuristics is the neglect of potentially relevant problem information. The use of heuristics also leads to systematically biased outcomes when a heuristic is wrongly applied by a decision maker in the process of making a decision (Bazerman, 1998). Moreover, while heuristics are useful for a large part of the time, they are not satisfactory all of the time since people use heuristics without being aware of them, and use them in unsuitable situations. When 'rules of thumb' break down, failed heuristics lead to systematic biases (Plous, 1993). Kahneman and Frederick (2002) added that because the target attributes and the heuristic attributes are different, the substitution of one for the other inevitably introduces systematic biases.

Biases

Gilovich and Griffin (2002) stated that each heuristic is associated with a set of biases: departures from the normative rational theory that serve as markers or signatures of the underlying heuristics. Bazerman (1998) listed 13 cognitive biases, which comprise those arising from the availability heuristic, the representativeness heuristic, and the biases arising from anchoring and adjustment. Cognitive biases are pervasive, systematic distortions of decision-makers' perceptions of reality that influence much of their everyday thinking. They often arise as a result of applying heuristics.

Marchant (2003) noticed that in trying to manage these biases, each individual needs to be aware of their own perceptions of risk and preference points, be cognisant of the way that the information and data are presented, and consider whether they are likely to act as a risk seeker or risk avoider in the situation being analysed. He recognised that up-side and down-side risk needs to be managed equally well as extremes in either direction can lead to adverse outcomes (Marchant, 2003). Bazerman (1998) implied that the key to improved judgment when using heuristics lies in learning to distinguish between appropriate and inappropriate use of them. Plous (1993), on the other hand, suggested that many of the most effective techniques for eliminating biases involve the consideration of alternative perspectives.

2.3.4   Section conclusion

This section presented some alternative methods of decision making and described the theoretical basis for several decision making methods including normative approaches (utility theory) and descriptive techniques (prospect theory). The neoclassical theory was

compared with prospect theory and reason-based choice theory, while the use of heuristics and consideration of biases were introduced. Utility theory was challenged as an appropriate method of making choices under uncertain conditions and prospect theory and reason-based choice were regarded as more acceptable ways to explain decisions made under uncertainty. However, it was recognised that presence of cognitive biases can lead to the incorrect use of heuristics in making decisions. The more recent theories of decision making attempt to relate the individual's personality to the decisions they make by recognising the nature of their judgements, their perceptions of risk, and how they frame risks in their minds.

When focused on the topic of this research, the review of literature in this section leads to the following research issue:

- ***How do southwest Queensland dryland farmers make decisions regarding risk management? Do they use 'rules of thumb' or other normative/descriptive approaches?***

2.4   Chapter summary

The aim of this chapter has been to document the various aspects of risk management, decision making, and decision theory. The research issues arising from this chapter are captured in two questions:

- ***How can the tools of risk assessment and the recorded knowledge about perceptions of risk be linked to develop appropriate risk management strategies that are likely to be implemented successfully by southwest Queensland dryland farmers?***
- ***How do southwest Queensland dryland farmers make decision regarding risk management? Do they use 'rules of thumb' or other normative/descriptive approaches?***

These research issues will be explored further and restated as formal research questions in Section 4.7 of this thesis. The following chapter will present a review of the literature addressing risk management in agriculture.

Chapter 3: Risk management in agriculture

3.1   Introduction

In the previous chapter, the more general aspects of risk management reported in the literature were reviewed. The extensive literature specifically addressing the issues of risk management in agriculture is reviewed in this chapter. The purpose of this review is to gain an insight into what has been done in relation to risk management in agriculture.

Agriculture involves a relatively higher level of risk and uncertainty than some other activities (*e.g.* manufacturing). This occurs because variable natural factors, such as weather conditions, have an influence on the level of output. Another reason is the length of the production cycle itself, *i.e.* a relatively long time period elapses between production decisions and the harvesting/marketing of the product (Mishra, 1996). Beal (1996) shared the same opinion, noting that farming is a high risk business because of the inherent variability of the natural environment in which it is conducted and the markets in which its products are sold. Adding to this point, Cummins and Santomero (1999) stated that agricultural prices are volatile as a result of variations in many production factors such as climate, demand, yields, and pest and disease incidence.

For several decades, agricultural economists have been concerned about gaining an understanding of farmers' decision-making behaviour when confronted with risk, and they have been interested in developing tools to address farmers' decision-making in the presence of risk (Coble and Barnett, 1999). The next section, therefore, examines the literature on farmers' attitudes towards risks. This is followed by a review of sources of risk faced by farmers (Section 3.3). Section 3.4 investigates the risk management tools available for farmers to use, while section 3.5 reports some risk management strategies actually used by farmers in different countries around the world.

3.2   Farmers' attitudes towards risks

3.2.1   Review of farmers' attitudes towards risks

Farmers operate in a multi-attribute environment in which many forces, choices, preferences, and events influence their behaviour and performance. Gaynor (1998) claimed

that the farmers' 'factory floor' is subject to all the variables of manufacturing – for example, performance of equipment and personnel, quality of inputs, supply of inputs, prices of inputs and products – as well as the variables of weather, pests, soils, diseases and genetics. Likewise, Pannell *et al.* (2000) noted that farmers face uncertainty about the economic consequences of their actions due to their limited ability to predict things such as weather, prices, and biological responses to different farming practices.

It is generally assumed that farmers are risk-averse, *i.e.* they are willing to pay a premium to reduce exposure to risk (Meuwissen *et al.*, 2001b). If farmers can trade away part of the risk associated with their farming practices at an acceptable cost, then their expected utility will increase (Arrow, 1996; Harrington and Niehaus, 1999).

According to many surveys and reports of current practices (McLeay *et al.*, 1996; Meuwissen, 2001b; Hall *et al.*, 2003), most farmers are risk-averse (concerned about risk) with respect to their income. They prefer a smaller gain which is certain to a larger gain which is uncertain. Many farmers diversify their production, preferring the lower, more stable income from a diversified set of enterprises to the higher, more variable income generally associated with specialization in a single enterprise.

A large body of empirical studies (Dillon and Scandizzo, 1978; Young, 1979; Binswanger, 1980; Bond and Wonder, 1980; Brennan, 1981) also shows that farmers behave in a risk-averse manner, and they seek to avoid risk through various risk management and risk sharing institutional mechanisms (Anderson and Hazell, 1997).

However, it is largely up to each individual farmer to decide which risks and which part of these risks to share. Factors that can influence this decision include the farmer's attitude to risk, the costs involved in risk sharing, the relative size of the potential loss and probability of it occurring, the correlation of the risk with other risks, other sources of indemnity, the farmer's perception of the nature of risk, and the farmer's financial state (Barry *et al.*, 1995; Hardaker *et al.*, 1997; Harrington and Niehaus, 1999).

Standard economic models of the farm firm demonstrate how risk influences farm decision making and it is an important factor affecting investment decisions and firm survival (Barry and Fraser, 1976; Gabriel and Baker, 1980; Sonka and Patrick, 1984; Boggess *et al.*, 1985; Johnson, 1992). If net operating income of a farm firm consistently fails to

exceed prior commitments, the survival of the business is threatened unless the farmer has a substantial reserve of wealth or another source of income. The objective of risk management is to reduce the chances of a vulnerable situation occurring, while, at the same time, maximising returns to owner's equity consistent with his/her attitudes to risk (Martin, 1996). In assessing the strategies available, the owner/manager must explicitly or implicitly rank the probabilities of adverse events occurring (as well as estimate the extent of the potential loss). Considerable research has taken place into methods for achieving such rankings with results that emphasise how risk perception varies from individual to individual, farm type to farm type, and region to region (Patrick *et al.*, 1985; Ralston and Beal, 1994; Scott, 1994; Martin, 1996).

A substantial body of literature has also accumulated from investigations that show the difficulty that individuals have in assessing risk, and how it is possible to elicit best estimate of expected subjective distributions of risky events from them (Hardaker *et al.*, 1997; Huirne *et al.*, 1997a). Eales *et al.* (1990) found that farmers were fairly accurate in forecasting price levels, but made significantly smaller estimates of price volatility when compared to the volatility implied by futures price movements. Poitras (1993) found evidence that farmers' subjective yield distributions deviated significantly from estimates derived from historical data. Findings such as these suggest that there is opportunity to teach farmers how to evaluate better the risks that they confront. Pingali and Carlson (1995) indicated that this kind of training can have a measurable impact on decision making.

There is a limited amount of research on Australian farmers' perceptions of risk and this deficit needs to be addressed to avoid relying too heavily on European and American studies to understand Australian experiences and context (Botterill and Mazur, 2004). A review of largely USA derived literature reveals that farmers are predominantly risk-neutral to slightly risk-averse (Eidman, 1994).

In Australia, the work that has been done on the risk attitudes of farmers (Bond and Wonder, 1980) has revealed findings that are consistent with other studies, although such studies have been limited and by no means conclusive. Bardsley and Harris (1987) used an econometric model to estimate risk aversion coefficients by using actual behaviour of farmers in the real economic environment. They found that Australian farmers were risk averse, and their partial coefficient of risk aversion decreased with wealth and increased

with income. It might be concluded from Ralston and Beal's study (1994) that a moderate degree of risk aversion is the dominant attitude towards risk in the rural sector but it could be dangerous to make generalisations on the basis of limited data. Pluske and Fraser (1995) used the contingent valuation method to estimate farmers' attitudes towards risk. Their results showed that the farmers' risk aversion coefficients were comparable to those estimated in the Australian literature. Abadi and Pannell's study (2003) revealed that elicited risk preferences of farmers in Western Australia were consistent with previous results for Australian farmers, in that most were found to be risk averse but the observed range of risk attitudes was wide. Using a relatively small sample of current and former dairy farmers in southeast Queensland, Marchant (2003) found the full range of risk attitudes from risk-averse (consistently for farmers who had left the dairy industry after deregulation) to risk-preferring (for those who were continuing in the industry and who saw a future for themselves in the industry).

Researchers have also been concerned with understanding the behaviour of farmers confronted with risk and in developing modelling tools to help farmers make decisions in situations where there is risk (Coble and Barnett, 1999). However, the behaviour of farmers does not always conform to theory and there is a need to understand their attitude towards risk and the way they adjust their farm operations because of it. A number of surveys have addressed this question, particularly in Australia (Ralston and Beal, 1994), in Canada (AAFC, 1998), New Zealand (Martin and McLeay, 1998), The Netherlands (Huirne *et al.*, 1997b), Germany (Noell and Odening, 1997), and the United States of America (USDA, 1996; Jose and Valluru, 1997; Harwood *et al.*, 1999).

3.2.2 Section conclusion

Because farmers vary in their attitudes toward risk, risk management cannot be viewed through a 'one size fits all' approach. Different farmers confront different situations in different ways, and their preferences toward risk and their risk-return trade-offs have a major effect on decision-making in each given situation.

The research issue arising from this section is:
- ***How do southwest Queensland dryland farmers perceive farming risks?***

3.3 Sources of risk faced by farmers

3.3.1 Introduction

Like the colours in the spectrum, the range of business risks contains many shades and variations, but these can be reduced to a few primary types of risk, like primary colours (Goucher, 1996). According to Goucher (1996), the primary risk types include production risks, market risks, and financial risks.

Other authors have described the various types of risk more precisely. The classification used by Hardaker *et al.* (1997), who differentiated between business risks and financial risks, can be used for most agricultural situations. Business risks include production risks, which are related to the unpredictable nature of the weather and to the uncertain performance of crops and livestock, and price risk, which refers to uncertainty of prices for farm inputs and outputs. In addition, business risks include personal risks, like illness or death of people who operate the farm, and institutional risks that originate from uncertainty about the impact of government policies on farm profits. Financial risks refer to the risks related to the way a farm is financed.

Generally speaking, scholars categorise sources of risk differently. It may even depend on the study objectives. For example, general sources include business risk (which incorporates production risk and market risk) and financial risk as classified by Gabriel and Baker (1980). Sonka and Patrick (1984) identified three additional categories of business risk, these being technological, legal/social, and human. More recently, Anderson (1994) argued that any categorisation of risk should include social, health, and policy risks as well as the traditional yield and price risks which are so familiar to agricultural economists. According to a range of scholars, the main sources of risk in farming include production or yield risk, financial risk, price or market risk, institutional risk, and human resource or personal risk (Boehlje and Trede, 1977; Fleisher, 1990; Baquet *et al.*, 1997; Hardaker *et al.*, 1997; Kay and Edwards, 1999; Burgaz, 2000). The following sub-sections are devoted to further discussion of these categories of risk.

3.3.2 Production risks

Production as a source of risk concerns variation in output arising from weather, pests and diseases, input quality and availability, the inherent variability of biological systems, and

technological change. It is the very essence of agricultural risk (Musser, 1998). Similarly, Goucher (1996) perceived production risk as the possibility that the level of physical output that is planned will not be achieved.

Production risk occurs because agriculture is affected by many uncontrollable events that are often related to weather, including excessive or insufficient rainfall, extreme temperatures, hail, insect pests, and diseases. Technology also plays a key role in production risk in farming (Harwood *et al.*, 1999). Fischhoff (2000) stressed that whether it be ozone depletion and consequent skin cancer from the use of aerosol spray cans, birth defects induced by tranquilizing drugs, or radiation damage from nuclear energy, every technological advance carries some risk of adverse side effects. In fact, farming has been so successful because it has adopted new technologies, *e.g.* pesticides and herbicides, but this has not been achieved without a significant increase in adverse consequences.

Gaynor (1998) emphasised that the most important risk management function on the farm is the control of production variability. If farmers cannot manage variability in production, they will not be able to use good price risk management techniques, as they will not have enough produce to sell. Unfortunately, production risks are likely to increase further in the future because of various issues such as rising quality requirements, stricter rules about the use of farm inputs, growing movement of people, and the effects of climate change. Scientists have warned in recent years that the earth's climate is changing, and are now sure that global changes (*e.g.* the enhanced greenhouse effect and consequent global warming) (Peters *et al.*, 2006) will increase the risk burden on agriculture.

3.3.3 Financial risks

Financial risk results from the way the firm's capital is raised and financed (Harwood *et al.*, 1999). It is reflected in the variability of the net cash flows to the owners of equity. It essentially represents the risk of being unable to meet prior claims on the business with cash generated by the farm. Debt servicing commitments usually account for a large component of these prior claims (Martin, 1996).

Farmers often do not have enough capital to invest in their businesses. The main source of credit for commercial farmers is still the banking system and risk is caused by fluctuating interest rates. These fluctuations in interest rates can make profits and viability volatile.

Moreover, the period of the loan and loan repayment deadlines are not always compatible with the farming cycle.

Financial risk has three overall dimensions: interest rate changes, liquidity, and solvency. The first is, in part, an independent source of risk arising from capital markets and institutional decisions. The other two effects arise from the interaction of farm management with other sources of risk (Musser, 1998).

Ralston and Beal (1994) claimed that while there was abundant literature dealing with research related to financial aspects of corporate and small business entities, little attention has been given to investigating farm finance and financial risk in farming, even though this sector is still important in most developed and developing economies. Special institutions (agricultural banks) were set up in most countries to provide credit to farmers which insulated them from both credit supply and risk management issues to some extent but these banks have now mostly been absorbed into the regular banking system and farmers have to compete with other businesses for credit and pay market rates of interest.

3.3.4 Market risks

Price or market risk reflects the risks associated with changes in the price of outputs or of inputs that may occur after the commitment to production has been made (Harwood *et al.*, 1999). In other words, market risk covers the possibility that the price which a product ultimately realises will differ from that which was planned. Gaynor (1998) noted that the risks faced in the agricultural produce market include changes in world price, changes in interest rates, price penalties for low quality produce, problems in shipping produce, and delayed or non-payment for goods. However, in the case of Australian producers, one of the biggest risks flows from exchange rate fluctuations.

Prices for agricultural commodities at the national or world level tend to be high when output is low, and vice versa, because total demand for food and other agricultural products changes only moderately from year to year, while supply can fluctuate considerably due to weather and other factors in major producing countries. Theoretically, prices are governed by the laws of supply and demand but there has been considerable institutional intervention in the agricultural market in many countries that has led to exaggerated fluctuations in world prices for many agricultural commodities. If prices for a particular commodity are

high, farmers produce more and prices eventually fall due to over-supply of the commodity. In practice, other things such as government subsidies, droughts, floods, exchange rates, and the level of economic growth among trading partners affect supply, demand, and prices (Fletcher, 1999). Increasingly, farmers in most countries of the world are being exposed to less predictable, competitive markets for inputs and outputs, so that price or market risk is often significant and may increase over time.

Liberalisation of international and, in some cases, even intra-regional trade has brought many farmers, and those working on policies concerned with their welfare, to realise they need to consider the implications of broader changes occurring in the world on commodity price risk. In some cases, there is scope to produce previously unfamiliar commodities, or to market commodities produced previously in new ways to new customers (Anderson, 1997).

Processors of raw commodities, such as grain, face a variety of price risks, one of the most significant of these being rising input costs (since a processor's profit margin is determined by the final price received less input costs). Australian agriculture faces high levels of risk of this nature because of its openness to international market conditions and prices, which themselves are made more variable as a result of the attempts by a number of other major producers to insulate domestic markets from global forces (AFFA, 2000).

3.3.5 Institutional risks

These risks relate to institutional changes such as changes in government intervention in agriculture, changes in food safety requirements, increasing environmental regulations, and macro-economic settings such as interest and exchange rate policies. Musser (1998) claimed that farmers are subject to an ever-increasing array of regulations from all levels of government.

Generally, farmers are also affected by policies that are not specific to the agricultural sector. Monetary and fiscal policies are the most obvious examples but other policies regulate the use or quantity of basic and intermediate goods used in agricultural production. In fact, almost all inputs used in agriculture are subject to some type of policy intervention (Fleisher, 1990). These policies include controlling emission levels, setting occupational health and safety regulations, controlling toxic wastes, regulating land use,

zoning, establishing water rights and area limitations, determining patent rights, regulating genetic engineering, controlling water quality, etc. Policy risk has adverse implications for agricultural decision makers both before and immediately after policy changes.

3.3.6 Human resource risks

Human resource risk may be associated with the labour and management functions of farming and can include the vulnerability of the farm to the health and continuing ability of the sole farm operator and the availability and reliability of labour (Anderson, 1994). Disruptive changes may result from such events as death, divorce, injury, or the poor health of the principal operator of the farm (Harwood *et al.*, 1999).

In economic terms, there are three essential inputs of farm production: labour, capital, and land. However, employees must be treated as human beings and part of the human capital associated with the farm, rather than just a physical farm input.

Risk of injury to key employees, or to the owner of an owner-operated farm, is one of the most important risks for farmers to manage. An injured farmer or manager who cannot make managerial decisions, or carry out farm operations, is likely to suffer the increased cost of employing somebody else, and even significant loss of revenue through lower production (Gaynor, 1998).

As farms become larger, technology more complex, and other risks increase, human resource risks become much more of an issue for farm businesses. In as much as farmers are more likely to have experience dealing with production problems, they are often less prepared to deal with these risks. While these risks are not directly increased by changes in production and price risk, consideration of human resource risk is part of comprehensive risk management for farms (Musser, 1998).

Another human resource issue is the flow of people from rural to urban areas. The continuing economic pressure on farming is making this situation worse than it once was. It is a problem facing an increasing number of rural communities worldwide, such that skilled rural labour is becoming less and less available for rural businesses.

3.3.7 Sources of risk as perceived by farmers

This sub-section has a heading that sounds similar to that of the previous section (3.2). However, it does not repeat what has been discussed there. Rather, it reviews farmers' perceptions of different sources of risk identified throughout this section (3.3).

Farmers often have to make both significant and less important decisions under conditions of imperfect knowledge and deal with important factors influencing farm profitability that are beyond their control. Indeed, risk exposure varies substantially from farmer to farmer. Whether a strategy to cope with risk is adopted, and what elements it includes does however depend on how those risks are perceived subjectively by the individual farmer. Risk perception of course can vary from farmer to farmer, depending for instance on the farmer's own experience and on the degree of his/her risk-aversion.

Of the five categories of risk that have been identified, price risks were perceived as the most important source by a group of farmers in The Netherlands (Meuwissen *et al.*, 2001b). Financial risks were the least important source of risk. Neither the categories of 'institutional risks' or 'financial risks' was perceived as really important in the survey of this group (Meuwissen *et al.*, 2001b).

Patrick and Musser (1997) collected data from participants in the 1991 and 1993 Top Farmer Crop Workshops held at Purdue University. They found that crop price and yield variability were the top rated sources of risk in 1991 but were in second and third place in 1993. Concern about injury, illness, or death of the operator, was the highest rated source of risk in 1993, significantly higher than in 1991.The importance of changes in government environmental regulations, land rents, and technology also increased significantly between 1991 and 1993. These authors concluded that farmers' focus on 'family' risks as an important source of risk, although agricultural economists typically do not consider it (Patrick and Musser, 1997). Perhaps the reason is that 'family risks' probably includes a whole mix of risks associated with continuation of the farm as a family business.

Harwood *et al.* (1999) found that risk perceptions differed among farmers depending on the production program. Wheat, corn, and soybean farmers, for example, were most concerned about yield and price risks, whereas livestock farmers perceived institutional risks as particularly high.

Knutson *et al.* (1998) reported risk perceptions from a series of focus group discussions held in Texas and Kansas with farmers, agricultural lenders, and agribusiness representatives. The participants listed price variability, yield uncertainty, and input cost changes as the three most important sources of risk which they faced. Agricultural economists have conducted extensive research in each of these areas. Following closely behind the first three sources of risk were changes in environmental regulations and unforeseen litigation (Ker and Coble, 1998).

In a recent analysis of USA beef producers' perceptions of risk, Hall *et al.* (2003) found that drought and cattle price variability were identified as the two greatest concerns. The next cluster of sources of risk included extremely cold weather and disease. Finally, the less important ones were land price variability, variation in rented pasture availability, and labour availability.

In New Zealand, a nationwide survey of risk management strategies used by farmers revealed that market risks were ranked as very important by all farmers (Martin, 1996). Farmers' assessments of production risks were not quite so uniform, while changes in interest rates were viewed as a moderate source of risk across all farm types. The human risk associated with accidents or health problems was also a moderately important risk for all farm types.

3.3.8 Section conclusion

Risk in farm management is an area that is receiving more attention than it did previously. As farms become larger, more capital, labour, and management inputs are used and this can create more risks related to financial and human resources. Increasing regulations are creating more legal and environmental responsibilities leading to greater institutional risk and adding different dimensions to other previously existing sources of risk. Increasing involvement by farmers in international trade in agricultural products and the forces of globalisation have also created more price risk for farmers worldwide.

All these sources of risk combine to make farming a rather precarious business, and so constant effort is required to minimise the exposure to risk on the farm. Farmers will necessarily spend some time during the year considering risk in a formal and structured manner, but a lot of the risk management on farms occurs 'on the run' and almost at a sub-

conscious level. This is why farmers must have a considered attitude to risk that becomes second nature.

Nevertheless, the sources of farming risk listed in this review and the ones that have been addressed in the literature may be different to what happens in the field. This leads to the research issue:

- ***In practice, what are the sources of farming risk that dryland farmers in southwest Queensland have to deal with? How do they perceive and rank these risks?***

3.4   Risk management tools available for use by farmers

3.4.1   General review of risk management tools

Coble and Barnett (1999) have stated that farmers are currently operating in an environment where new risk management tools or strategies are being developed quite rapidly. The large number of potential activities that can be used to manage risk have been classified into production, marketing, and financial risk management strategies or activities (Barry and Fraser, 1976; Sonka and Patrick, 1984; Patrick and Ullerich, 1996). In the opinion of Hardaker *et al.* (1997), the most important risk management strategy is based on maintaining flexibility. Strategies that can be adopted by farmers to enhance flexibility include asset, product, market, cost, and time flexibility.

According to Meuwissen *et al.* (1999), two types of risk management strategy are normally distinguished: (1) strategies concerning on-farm measures; and (2) risk-sharing with others. On-farm strategies concern farm management and include selecting products with low risk exposure, choosing products with short production cycles, diversifying production programs, and holding sufficient liquidity. Risk-sharing strategies include marketing contracts, production contracts, vertical integration, hedging on futures markets, participation in mutual funds, and insurance.

The ECDAG (2001) added two more types of strategy to the above-mentioned list. They included diversification through increasing the share of income from sources outside agriculture and relying on public assistance (*e.g.* disaster aid).

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Strategies used to manage risk can have two broad effects. There are those strategies which can be used to control risk exposure, and those which aim to control the impact of risk on the farm business (Jolly, 1983). Martin (1996) indicated that exposure to business risk can be controlled by manipulating the probability distributions for important variables such as yields, prices, and input costs facing the farm business so that variability is reduced. This can be done by either smoothing out yields and prices or by cutting off the lower tails of these distributions. Examples of risk responses which smooth out yields and prices include efficient pest and disease control, irrigation, and conservation farming as well as enterprise selection, enterprise diversification, and marketing strategies which smooth out price fluctuations.

In practice, farmers have many options among which to choose to manage risk. They can adjust the enterprise mix (diversification) or the financial structure of the farm (the mix of debt and equity capital). Furthermore, farmers have access to many tools, such as insurance and hedging, which can help reduce their farm-level risks. Off-farm earnings are a major source of income for many farmers that can help stabilise farm household income. Harwood *et al.* (1999) recommended many tools or strategies that farmers can use to manage risk. In addition to those already mentioned, they included maintaining financial reserves and leveraging.

Overall, it can be concluded from this review that there are four major strategies that farmers can use to manage risks including controlling fluctuations in income, diversification, risk-sharing, and price risk management.

3.4.2 Avoiding fluctuations in income

Strategies used by farm households to manage fluctuations in income are diverse. They depend on the type and level of risk faced as well as on the range of solutions available and the willingness of governments to become involved. Strategies entail acknowledging risk and its consequences in the first place, and then managing the losses incurred or adopting techniques to reduce risk by spreading it across activities (diversification) or transferring it to other agents. Risk management strategies can combine market-based approaches and government intervention, although in countries like Australia, this is a strategy less favoured by government than it once was. These risk management strategies include a whole range of tools and instruments, such as those mentioned in OECD (2000): financial

management (*e.g.* keeping a low debt/asset ratio); production techniques (*e.g.* choosing outputs and inputs that are subject to less variability in supply and price); marketing techniques (*e.g.* spreading sales and using futures markets); insurance systems; and social, fiscal, and agricultural safety nets.

3.4.3 Diversification

The phrase 'Don't put all your eggs in one basket' is commonly used in business. It certainly applies in agriculture. This is the principle of diversification and it is one of the most commonly used risk management strategies. Producers can diversify by engaging in many different activities in one time period, engaging in the same activity in many different physical environments or locations, or engaging in the same activity over successive periods of time.

The idea behind diversification is that returns from various enterprises or activities are not perfectly positively correlated. In fact, for diversification to be of benefit from a risk perspective, all that is required is a lack of perfect positive correlation. Of course, the benefits are larger if there is a negative correlation. A favourable result in one enterprise may help to cope with a loss in another enterprise. Diversification thus reduces overall risk.

Diversification of activities is a successful risk management strategy because not all activities, such as two crops or two investments, react in the same way to events that occur in any one time period. For example, a grain grower may produce wheat, barley, oats, peas, and vetch (or different cultivars within these crop types), which helps spread risk. Not all grains are affected equally by weather and the markets for them react relatively independently. This means that while the price for one commodity is low, prices for others may be relatively high, so helping maintain a reasonable level of farm income.

3.4.4 Risk-sharing tools

Risk-sharing tools differ in the type of risk shared (*e.g.* price versus production risk), the party with whom the risk is shared (*e.g.* a colleague farmer, a contractor, or a product buyer) and whether the risk is shared directly (*e.g.* production versus insurance contract). According to Meuwissen *et al.* (2001b), major forms of risk-sharing contracts include:

- Share tenancies (also called share cropping or share leasing) is a land lease under which the rent paid by the tenant is a contracted percentage of the value of output per unit of time.

- Production contracts typically give the contractor considerable control over the production process. Contractors enter production contracts to ensure timeliness and quality of commodity deliveries.

- Marketing contracts are agreements between a buyer and a producer that set a price or arrange an outlet for a commodity before harvest or before the commodity is ready to be marketed.

- Insurance where the insured typically pays a premium to the insurer and receives an indemnity from the insurer once an insured loss occurs.

- Financial leverage is defined as the use of debt capital and other fixed-obligation financing relative to the use of equity capital. Lenders pool the risk of loan defaults over many clients.

- External equity financing can be used when equity investors receive a share of the returns from the firms in which they have invested. Investors pool the risk of the firm making low or negative returns over a diversified portfolio.

3.4.5 Price risk management

Hardaker *et al.* (1997) observed that farmers often have the opportunity to reduce the risks associated with prices for commodities not yet produced, or for inputs needed in the future, by various marketing arrangements. The most important alternatives, from a risk management perspective, include cooperative marketing with price pooling, forward contracts for commodity sales or for input requirements, and hedging on futures markets.

The most basic means of price protection is forward selling of produce in the cash market. This can provide a fixed price for the produce in advance of production occurring, and may also reduce some of the risks associated with shipping and payment, if the contract is made with known or reputable buyers or agents. More sophisticated price risk management is achieved through hedging in the agricultural and currency futures markets and also by trading options on those futures markets. This type of risk management is well established in the Australian cotton industry, and is currently being adopted by other agricultural producers particularly in the grains industries (Gaynor, 1998).

3.4.6 Section conclusion

Obviously, managing risk in agriculture does not necessarily involve avoiding risk. It involves finding the best available combination of risk and return given a person's capacity to cope with a wide range of outcomes. Indeed, most farmers combine many of the different strategies and tools available to them. In other words, they rely on a mix of strategies to manage risk.

In summary, management of risk is an important activity for farmers worldwide. Many strategies for managing risk are conceptually possible, including a number of production, marketing, and financial strategies. The management task facing farmers is to choose a combination of risk management strategies that best suits the unique conditions of their particular farm and their personal circumstances.

The review of this section leads to the question being raised:

- ***What are the risk management tools/strategies that can be used by dryland farmers in southwest Queensland?***

3.5   Risk management strategies used by farmers

3.5.1   Introduction

The previous section (3.4) has focused on addressing the wide range of strategies that farmers can use to manage their farm-level risks. This section, in contrast, addresses the questions: 'How have farmers used these tools and strategies in their farming operations?' and 'What factors are associated with farmers' use of different strategies?'

Risk is a normal part of the agricultural environment and farmers should adopt risk management strategies to decrease the potential impact of risk on their businesses. As mentioned previously, risk management strategies adopted by farm managers/owners will be in accordance with their personal preferences for risk. Research suggests that the majority of farmers are risk-averse, and they manage their resources accordingly.

Obviously, in a situation involving considerable uncertainty such as primary production, the estimation of probable outcomes is particularly difficult. Farmers do, however, have a great deal of information accumulated through experience and technical knowledge in

addition to information provided from external sources such as weather forecasts, modelling studies, and extension officers. Eidman (1994) acknowledged that farmers' ability to assess expected yields has often been found to be surprisingly accurate.

Worldwide, several surveys of farmers' use of risk management strategies have been conducted over the past two decades. Most research has been conducted in the USA, although studies have also been carried out in other countries such as Australia, The Netherlands, Canada, and New Zealand. The following sub-sections will briefly review some of these studies.

3.5.2   Australia

In 1994, Ralston and Beal (1994) conducted a survey of 770 farmers in southern Queensland to investigate the relationship between financial performance in agricultural enterprises and the ability of primary producers to manage risk. Results of this study revealed that the majority of respondents favoured storage of produce as a way to manage the risk associated with fluctuating prices since storage was used to at least some extent by 90 percent of broadacre crop farmers, 84 percent of mixed farmers, 67 percent of fruit and vegetable growers, and 44 percent of live stock producers. In addition, marketing through pools was highly favoured by broadacre crop farmers (75 percent) and mixed farmers (76 percent), while forward selling was practised by crop farmers (83 percent), mixed farmers (50 percent), and fruit and vegetable growers (45 percent).

Brorsen's study (Brorsen, 1995) into price risk management found that more highly geared producers (*i.e.* those with high levels of borrowings) were more likely to use futures as a hedging strategy due to their greater exposure to loan repayment schedules. Brorsen's finding supports Simmons' (2002) observation that a higher proportion of Australian cotton producers than wheat and wool producers were likely to use futures contracts in their price risk management strategies.

In his study into price risk management for Australian broadacre farmers, Kingwell (2000) proposed that because many Australian agricultural commodity producers do not generate large cash incomes and are in a reasonably sound equity position, many see little merit in expenditure on price risk management. He went on to suggest that farms with large cash

incomes and/or large cash expenditures are more likely to see merit in investing in price risk management.

In their study, Wynter and Cooper (2004) analysed the variety of markets and the price risk management products available to South Australian wheat farmers over the past decade. They found that some farmers used a number of strategies (*e.g.* cash sales, pools, forward contracts, futures and options) each year to reduce the risk of price fluctuations. However, they concluded that the majority of wheat growers still relied instead on pool managers to price their grain.

The conclusion from Wynter and Cooper's study was consistent with results from another study conducted in the Eyre Peninsula of South Australia (Nguyen, 2002). This study found that 'leaving it to experts' was the strategy most commonly used by farmers in that region to manage marketing risk. Farmers in that study shared a common perception that it was better for them to focus on things that they were good at (for example, improving yields) rather than staying in the office and studying futures and options contracts (jobs that should be left to farm consultants). They also preferred keeping stock for high-priced times. Practically, farmers in this region had implemented many strategies to manage the risks they faced. Diversifying varieties and practicing zero or minimum tillage were commonly used strategies to manage production risks. Moreover, they often planted minimal areas of risky crops (*e.g.* peas, canola, and vetch) and maximised the area of less risky crop (*e.g.* wheat) to avoid the consequences. Having high equity and off-farm investments were the most frequently used strategies to manage financial risks.

Ritchie *et al.* (2004) examined the use of seasonal climate forecasting when calculating planting areas for irrigated cotton in the northern Murray Darling Basin of Australia. Results of their study showed that minimising risk by adjusting planted areas in response to the seasonal climate forecast can lead to significant gains in gross margin returns. However, how farmers respond to seasonal climate forecasts was dependent on several other factors including their attitude towards risk.

Recently, Adam *et al.* (2006) conducted a survey with a sample of 500 cotton producers in Australia, that revealed that price risk management was an important part of farm business management, but adoption of price risk management practices was influenced by a range of demographic, agronomic, and biophysical factors, as well as the individual make-up of

the farmer. Over 97 percent of the cotton producers surveyed had actively managed price risk at some time. Price risk management was reported to have had a positive effect on the farm business of nearly 60 percent of these cotton producers. This survey also found that the decision to adopt price risk management strategies was influenced significantly by production risk. In addition, the uptake and effectiveness of price risk management was limited by poor understanding and a lack of confidence by many producers.

3.5.3   USA

Several surveys provided information on the history of the use of forward contracting and futures hedging, and suggested that the use of these strategies may have increased over time. For example, in a 1986 Wisconsin study (Campbell and Shiha, 1987), about 20 percent of the respondents had used cash forward contracts at least once in the most recent five years, and eight percent had used futures contracts within that period. The survey also indicated that large-scale farmers were more frequent users of both forward contracting and futures than were small-scale farmers. In another study (Mintert, 1987), only seven percent of Kansas grain farmers reported hedging in 1983, and 18 percent had used forward contracts at any time in prior years.

Empirical studies have at times extended survey data and examined the relationship between the use of various strategies and farmers' characteristics. For example, a study of 41 selected farmers in Indiana in 1985 (Shapiro and Brorsen, 1988), found that the use of hedging was positively related to the farmer's perceptions of the income-stabilizing potential of hedging, their debt position, and farm size. Contrary to expectations, education was found to be inversely related to hedging, a result that may be peculiar to the sample of farmers analysed in the study. In addition, risk attitudes were not significantly related to the use of forward pricing methods.

Other studies of this type have been based on larger samples of participants. For example, a survey of 677 Iowa grain, swine, and fed-cattle farmers in 1988 (Edelman *et al.*, 1990), indicated that use of hedging over the previous two years to reduce the risk associated with grain sales was positively and significantly related to gross farm sales and to the use of other forward pricing tools. In a study of 595 farmers participating in USDA's Futures and Options Marketing Program between 1986 and 1988 (Makus *et al.*, 1990), results indicated that prior use of forward contracts, possession of a bachelor degree or above, membership

of a marketing club, and value of gross sales had the greatest positive impact on the probability of using futures and options. A survey of 1,963 Kansas farms in 1992 (Goodwin and Schroder, 1994) found that the use of forward pricing techniques was positively and significantly related to years of formal education, cropland acreage, total farm area, leverage, risk preference, input intensity, marketing seminar participation, and the use of crop insurance.

Results of the USDA's survey (USDA, 1996), conducted shortly after passage of the 1996 Farm Bill, indicated that operators in the largest gross income categories (more than US$250,000 annually) were most likely to use hedging, forward contracting, and virtually all other risk management strategies. In contrast, operators with less than US$50,000 in sales were less likely to use forward contracting or hedging, and significantly fewer reported diversification as a method of reducing risk. Keeping cash on hand, for emergencies and 'good buys', was the most frequently used strategy for every size farm in every region.

The national magazine *Farm Futures* surveyed its readers about their use of various risk management strategies (Harwood *et al.*, 1999). Commonly used strategies reported by a high proportion of those respondents included using government farm programs, diversifying into both crops and livestock, planting varieties with different maturity dates, contracting inputs to lock in a favourable price, buying crop insurance, and using crop-share rental arrangements.

Recently, a survey of 1,113 beef producers in Texas and Nebraska (Hall *et al.*, 2003) found that producers perceived understocking pasture and storing a hay reserve as the most effective drought management strategies. Adjusting stocking rate, weaning calves early, and reducing the breeding herd in times of drought were ranked as slightly less effective. Purchase of hay during drought was ranked as the least effective strategy.

3.5.4   The Netherlands

In a survey of risk perceptions among Dutch livestock farmers, it was generally found that risk-sharing strategies were perceived as more important risk management strategies than on-farm strategies. In judging strategies, producing at lowest possible cost, and buying business and personal insurance were regarded by farmers in this survey as the most

important. Although, on average, price risk was perceived by them as the major source of risk, risk-sharing strategies to deal with price risk were not considered by these farmers as important (Meuwissen *et al.*, 2001b).

Results of this survey also showed that, in general, price and production risks were perceived as important sources of risk. Insurance schemes were perceived as relevant strategies to manage risks. More detailed analyses of the risk perceptions of farmers in this survey showed that dairy farmers generally saw price risks as very important, while pig and mixed farmers were more likely to rank production risks as very important. It was also found from this survey that insurance was perceived as relatively less important by mixed farmers than by other farmers (Meuwissen *et al.*, 2001a).

3.5.5 Canada

Results from a study in Canada revealed that most farmers had strategies in place for managing risk. Tools such as production contracts were most frequently mentioned by farmers in the study. About one-in-five participants reported using options and futures. Other strategies included producing commodities that were marketed at different times of the year or buying and selling throughout the year (AAFC, 1998).

3.5.6 New Zealand

A nationwide survey of New Zealand farmers found a range of production, marketing, and financial risk management strategies used by farmers. Some strategies appeared to be favoured by farmers in all industries, others seemed to be industry specific, and some were universally unpopular. The mix of strategies employed seemed to vary by farm type (Martin, 1996).

This research suggested that the use of different risk management strategies in agriculture and horticulture varies among groups of farmers for various reasons. These included climatic realities, the nature of the product, market factors and market structure, the full or part-time status of farmers, the industry life cycle, dynamic risk adjustment considerations, and the regulatory environment (Martin, 1996).

3.5.7 Section conclusion

In conclusion, this section has selectively reviewed risk management strategies used by farmers in some developed countries. Farmers in these countries have used a range of different tools and strategies to manage the various sources of risks that they have to face in their farming operations. Although price risk management appears to be the most commonly used strategy, the risk management strategies used by farmers in different countries vary for a number of reasons including farm sizes, type of enterprises, market factors, climate conditions, etc.

The research issue emerging from the review of this section is:

- ***What are the risk management strategies currently used/employed by southwest Queensland dryland farmers?***

3.6 Chapter summary

This chapter has reviewed the various aspects of risk management covered in the agricultural economics literature. Research issues have been identified at the end of each section and are brought together here:

- ***How do southwest Queensland dryland farmers perceive farming risks?***
- ***In practice, what are the sources of farming risk that dryland farmers in southwest Queensland have to deal with? How do they perceive and rank these risks?***
- ***What are the risk management tools and strategies that can be used by dryland farmers in southwest Queensland?***
- ***What are the risk management strategies currently used/employed by southwest Queensland dryland farmers?***

These research issues will be restated and combined into formal research questions in Section 4.7 of the thesis. The following chapter will review the literature on decision support systems in agriculture and examine some models and tools that can be used to help farmers make decisions under risky conditions.

Chapter 4: Models and decision support systems applied to risk management

4.1   Introduction

This chapter reviews the advantages and disadvantages mentioned in the literature about decision support systems (DSS) in Australian agriculture. It also examines some programming and simulation models which can be applied to risk management. After the introductory section, Section 4.2 discusses the low adoption rate of DSS by farmers and points out the reasons that led to the unsuccessful uptake of DSS. Section 4.3 introduces an overview of models used for risk analysis, while Section 4.4 describes some relevant models applied to risk management. Section 4.5 reports other modelling work in Australian agriculture, and Section 4.6 presents a summary to the chapter. Lastly, Section 4.7 brings the research issues together and poses several research questions.

4.2   Decision support systems

4.2.1   Definition of a DSS

A brief history of decision support systems (DSS) can be found in the work of Power (2003). DSS are interactive and usually computer-based systems that help decision-makers utilise data and models to solve unstructured problems (Turban and Aronson, 1998). Similarly, Hayman (2004), adapted from Sage (1991), defined a DSS as a computer-based and interactive system which offers both information and decision-making procedures, and is designed to support a specific set of decisions.

Finlay (1994) defined a DSS broadly as a computer-based system supporting the process of decision making. Lynch *et al.* (2000) and Lynch (2003) called these systems 'Intelligent support systems', while Cox (1996) noted that the phrase 'DSS' was used increasingly in a loose sense to indicate any kind of decision aid, whether computer-based or not, and whether the problem it purported to address was more or less well structured. Likewise, Meinke *et al.* (2001) stated that a DSS could refer to any 'normative' approach using simulation-based information, including software products, and dissemination of such information via printed or web-based media. According to Kearney (1992), a DSS can

organise and process a large quantity of information, helping farmers to identify and concentrate on the most important information for each management decision.

Hayman (2004) noted that the use of DSS in Australian broadacre farming has been reviewed from several perspectives. Macadam *et al.* (1990) took a soft systems approach, Cox (1996) reviewed the design of these aids, and Lynch *et al.* (2000) examined the degree of end-users' involvement. McCown (2002b) reported that development work in DSS in the 1980s and early 1990s was an exciting adventure. He suggested that the optimism of modellers seemed to grow in proportion to advances in personal computing technology. Nevertheless, the increase in computer ownership by farmers has not resulted in growth in the use of DSS. The following sub-sections will review the slow uptake of DSS by Australian farmers and discuss why end-users have not adopted DSS enthusiastically.

4.2.2   Poor adoption of DSS

Edwards-Jones (1992), Lynch *et al.* (2000), and McCown (2001) all presented evidence of continued lack of success in implementing DSS in agricultural decision-making. In their role as guest editors of a special issue of *Agricultural Systems*, McCown, Hochman, and Carberry concluded:

> "Although there are cases of local successes, as a field of agricultural research, DSS work is in a state of crisis…. As laudable as the idea of computerised scientific tools to aid farmers' decision making may be to some researchers, persistent lack of demand by farmers for DSS cannot be ignored" (McCown *et al.*, 2002, p.1).

Many other scholars have also commented on the slow rate of adoption of DSS by farmers in Australia. For instance, in his analysis of design issues in decision support systems, Cox (1996) warned against agricultural DSS representing an abdication of professional responsibility and a failure of accountability. Unfortunately, despite much effort to encourage their adoption, the unwelcome fact is that the use of agricultural DSS by managers of farms has been low (McCown, 2002a; Nelson *et al.*, 2002; Carberry, 2004). Adding to these observations, Wensveen (2004) reported that research into the uptake of DSS by farmers, nationally and internationally, revealed a surprisingly low acceptance of this technology.

The question posed here is why has there been such poor adoption of DSS? Is it because farmers today who want access to a DSS cannot find what they need? In a detailed study of modelling and DSS, Hook (1997) listed 10 groups actively producing and promoting DSS and 14 such products available to farmers. More recently, McCown *et al.* (2002) noted that hundreds of agricultural decision support packages had been readily available to farmers and were quite affordable.

Why has there been so little uptake of these aids? Robinson (2005) suggested two reasons for the failure of farmers to adopt DSS technology. The first reason that Robinson gave was that scientists developed and applied the tools, thinking that good decision-making and better farm management was a rational and information-limited process. Robinson (2005) said that while this sounds fair and reasonable, the decision-making literature points out the rarity of such situations. The second reason that DSS have failed was that they have been unable to compete with simple, more efficient, and more attractive systems of supporting decisions (*e.g.* from farm consultants).

Other authors, *e.g.* Cox (1996), Hayman and Easdown (2002), and McCown (2002a), have also listed various attributes that dissuade DSS users including phobias about using computers, tedious data entry, complicated set up processes, lack of software support, lack of technical interpretation and application, and lack of local relevance. The following sub-sections will discuss in more detail the main reasons why the uptake of DSS has been so unsuccessful.

4.2.3 DSS and computer ownership

Hayman and Easdown (2002) commented that although there were some dissenting comments, the 1980s and the first half of 1990s were characterised by optimism among developers of computerised DSS. Nonetheless, contrary to expectations, the use of DSS in management of contemporary family farms has not grown with computer ownership, as might have been expected (Ascough *et al.*, 1999).

At the 2nd Australian National Conference on Computers in Agriculture (Childs, 1986), there were 30 presentations and the development of 12 specific DSS was discussed; by the 4th National Conference (Childs, 1989), there were 111 presentations and over 50 DSS and

expert systems featured. However, Hayman (2004) claimed that few, if any, of these systems were then being used.

In a study that went beyond computer ownership and examined computer use in Australian farming families, Bryant (1999) found a gender difference whereby women on family farms had the responsibility for record keeping (largely for tax purposes) while men made most of the operational and tactical decisions using their heads or paper and pen. In Bryant's sample, past records were rarely used for future decisions (Bryant, 1999). A recent survey by the Australian Bureau of Statistics found that 56 percent (72,828) of the 129,934 Australian farms (in 2004-05) used a computer as part of their business operation (ABS, 2006c). The percentage of farms using computers in southwest Queensland was relatively higher, in that 68 percent (1,097) of 1,628 farms in the region in 2004-05 reported using a computer as part of their business operation (ABS, 2006c).

However, it seems that desktop and even laptop computers do not fit easily into the farm workshop or paddock where many decisions are made. Hayman (2004) noted that farmers who were reluctant to run a simple computer program would usually have no trouble pulling apart and adapting complex farm machinery. In concluding his paper, Hayman (2004) warned that the high ownership, but low use of computers for farm management decision making, was one of the major reasons for a rethink by whoever promoted DSS as a direct means of improving farm management.

4.2.4 Mismatch between DSS developers and end-users

In the late 1980s, the limit to widespread adoption of DSS was identified as computer hardware. However, Robinson (2004) claimed that the notion that the adoption of the DSS was limited by availability, or fear or dislike of computers, should logically be dismissed in the twenty first century. Many recent studies have identified the lack of end-user involvement as a major limit on the adoption of DSS (Hochman *et al.*, 1994; Lynch *et al.*, 2000; Armstrong *et al.*, 2003).

Robinson and Freebairn (2000) argued that some developers seemed more concerned with model use than users. They repeated the story of an old farmer tinkering with a rusty harrow who was interrupted by a young extension officer offering a manual on improved farming techniques. After listening politely to the polished speech, the old farmer replied:

"Son, I don't farm half as good as I know how to already" (Robinson and Freebairn, 2000, p.1). In addition, Hayman and Collett (1996) and Hayman (2004) pointed out that there was a mismatch between the understanding of risk by farmers dealing with farm level business risk with clever but relatively simple intuition and the detailed specification of risk used by scientists to model relatively constrained agricultural production systems at paddock level with complex formal analysis. Brennan and McCown (2003) argued that agricultural economists saw farm management practice from the 'outside', rather than from the 'inside' of the management system as farmers did.

Furthermore, many DSS had little relevance to intended users and the technology transfer model used by developers has contributed to poor adoption (Cox and McCown, 1993). Newman *et al.* (1999) and Keating and McCown (2001) reinforced this view on supply-driven development, and lack of relevance to decision makers. McCown (2001) suggested that DSS were not successful because they focused on the production component of the farming system and failed to address the subjective/social dimensions of the management system. This reinforced the point made by Newman *et al.* (1999) concerning the need for greater involvement of end-users through participatory learning approaches to enhance adoption (Nelson *et al.*, 2002). Malcolm (2004) claimed that the key to successful adoption of DSS was extensive involvement by the potential users in the initial development of the tool, and intensive investment in education of the direct users of the DSS.

Decision makers often behave in ways that seem irrational or biased to scientific model developers. However, scientific model developers rarely built models that were flexible, easily used, or comprehensive, which was discouraging to decision makers seeking support (Robinson and Freebairn, 2000). These problems appeared to stem, in part, from important differences in the ways model developers and users viewed models. The model developers regarded models as instruments to represent the world, while model users wanted instruments to manage or change the world (Robinson and Freebairn, 2001). Robinson and Freebairn went on to criticize the reward systems for researchers that was oriented towards development rather than application. They said that it was far quicker and simpler to write a scientific paper than to wade through the complications and tribulations of getting a model used by decision makers (Robinson and Freebairn, 2001).

Decision makers are important in model development because they are capable of providing feedback concerning design issues, relevance, needs, and perceptions. McGill

(2001) found that end-users who developed DSS applications were able to gain greater insights into the problem they were facing. They also differed, sometimes critically, from professional model developers in their perceptions of the biophysical aspects of the real world or the model (Robinson and Freebairn, 2000).

4.2.5 Preferences for simple DSS

Simple, single-issue decision support tools or models have several advantages over larger models including speed and cost of development, accessibility, ease of use, and transparency. Disadvantages of such simple tools include less comprehensive representation of processes, less flexibility, and reduced ability to include complex interactions (Freebairn *et al.*, 2002).

In reality, however, there are many relatively simple decision support tools in use by service providers and experienced managers (Armstrong *et al.*, 2003). Freebairn *et al.* (2002) suggested that making models and modelling tools simpler can make them more usable, understandable, and effective.

Knight and Mumford (1994) believed that, in general, people prefer to get their advice from other people, rather than from machines. Cox *et al.* (2004), in supporting the use of simple DSS, indicated that as long as the program was relevant to farmers' needs, and was not so generic that it failed to match local conditions, then it was expected that even experienced farmers could benefit from an easy-to-use information/scenario analysis system.

Ridge and Cox (2000) conducted some market research into decision support systems for dryland crop production. One of their key findings was that although farmers' decision-making was based on simple and stable models that had many faults, scientists' models were 'partial, opaque, unstable, and not-adaptive'.

As noted previously, the DSS has fallen far short of expectations in its influence on farm management. Nevertheless, the experience has been instructive to both farmers and professionals in agriculture in many ways. McCown (2002a) pointed out that in many cases, farmers learned from the DSS and could then jettison it without loss and scientists,

from their disappointments, could learn what was needed to achieve a better outcome. Important lessons for the future could be drawn from collated DSS experiences.

4.2.6 Criteria for designing DSS

Robinson's PhD research (Robinson, 2004) is one of the most detailed studies of DSS in Australia (Dr David Freebairn, QDNR&M, *pers. comm.*, 18 May 2005). In his study, Robinson reviewed various guidelines or criteria suggested and implied by Australian authors who had reported deficiencies in the development and application of DSS. This sub-section summarises Robinson's review in the form of dot-point suggestions from each author.

If Dillon's five rules (Dillon, 1979b) for successful farm management economics could be applied to the development of DSS, and if they could be summarised to a dot-point each, they were:

- Data must be available for specifying processes;
- The biophysical representations must be dynamic, not static;
- Complexity and cost should be avoided;
- Uncertainty must be represented; and
- The farmer's preferences and goals must be represented.

According to Malcolm (1990), the great success of the spreadsheet/budget tools relative to other farming systems research tools could be attributed to three main features:

- Having a broader coverage of the elements of a problem relevant to the decision maker;
- Enabling involvement by the decision maker; and
- Allowing the representation of the problem to be customised.

In simple terms, Hamilton's six guidelines (Hamilton, 1995) for effective tools were:

- They are used by participants, not researchers;
- They should have capacity for comparative analysis;
- They should have high relative accuracy, not necessarily absolute accuracy;
- Tangible variables should be emphasised;
- Intangibles should be represented graphically; and
- Any models must be available for validation to establish trust.

Cox (1996) and Cox *et al.* (1996) proposed four sets of questions that should have allowed successful re-engineering of DSS:

- Knowledge of purpose (What are we in the business for?);
- Knowledge of culture (How do we generate a better organisational environment?);
- Knowledge of process and performance (What is the most effective means of getting the results we want?); and
- Knowledge of people (Who do we want or have to work with?).

McCown (2002a) suggested three essential ingredients in effective development and application of DSS:

- Degree of realism must be high;
- They must be easily parameterised to a specific site and situation; and
- The ability to evaluate management options with farmers must be high.

Lynch *et al.* (2000) and Lynch (2003) emphasised three guidelines:

- Users should be deeply involved in the development of DSS;
- Particular styles of users' participation need to be recognised; and
- Users should have a substantial influence on the system design.

It is clear that many different criteria and processes have been proposed as solutions to the problem of slow adoption of DSS. Robinson (2004) summarised the contributions of several previous authors who had addressed this problem with their own biases and criteria. They were:

- Having better technical representation of the problem (Dillon, 1979b);
- Having less zealous theoretical and technical analysis (Malcolm, 1990);
- Bridging the 'leaning gap' by having researchers understand farmers (Hamilton, 1995);
- Researching the 'gap' between management and science (McCown, 2001; 2002a);
- Reducing reductionism and over-confidence (Cox *et al.*, 1996); and
- Having greater participation by farmers in the development and use of DSS (Lynch *et al.*, 2000).

In concluding his study, Robinson (2004) suggested five criteria that DSS should meet to make them useful complements to farmers' existing decision-making aids:

- A decision-oriented development process;
- Identifying a motivated and committed audience;
- A thorough understanding of the decision-makers' context;
- Using learning as the yardstick of success; and
- Understanding the contrasts, contradictions, and conflicts between the decision-making processes of researchers and farmers.

The criteria summarised in this sub-section will be considered carefully and applied in later stages of this study.

4.2.7   Future development of DSS

Cox (1996) noticed that there was increasing concern in the mid-1990s by R&D funding bodies that investment in the development of DSS to improve agricultural practices had been largely wasted because these products had not been widely taken up by producers. That might explain why there were only two papers on DSS at the most recent Australian Farming Systems conference (Armstrong *et al.*, 2003; McCown *et al.*, 2003).

These days, farmers are likely to have their decisions supported by consultants (Hayman, 2004). Hayman said that the lack of institutional effort in building DSS may encourage the people who will use them to try to build them. They should reflect the decision-making style of the users, and the time to construct one may be short – perhaps a few days – and it could be seen as an adjunct to other procedures (Hayman, 2004). Sharing the same opinion, Freebairn *et al.* (2002) argued that farm decision support systems must be quick and easy to use. Inputs must be well-known or easily obtained because farmers tend to integrate intuitively the complexities of their enterprises into a small number of relevant options.

Robinson (2005) noted that only recently have DSS developers recognised that they are competitors for farmers' time (and other resources). In the area of DSS, this means that new systems must be more efficient, effective, and more accessible than the decision support to which farmers already have access (from advisors, neighbours, etc.). According to Robinson (2005), the high level of 'indigenous knowledge', and generally competent

management by farmers and their advisors, creates an environment in which the development of a successful DSS is an extremely difficult task.

Nevertheless, McCown (2002a) believed that even though by 2002 the realism concerning the past was setting in, confidence about the future of DSS was being maintained. Robinson (2004) added that DSS development was not yet dead, and there were many opportunities for learnings to come from future application of DSS, quoting Woodruff (1992) who suggested that models and their outputs are the starting point rather than the end point to decision making under uncertainty.

4.3   General review of models used for risk analysis

A model may be as simple as a verbal description of a system or a complex mathematical representation. Wegener (1994, p.18) quoted Radford (1968), who said that:

> "Models can aid in understanding of some particular aspects of a real object because they are simplifications of reality. The essential element in their construction is a degree of abstraction of particular features of the object being modelled. The essential features are presented uncluttered by all other features which are not essential. It is a way to see the wood, unconfused by the trees".

In definitional terms, any analytical method meant to imitate a real-life system might be referred to as a simulation model, especially when other analyses are mathematically complex, or difficult to reproduce.

According to Wegener (1994), models used to simulate farming systems could essentially be placed in two broad categories: biophysical models and economic models. Wegener (1994) suggested that biophysical models could be used to describe almost any aspect of the agricultural production system while models that had an economic orientation included those used to achieve economic efficiency in the allocation of resources and those used for risk analysis.

In 1997, an International Seminar, that addressed 'Risk Management Strategies in Agriculture: State of the Art and Future Perspective', was held at Wageningen Agricultural University, The Netherlands (Huirne *et al.*, 1997a). The purpose of the seminar was to examine the state of the art in agricultural risk management and to assess the future

prospects for improving the way that risks are managed by farmers, agribusinesses, and rural policy makers. One of the key conclusions of the seminar was that recent developments in software packages for risk analyses could be the theme of a future conference. User-friendly decision aids could play a vital role in educating decision makers about risk analysis and in bridging the still wide gap between theoretical and practical applications. Seminar participants concluded that significant progress in software development was occurring and further communication about these technologies was needed (Huirne *et al.*, 1997a).

It is acknowledged universally that risk and uncertainty play an important role in agriculture worldwide, and it is not surprising that a substantial focus on techniques for analysing risky decisions has emerged in the literature (Martin, 1996). Furthermore, much research has been devoted to developing and refining these techniques. Some examples include various econometric models and production functions, or more sophisticated formulations such as quadratic programming models or specific linear alternatives such as MOTAD (Hazell, 1971), separable linear programming (Thomas *et al.*, 1972), marginal risk constrained linear programming (Chen and Baker, 1974), whole-farm mathematical programming (Kingwell and Pannell, 1987), utility-efficient programming (Patten *et al.*, 1988), and linear programming model (Pannell and Nordblom, 1998). In general, these models help to identify risk-efficient farm plans from a range of alternatives with specific resource constraints.

While these risk programming approaches can help identify risk-efficient outcomes at the farm level, concern has been expressed that the solutions from some models such as MOTAD and quadratic programming may be very sensitive to the model's structure (Mapp and Helmers, 1984). A failure to specify the resource situation and constraint set completely may contribute to solution sensitivity. This may occur because farmers operate in a multi-attribute environment in which many forces, choices, preferences, and events influence behaviour and performance (Mapp and Helmers, 1984). Such complexities are increasing as farming systems in many countries face a wider range of external forces (Tyler and Lattimore, 1990; Eidman, 1994), and are likely to make it increasingly difficult to model farmers' behaviour. In addition to inadequate specification of resources and constraints, modelling bias could also arise if an incomplete set of risk management alternatives is considered in the analysis. The nature of risk modelling implies quantification of outcomes which may lead to the exclusion of risk management activities

or strategies which are difficult to quantify. For example, marketing activities such as forward contracting are amenable to risk analysis whereas the use of market information is not (Martin and McLeay, 1998).

Models based on multiplying production risk and price variation have generally been used to address the more realistic case of both price and yield risks (Pope and Kramer, 1979; Newbery and Stiglitz, 1981; Innes, 1990). McKinnon (1967) and Grant (1985) showed, in a variance minimization framework, the correlation between price and yield significantly affected the hedging decision. Expected utility theory has been used as the theoretical base for much risk analysis work. Sakong *et al.* (1993) and Moschini and Lapan (1995) used it to analyse yield risk. They found that some options were no longer dominated in the choice set, particularly when there was significant expected correlation between yield and price variables.

While theoretical models for planning and decision making under uncertainty have been treated extensively in the economic literature on farm management, the application of these models in extension work and practical planning and decision making has been rather modest. One of the main reasons, as suggested by Rasmussen (1997), was that no empirical background for efficient application of such risk models was available.

Just and Pope (2001) and Just (2003), using mainly an econometric focus, have assessed possibilities and proposed sound principles for research on decision analysis and risk in agriculture. Recently, Hardaker and Lien (2005) proposed sixteen principles of good practice for decision analysis in agriculture. These principles were based on reasoned argument and many relevant findings in the literature. The main principles identified that all decisions are risky, and that risk analysis is 'the art of the possible'. Measuring the risk attitudes of decision makers is difficult, and the importance of risk aversion has generally been exaggerated (Hardaker and Lien, 2005).

4.4 Review of some relevant models

A review of all the models that have been used in risk analysis and decisions making under uncertainty is beyond the scope of this chapter. However, this section will selectively review some past and some recent models which can be used to help farmers make better

decisions under risky conditions. These models were reviewed because they were considered relevant to the objectives of this study.

4.4.1 The MIDAS model

The MIDAS (Model of an Integrated Dryland Agricultural System), a whole-farm mathematical programming model of the agricultural system in the eastern wheatbelt of Western Australia, was developed in the mid-1980s (Kingwell and Pannell, 1987). MIDAS was a whole-farm model jointly describing biological, managerial, financial, and technical aspects of the dryland farming system. The main managerial goal considered by MIDAS was profit maximization although soil conservation and leisure goals were also implicitly considered.

There have been various applications of MIDAS in the field. For example, it was used to resolve an issue where researchers had long claimed farmers should do one thing, but farmers continued with another practice (Falconer and Morrison, 1987). Pannell (1987) used the model to evaluate the relative profitability of cropping and livestock enterprises while Kingwell (1987b) used the model to show that the profitability of deep-ripping was affected by whole-farm considerations which were overlooked in partial analysis. Pannell and Bennett's application (1987) of the model found that the use of alkali treatment to increase stubble digestibility would incur substantially more costs than returns. Pannell (1996) presented a comprehensive discussion of important lessons and experiences gained in the development and use of MIDAS including the model's history, strengths and weaknesses, uses, positive outcomes, and negative aspects.

MIDAS did not originally address risk but a modified version MUDAS (Model of an Uncertain Dryland Agricultural System) was developed to do that. MUDAS was a discrete stochastic programming version of MIDAS that dealt with seasonal and price variability as well as with farmers' attitudes to income risk (Kingwell *et al.*, 1991). Its development in the late 1980s was stimulated by the criticism of MIDAS that it did not allow for risk. MUDAS not only provides a deeper insight into the farming system, but it also allows for biases resulting from the simplifications inherent in MIDAS to be tested (DAFWA, 2003).

4.4.2 Risky Business

The 'Risky Business' approach to analysing risk and uncertainty was developed by a team of agricultural and resource economists at the University of Western Australia and the Department of Agriculture and Food in Western Australia. Risky Business is a suite of interactive computer simulations of a typical farm business used in a workshop setting to evaluate various marketing and investment strategies (Stewart *et al.*, 2000). It was designed to enable workshop participants to gain a greater understanding of the principles and processes of decision making under risky and uncertain conditions from a business manager's point of view. The framework and contents were designed with the aim of teaching participants from all levels of student learning and from a variety of discipline backgrounds related to the rural sector (Abadi, 2003).

Basically, Risky Business offers participatory action learning opportunities by putting workshop participants in charge of a hypothetical farm business. It incorporates a computer-aided game designed to achieve specific educational goals related to planning farm enterprises and managing production and marketing activities that are subject to seasonal variability. All participants are given the same hypothetical farm to manage and all farms face the same climate and market conditions. There are constraints under which the decision makers must plan their farm to maximise their financial well-being over several seasons. The key constraints include land, finance, and the type of enterprises.

According to Abadi (2003), Risky Business had been used at that time to train an estimated 1,200 individuals around Australia. Participants came from a variety of backgrounds such as farming, agribusiness, agricultural education, technology transfer, and research. Abadi (2003) said that groups of farmers in WA, SA, and NSW, as well as rural bank managers, agronomists and farm consultants, students of agricultural colleges and universities had all found that the game helped them experience the practical ramifications of the principles and theories of risk management. A typical program for a Risky Business workshop was listed in Abadi (2005).

4.4.3 The WhopperCropper model

WhopperCropper is a database of solutions to many computer runs describing crop production under a wide range of soil and climate conditions. It was developed by the APSRU consortium (Queensland Departments of Primary Industries and Fisheries and

Natural Resources and Mines, the Commonwealth Scientific and Industrial Research Organisation, and The University of Queensland – collectively called the Agricultural Production Systems Research Unit – APSRU).

WhopperCropper was designed to provide crop management advisers, producers, and other users with access to the latest technology in cropping systems modelling and seasonal climate forecasting. The highly variable climate of northeast Australia makes cropping a complex and risky business that is difficult to study using short-term field trials. Therefore APSRU has developed a cropping systems model, APSIM (Keating *et al.*, 2003), which could be used to support improved risk management in cropping systems.

WhopperCropper is a database of pre-run APSIM simulations with an easy-to-use graphical interface facilitating time series, probability, and diagnostic analyses. Several types of graphs are available to present outcomes. A gross margin section has been incorporated to allow presentation of outcomes in dollar terms. The program demonstrates principles for a district rather than detail at paddock level. Eight crop types were included together with a number of physiological and climate factors (APSRU, 2002).

Cox *et al.* (2003) pointed out that by providing insights into the effects of variable input options, WhopperCropper could help farmers to manage production and economic risks better. According to these authors, farmers and advisors could compare the effect of different management options, either individually, or in combination. These options included soil water-holding capacity, soil water at sowing, sowing date, crop maturity type, sowing density, nitrogen fertiliser rate, soil fertility type, climate forecast (SOI), and price and cost inputs.

WhopperCropper allows probability analysis of the effects of a range of selected crop inputs and existing resources on yield and economic outcomes. WhopperCropper has been developed and refined as a discussion support process for decision makers and their advisers in the northern grain-growing region of Australia (Cox *et al.*, 2004). The most recent version of WhopperCropper and its complete description was reported in Cox *et al.* (2006).

4.5   Other modelling work in Australian agriculture

Kingwell (1987a) noted that simulation models of parts of farming systems in Australia were constructed in the 1970s and 1980s (Graham *et al.*, 1976; Smith and Williams, 1976; Biddiscombe *et al.*, 1981; Galbraith *et al.*, 1981; White *et al.*, 1983). According to Kingwell (1987a), these models emphasized biological relationships and the interactions among various parts of the farming system, but they often ignored economic considerations and management goals of farmers. Likewise, models which included economic and managerial aspects of farming systems, *e.g.* Davis (1974), Monypenny and Walker (1976), and Ockwell and Batterham (1982), often ignored important biological considerations and generally treated the complex biology of farming systems rather simply (Kingwell, 1987a).

Wegener (1994) conducted a comprehensive study on modelling work in the Australian sugar industry. In his study, Wegener examined the choice of appropriate production strategies on individual farms and resource management decisions for whole agricultural regions. Part of Wegener's work, comparing two irrigation strategies with rain-grown cane in Mackay where cane yields were generated by the AUSCANE simulation model (Russell *et al.*, 1991), reported to the Society for Computer Simulation conference in Austin, Texas in 1989, was an early example of how these models could be used to support farm management decisions (Wegener, 1989).

The use of seasonal weather forecasting techniques to manage risk at the farm scale has been reported by many authors (Hammer *et al.*, 1996; Marshall *et al.*, 1996; Hammer *et al.*, 2001). At the field and farm level, discussion support tools based on simulation analyses are available to provide objective assessments of management alternatives for specific crops and locations (Keating and Meinke, 1998; Nelson *et al.*, 2002). At the regional scale, studies to develop drought and land condition alerts were undertaken (Carter and Brook, 1996). At the national scale, preliminary studies aimed at commodity forecasting were conducted (Stephens, 1996). A number of other studies, *e.g.* Rimmington and Nicholls (1993) and Meinke and Hammer (1997), have analysed associations of agricultural system outputs with seasonal weather forecasts.

Decision support systems, which have included some attempt to address seasonal weather variability in a dynamic way, for example, SIRATAC (Hearn *et al.*, 1981) and WHEATMAN (Woodruff, 1992), have been part of research, development and extension

programs that have facilitated social interaction between researchers and farmers (Nelson *et al.*, 2002). Meinke *et al.* (2001) introduced the use of participatory systems simulation approaches to increase profits and reduce risks in crop production. They demonstrated that well-defined financial and environmental benefits can be obtained on-farm from the use of models. Their work highlighted the importance of 'relevance' and hence the importance of true partnerships between all stakeholders (farmers, scientists, advisers) for the successful development and adoption of simulation approaches.

There have been various models and programs developed for most crops. Some of these models were described in detail by McCown *et al.* (2002) including SIRATRAC, CALEX-Cotton and CottonPro, GOSSYM/COMAX, WHEATMAN, GLA and NUTBAL, GrazFeed and GrassGro, as well as FARMSCAPE. In addition, CSIRO has developed a range of decision support tools for extensive and semi-intensive agriculture in southern Australia. Moore *et al.* (2004) summarised the description and use of these tools including Met Access, CottonLOGIC, maNage Rice, maNage Wheat, Lime & Nutrient Balance, and FarmWi$e.

The most comprehensive model of this type developed in Australia by the APSRU group is APSIM (<u>A</u>gricultural <u>P</u>roduction <u>S</u>ystems <u>Sim</u>ulator). APSIM was developed to simulate biophysical processes in farming systems, in particular where there is interest in the economic and ecological outcomes of management practice in the face of climatic risk (Keating *et al.*, 2003).

APSIM has been used in a broad range of applications, including support for on-farm decision making, farming systems design for production or resource management objectives, assessment of the value of seasonal weather forecasting, analysis of supply chain issues in agribusiness activities, development of waste management guidelines, risk assessment for government policy making, and as a guide to research and education activities (Keating *et al.*, 2003). Freebairn *et al.* (2002) reported several programs (Howwet?, Howoften?, Howmuch?, and HowLeaky?) that have been developed as applications of APSIM to support on-farm decision making.

4.6   Chapter summary

In summary, there are many existing tools and models that address various aspects of risk management. However, they are either mathematically or statistically complicated, or not easy for farmers to understand and use. The literature reviewed in this chapter leads to the following research issue:

- ***What decision support tools or models can be used to help dryland farmers in southwest Queensland make better decisions under risky conditions?***

The key issue that needs to be tackled is whether it would be possible to adapt one or some of the models reviewed in this chapter to the study area, or try to work with farmers in this area to design something simple that can help them. This issue was examined and identified through a series of interviews, group discussions, and workshops conducted with farmers in the study area. Results of these activities will be reported in Chapters 7 and 8 of this thesis.

4.7   Summary of literature review and research questions

This section summarises the review of literature by posing a number of research questions that are relevant to farmers in the study area in southwest Queensland. As outlined in Chapter 1, the title of this thesis expresses the major research question being asked. Various research issues have been identified throughout the review of literature, and they are reported again below:

- ***How can the tools of risk assessment and the recorded knowledge about perceptions of risk be linked to develop appropriate risk management strategies that are likely to be implemented successfully by southwest Queensland dryland farmers?***

- ***How do southwest Queensland dryland farmers make decision regarding risk management? Do they use 'rules of thumb' or other normative/descriptive approaches?***

- ***How do southwest Queensland dryland farmers perceive farming risks?***

- ***In practice, what are the sources of farming risk that dryland farmers in southwest Queensland have to deal with? How do they perceive and rank these risks?***

- ***What are the risk management tools and strategies that can be used by southwest Queensland dryland farmers?***

- ***What are the risk management strategies currently used/employed by southwest Queensland dryland farmers?***
- ***What decision support tools or models can be used to help southwest Queensland dryland farmers make better decisions under risky conditions?***

All of these research issues relate directly to, and stem from the single, core research topic:

What are the appropriate risk management strategies and decision support tools for dryland farmers in southwest Queensland?

This topic has been disaggregated into four well-focused questions. These four fundamental questions being asked are:

1. ***Research question 1***: *What are the current trends in the theory and practice of risk management in general and in agriculture in particular, with a focus on Queensland agriculture?*

2. ***Research question 2***: *What are the sources of risk that dryland farmers in southwest Queensland have to deal with? How do they perceive and rank these risks?*

3. ***Research question 3***: *How do dryland farmers in southwest Queensland manage farming risks?*

4. ***Research question 4***: *What decision support tools or models can be used to help southwest Queensland dryland farmers make better decisions under risky conditions?*

Generally, the first research question has been answered through the review of literature in Part I of this thesis. The following parts (II and III) of the thesis will examine possible answers for the remaining research questions.

Part II: Study context and Research methods

This part presents an overview of the area in southwest Queensland where this study was located. It also describes various methods used to examine the issues of inquiry.

Chapter 5: The study area

5.1   Introduction

This chapter consists of three sections and describes the study area. After the introduction, Section 5.2 presents an overview of the area where the study was conducted. This includes a description of the location, climate, soils, vegetation, land use, farming systems, and selected socio-economic statistics. The section also reviews past and current farming systems research in the area. Lastly, Section 5.3 summarises the chapter and provides a lead into the next chapter.

Map 5.1: The study area

5.2   The study area

5.2.1   Location

The study area (Map 5.1) is located in the eastern part of South West Queensland (SW Qld), in the area described as the Balonne-Maranoa region. It covers the whole of the area covered by the Western Farming Systems (WFS) project[1], which includes the shires (S) and towns (T) of Booringa (S), Bungil (S), Bendemere (S), Warroo (S), Balonne (S), Waggamba (S), Goondiwindi (T), and Roma (T). This area extends northwards from the New South Wales border between longitudes 147^0 and 150^0E (Galloway, 1974a). It shares

common boundaries with the shires of Murweh and Paroo (in South West Queensland) to the west, Taroom, Jericho, and Bauhimia (in Central Queensland) to the north, the Darling Downs to the east, and the New South Wales border to the south.

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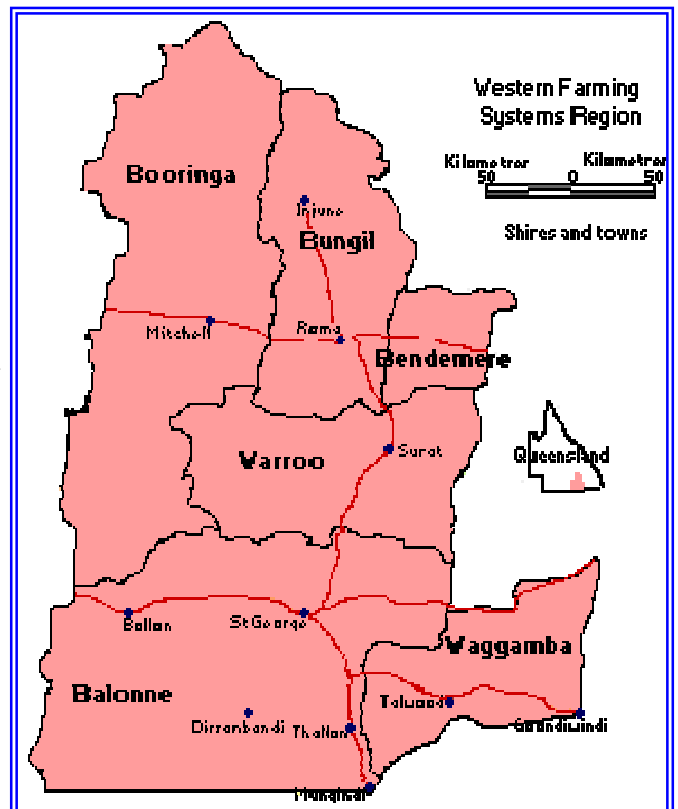
[1] Please refer to this link for more detail of the WFS project: http://www.apsru.gov.au/apsru/wfs/

Table 5.1 provides some general information about the study area, and more detailed information will be given in the following sub-sections. Information presented in this section (5.2) was sourced mainly from the recent Australian Census of Population and Housing (ACPH) and the Australian Agricultural Census (AAC) conducted in 2001. Results of the latest ACPH and AAC, which were conducted in 2006, were not available at the time this thesis was written.

As illustrated in Table 5.1, the study area covers a total of 103,422 square kilometres, which accounts for 32.3 percent and 6.0 percent of the total area of SW Qld and Queensland, respectively. The total population in the study area (2001 Census) was 25,453 persons, which accounted for 94.3 percent and 0.7 percent of the total population of SW Qld and Queensland, respectively. Approximately half of the population lived in two major towns, Roma and Goondiwindi. By road, the eastern boundary of the study area is about 350 kilometres from Brisbane (Queensland's capital city). The shires most distant from Brisbane are Booringa and Balonne, which are approximately 600 kilometres west of the capital city.

Table 5.1: **Location and population of the study area**

Location	Area (km^2)	Population (persons)	Distance from Brisbane (km)
Booringa (S)	27,793	1,966	600
Bungil (S)	13,302	1,999	465
Bendemere (S)	3,955	919	440
Warroo (S)	13,660	1,068	500
Balonne (S)	31,119	5,420	560
Waggamba (S)	13,500	2,975	350
Goondiwindi (T)	15	4,760	350
Roma (T)	78	6,346	480
Total	**103,422**	**25,453**	**-**
SW Qld	*319,860*	*27,002*	*-*
Queensland	*1,734,156*	*3,628,946*	*-*

Source: Table developed by author from shires' websites (Oultwood, 2005) and Australian Bureau of Statistics data (ABS, 2001; 2006b)

5.2.2 Climate

The climate of the study area has been described as sub-humid to semi-arid warm temperate (Kalma, 1974; Reid *et al.*, 1990). Low rainfall, high temperatures, and high evaporation result in inadequate soil moisture for reliable crop production. However, both summer and winter crops can be grown successfully and economically in this environment if sufficient moisture is stored in the soil before sowing to provide a buffer against dehydration (Robinson, 2004).

Rainfall

Mean annual rainfall decreases from about 620 mm in the east of the area to less than 520 mm in the west (Table 5.2). Distance from the coast and the effect of the Great Dividing Range both play a role in the increasing aridity in the west and southwest of the region (Kalma, 1974). Rainfall is variable and summer dominant with 60 to 70 percent falling at that time of the year (October to March).

Table 5.2: **Mean seasonal and annual rainfall at selected centres in the study area**

Centre	Summer (Oct-Mar)	Winter (Apr-Sep)	Mean Annual	% Summer	Number of years
Booringa Shire: Mitchell PO[1]	382	186	568	67	100
Bungil Shire: Roma PO	394	205	599	66	100
Warroo Shire: Surat PO	379	201	579	65	100
Balonne Shire: St George PO	327	190	517	63	100
Waggamba Shire: Goondiwindi PO	385	236	622	62	100

Source: Table developed by author from Bureau of Meteorology data (BOM, 2005)

Figure 5.1 illustrates the mean monthly rainfall at selected centres in the study area (data recorded for the recent 100 years, 1904 to 2004). Generally, there is not much difference between mean monthly rainfall at these centres. It is less than 100 mm in every month at all centres. January is usually the wettest month, with 70-80 mm mean precipitation. August and September are the driest months, with most centres recording between 20 and 30 mm precipitation on average. Variability is somewhat greater in summer than in winter.

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[1] : Post Office
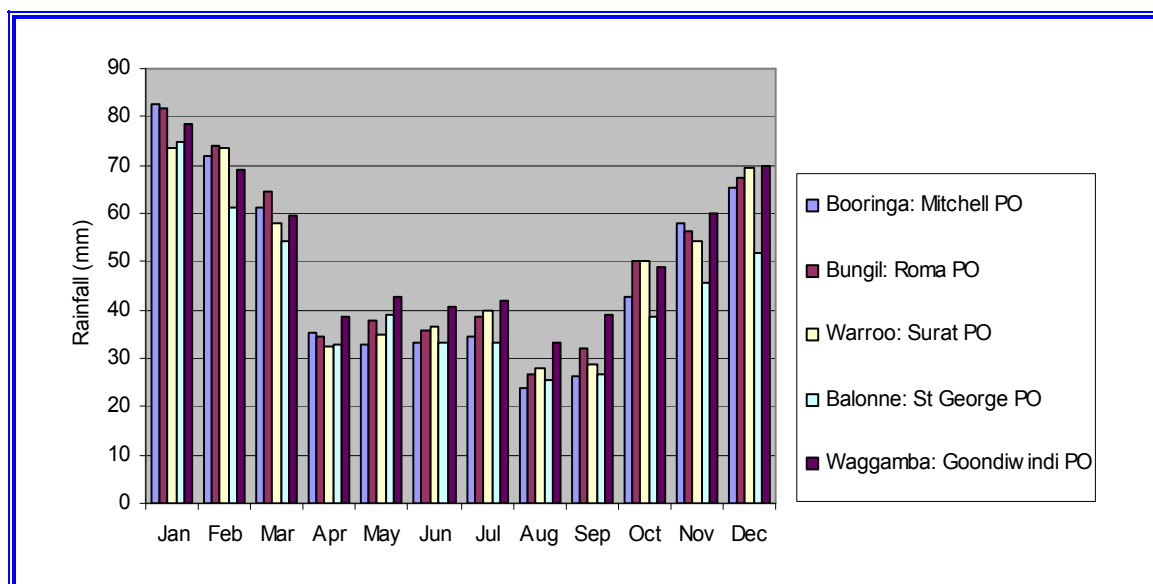
Figure 5.1: Mean monthly rainfall at selected centres in the study area

Source: Figure developed by author from Bureau of Meteorology data (BOM, 2005)

Temperature

Temperatures recorded in the region range from 47^0C to minus 9^0C (Table 5.3). Mean daily temperatures range from 27-28^{0}C in early February to 12-14^{0}C in mid July. Temperatures over 40^0C are common in summer and frosts occur frequently in winter. The diurnal temperature range is considerable, being about 15^{0}C throughout the year. Relative humidity is low, rising only during periods of rainfall activity.

Table 5.3: **Temperature, humidity, evaporation at selected centres in the study area**

Centre	Mean daily max temp (^{0}C)	Mean daily min temp (^{0}C)	Highest daily max temp (^{0}C)	Lowest daily min temp (^{0}C)	Mean 3pm relative humidity (%)	Mean annual evap. (mm)
Booringa: Mitchell PO	27	12	47	-9	34	1825
Bungil: Roma PO	28	13	45	-5	37	2482
Warroo: Surat PO	28	13	44	-6	39	n.a
Balonne: St George PO	28	14	45	-2	36	n.a
Waggamba: Goondiwindi PO	27	13	45	-6	42	n.a

Sources: Table developed by author from Bureau of Meteorology data (BOM, 2004)

Because of high temperatures and low relative humidity, annual evaporation rates are high. For instance, mean annual evaporation for Booringa (Mitchell Post Office) was 1825 mm, which was more than three times mean annual rainfall (568 mm). Robinson (2004) reported that the mean potential evaporation rate is about double the mean rainfall in every month in this area.

Temperature extremes influence plant growth and animal productivity. The bulk of pasture growth occurs in the summer months provided moisture is available. However, Drysdale (1995) claimed that high temperatures affect the eating, drinking, and resting behaviour of stock even when forage is available. Therefore, animal production can fall during excessively hot weather. On the other hand, low temperatures can limit the growth of pasture and crop.

Calculations indicating that soil moisture conditions were least favourable for crops in spring, and that they could improve through summer and autumn to optimal conditions in winter were presented by Galloway (1974b). Droughts occur approximately one year in five in this area (Hamilton, 1995). In addition, Kalma (1974) noted that heat-waves and night frosts were also appreciable risks in this area.

5.2.3 Soils, vegetation, and land use

It is generally accepted that information such as soils and vegetation does not change much over time. Therefore, the information presented in this sub-section was drawn largely from the book 'Lands of the Balonne-Maranoa area, Queensland' (Galloway *et al.*, 1974). The Balonne-Maranoa area (110,000 km^2) covers all significant parts of the shires and towns of the study area together with the shires of Tara in Queensland and Boomi in New South Wales.

Soils

According to Galloway *et al.* (1974), seven major groups of soils have been recognized in the area, and the following descriptions come from that source:

- *Alluvial Soils:* These youthful soils occur near present stream channels and their surface texture ranges from clays to sands. They occupy 1% of the area.

- *Brown and Grey-brown Soils:* The texture of this group of soil is either uniformly fine, or gradational. They occur on both weathered and fresh labile sedimentary rocks and on alluvium and cover 8% of the area.

- *Cracking Clay Soils:* These soils are generally deep clays with marked shrinking and swelling properties. They cover 21% of the area.

- *Duplex Soils:* A sharp break between sandy or loamy surface horizons and clayey subsoils characterizes this group which occupies 33% of the area.

- *Massive Earths:* This widespread group covers 22% of the area and is characterized by gradational textures, massive structure, and porous or earthy fabric.

- *Uniform Sandy Soils:* These soils occur on sandy levees and quartzose sandstone and occupy 10% of the area.

- *Skeletal Soils:* Texture of this group is sandy on sandstone and loamy or clayey on finer textured rocks. They occur in hilly terrain and cover 5% of the area.

Vegetation

The vegetation in the area consists predominantly of grassland, low open-woodland, open-woodland, woodland, and open-forest (Galloway *et al.*, 1974), and the following descriptions come from that source:

- *Grassland:* This vegetation type is dominantly Mitchell grass (*Astrebla squarrosa)*, although white spear grass (*Angophora leptopoda*) is widespread and has increased in area as a result of grazing. It occurs on fairly fresh base-rich sediments and fine-textured alluvial flats. Fairly small areas of open-grassland occur in the southwest of the area.

- *Low-open woodland:* This relatively minor vegetation type includes leopardwood (*Flindersia maculosa*), whitewood (*Atalaya hemiglauca*), and some brigalow (*Acacia harpophylla*). The leopardwood grows on alluvial soils in the southwest; the whitewood is dominantly on slightly weathered sedimentary rocks on the margins of the downs; while low open-woodlands of brigalow occur only on the clay soils in the extreme southwest.

- *Open-woodland:* Coolibah (*Eucalyptus microtheca*) woodland occurs mainly on alluvial clay soils in the south of the area. The widespread poplar box (*Eucalyptus populnea*) communities are on texture-contrast soils derived from shales or alluvium. Carbeen (*Eucalyptus tessellaris*) occupies sandy levees and minor dunes.

- *Woodland:* This is the dominant vegetation formation and occupies more than half the area. Poplar box (*Eucalyptus populnea*) woodland is the most widespread and

includes types with understoreys of cypress pine (*Callitris columellaris*), bull oak (*Casuarina luehmannii*), mulga (*Racosperma aneurum*), belah (*Casuarina cristate*), brigalow (*Acacia harpophylla*), and sandalwood (*Eremophila mitchellii*). Belah woodland, often associated with brigalow or bauhinia (*Bauhinia carronii*), occurs on fine-textured soils near Surat and Roma but most belah occurs as forest rather than woodland.

- *Open-forests:* Open forests of cypress pine are widespread on sandy soils in the north of the region, while mulga dominates extensive loamy red earth areas in the west, and belah occurs widely on fine-textured soils mainly in the east and centre of the area. Open brigalow forest is found on predominantly clay soils and often has a shrub layer of wilga (*Geijera parviflora*) and false sandalwood (*Eremophila mitchellii*).

Land use

Land use in this area was described by Galloway *et al.* (1974) and the following paragraphs are summarised from that report (except where indicated by specific reference). In the rugged isolated north and west of the area, cattle-breeding was by far the dominant land use, with large holdings extending up to 25,000 ha. Despite the relatively good rainfall in those parts of the region, the poor soils and rough topography make it unlikely that other forms of agricultural production would be introduced.

Through the centre of the area, the properties were generally 4,000-8,000 ha in size and combined both sheep and cattle production in varying proportions. Cereal production was minor but increasing in the 1970s, especially on the better soils in the higher-rainfall eastern part of this area. In the east, holdings were mainly 1,000-4,000 ha, occasionally falling below 1,000 ha in places along the railway line.

Over most of the area, livestock were grazed on natural pastures and improvement was confined to ring-barking and clearing, operations which were believed to improve the carrying capacity significantly. Sheep numbers have decreased dramatically since 1970 and cattle numbers have increased. The area of land cropped is significant and increasing, from 494,000 ha in 1996 to 552,000 ha in 2000 (WFS, 2000). Wheat production is the main cropping activity, although grain legumes and ley pastures have been increasing in importance. The area of grain legumes increased approximately five-fold between 1996 and 2000 (WFS, 2000).

Historically, commodity prices have significantly affected land use in this area. Cropping increased around 1975, when beef prices fell, and again in the 1980s when wool prices fell but wheat prices remained strong. Hence cropping history in many parts of this area is less than 40 years, and often less than 20 years (Robinson, 2004).

5.2.4   Socio-economic situation

In 2001, the total population in the study area was 25,453 persons (ABS, 2001). Table 5.4 presents some selected socio-economic statistics for the study area (based on ABS 2001 Census).

Table 5.4: **Selected socio-economic statistics for the study area**

Location	Median age (years)	Median household size (persons)	Mean weekly individual income ($)	Internet use (persons) Yes	No	Number of vehicles and motorbikes
Booringa	38	2.5	300-399	392	1516	780
Bungil	37	2.6	400-499	533	1383	780
Bendemere	37	2.6	300-399	184	712	366
Warroo	39	2.5	300-399	227	806	409
Balonne	32	2.8	400-499	1142	4022	1936
Waggamba	34	2.8	400-499	763	2076	1087
Goondiwindi	33	2.6	400-499	1037	3284	1729
Roma	32	2.6	400-499	1733	4384	2377
Total	-	-	-	**6011**	**18183**	**9464**

Source: Table developed by author from Australian Bureau of Statistics data (ABS, 2001)

As demonstrated in the table, the median age of people varied between shires and towns, ranging from 32 to 38 years. There was no significant difference between median household size (approximately 2.6 persons per household in all shires and towns). Mean weekly individual income ranged from $300 to $499. About one in every three persons in the study area either used internet at home, at work, or elsewhere. The number of vehicles, motorbikes, and scooters in the area was 9,464.

According to ABS 2001 Census data, the total number of persons employed in the study area was 12,807, of which 29 percent were farmers (Table 5.5). Farmers accounted for approximately half of the total persons employed in all locations, except for the two towns of Goondiwindi and Roma (in which the percentage of farmers/employed persons was 11 percent and four percent, respectively).

Table 5.5: **Agricultural employees by age groups in the study area**

Location	Young farmers (15-34 yrs)	Middle-aged farmers (35-55 yrs)	Senior farmers (over 55 yrs)	Total farmers (persons)	Total employed persons (persons)	Farmers/ employed persons (%)
Booringa	124	101	185	410	935	44
Bungil	144	210	206	560	1148	49
Bendemere	49	77	69	195	421	46
Warroo	88	154	82	324	590	55
Balonne	395	470	190	1055	2809	38
Waggamba	281	380	184	845	1526	55
Goondiwindi	110	89	52	251	2295	11
Roma	33	55	39	127	3083	4
Total	**1224**	**1536**	**1007**	**3767**	**12807**	**29**
% Total	*32.5*	*40.8*	*26.7*	*100.0*	*-*	*-*

Source: Table developed by author from Australian Bureau of Statistics data (ABS, 2001)

The majority of farmers (73.3 percent) in the area fell into the young and middle-aged categories. However, there were about a quarter of farmers (26.7 percent) classified as older farmers (over 55 years of age). This might indicate positive signs about farmers' attitudes towards risk management in this area because a study of risk management strategies among farmers in the Eyre Peninsula of South Australia (Nguyen, 2002) revealed that young and middle-aged farmers were more innovative than older farmers. They carried out practices related to risk management (such as calculating gross margins and planning grain marketing) more often than the older group. In terms of trying new technology, the older group was less risk-taking than the young and middle-aged groups. For instance, the older group indicated strongly that they would not try a new chemical until it was well proven in the district, and they were more likely to consider themselves as fairly conservative and traditional farmers (Nguyen *et al.*, 2002).

5.2.5 Farming systems

Farm types

Table 5.6 shows the number of farm types in the study area (based on data from ABS 2001 Agricultural Census). As presented in this table, there were 1,548 farms in total, and approximately half of these were beef cattle farms (48.1 percent).

Table 5.6: **Number of farm types in the study area**

Location	Grain Growing	Grain & Cattle	Sheep & Beef	Sheep Farming	Beef Cattle	Cotton Growing	Other Types	Total
Booringa	2	9	56	22	107	0	7	**203**
Bungil	14	53	10	1	258	1	10	**347**
Bendemere	7	28	1	0	106	0	11	**153**
Warroo	11	24	13	9	65	0	6	**128**
Balonne	15	55	51	35	70	58	16	**300**
Waggamba	74	90	35	11	92	34	13	**349**
Roma	3	12	1	0	47	0	5	**68**
Total	**126**	**271**	**167**	**78**	**745**	**93**	**68**	**1548**
% Total	*8.1*	*17.5*	*10.8*	*5.0*	*48.1*	*6.0*	*4.4*	*100.0*

Source: Table developed by author from Australian Bureau of Statistics data (ABS, 2003)

The number of grain-growing farms (including grain-growing only and grain-growing with cattle) was 397 farms which accounted for 26 percent of the total. The majority farm type was livestock farms (including sheep only, beef only, and sheep mixed with beef), which accounted for 64 percent of the total number of properties in this area. There were 93 cotton growing farms (six percent of the total) located in the shires of Balonne and Waggamba. Other farm types (68 farms) accounted for only a small percentage of the total (approximately four percent), and included plant nurseries, fruit growing, other livestock such as poultry farming, dairy farming, crop, and vegetable growing. Grain growing and beef cattle raising and fattening were the two predominant farming activities in the study area.

Estimated Value of Agricultural Operations

Figure 5.2 illustrates the percentage and cumulative percentage of farms in different value groups (based on ABS 2001 Agricultural Census data for Estimated Value of Agricultural Operations – EVAO). As shown in the figure, there were approximately three percent of

the total numbers of farms (1,548 farms) that had an EVAO of $2,000,000 or more, and about four percent of the total farms had an EVAO in the $1,000,000 to $2,000,000 bracket.
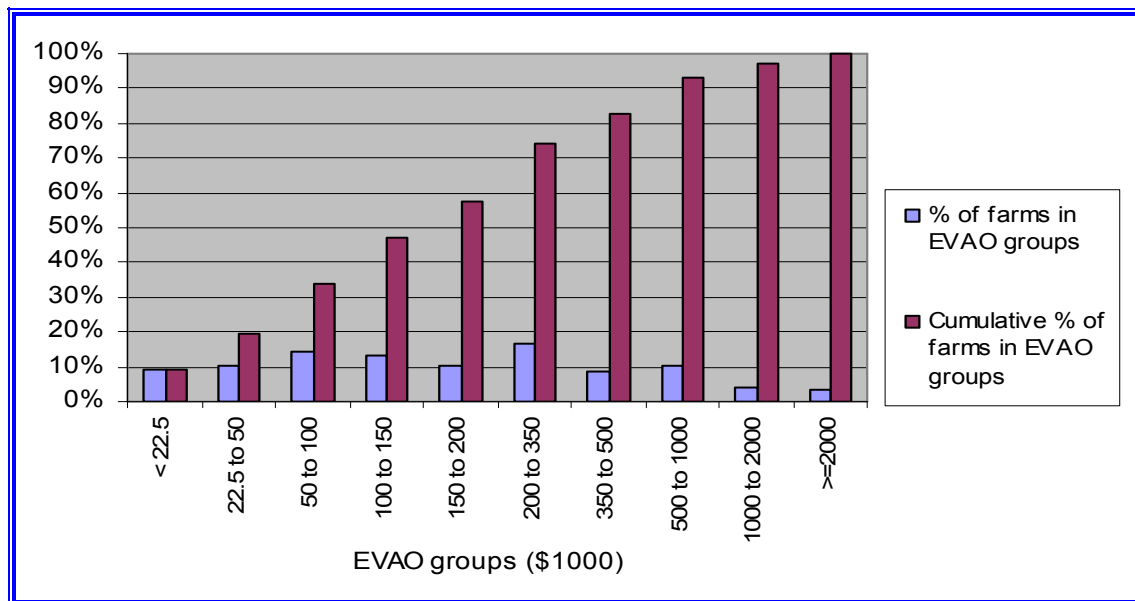
Figure 5.2: Percentage and cumulative percentage of farms in EVAO groups

Source: Figure developed by author from Australian Bureau of Statistics data (ABS, 2003)

The percentage of farms for other EVAO groups were quite similar (approximately 10 percent for each EVAO group), except for the $200,000 to $350,000 category where there were approximately 17 percent of farms in that range. Cumulatively, there were nine percent of farms that had an EVAO less than $22,500, and approximately 50 percent of farms had an EVAO less than $150,000. Going further up the scale, there were about 20 percent of farms had an EVAO of more than half a million dollars in 2001.

In regard to farm types in different EVAO groups, approximately half of the grain growing farms had an EVAO exceeding $350,000 in 2001 (Figure 5.3). Also, one in every four mixed farms (grain growing with cattle farming) had an EVAO greater than half a million dollars in that year. Regardless of type, only 10 percent of livestock properties (sheep-beef cattle, sheep, or beef cattle) had an EVAO more than $350,000 in 2001. Cotton growing farms, which were located only in the shires of Balonne and Waggamba, had high EVAO (about 50 percent of cotton farms had an EVAO exceeding one million dollars in 2001). This was not surprising because cotton farming has a high capital requirement and the returns can be very rewarding (QDPI&F, 1997).
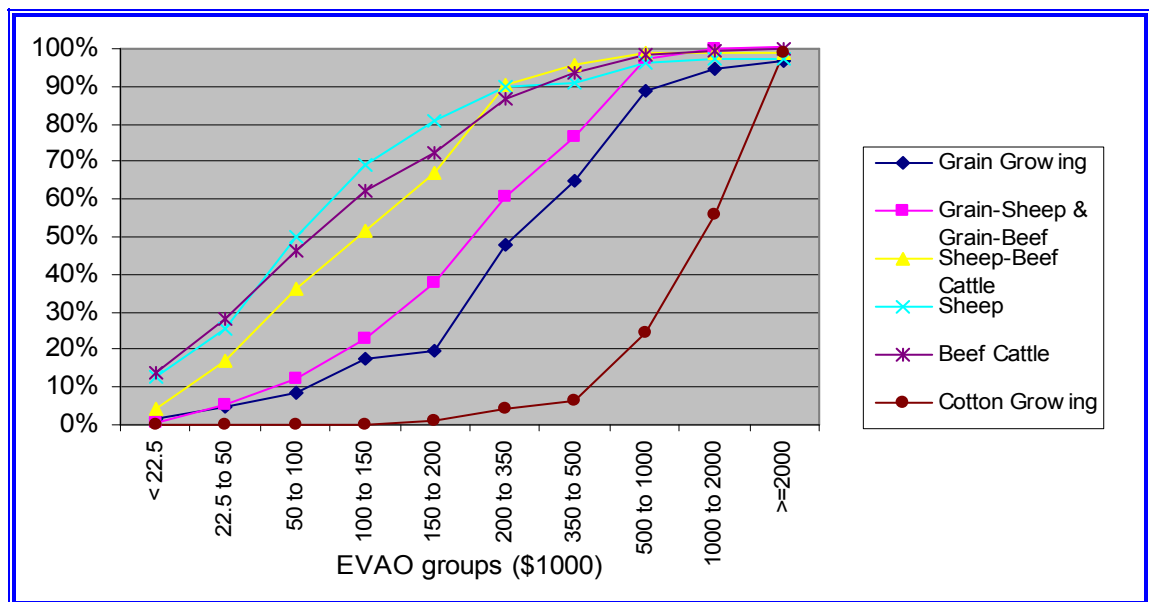
Figure 5.3: Cumulative percentage of farm types in EVAO groups

Source: Figure developed by author from Australian Bureau of Statistics data (ABS, 2003)

5.2.6 Farming systems research

The first phase of the Western Farming Systems (WFS) project, 'Sustainable farming systems for the marginal cropping areas of southwest Queensland', commenced in 1996, and the second phase finished in 2004. It was one of the first of the 'new generation' of farming systems research projects in the grain industry in Australia (Martin *et al.*, 1996). Funding agencies for the project were GRDC and the Queensland Government through QDPI&F and QDNR&M.

The vision for the WFS project was to foster an enthusiastic and vibrant partnership between the farming community and the WFS team by encouraging all parties to learn from each other to improve research and farm decision making. It sought to enhance progress towards more environmentally, economically, and socially sustainable farming systems in southwest Queensland. It was a project where researchers, interested farmers, and funding organisations became involved cooperatively in farming systems research using a combination of rigorous participatory research, development, and evaluation methods (WFS, 2002a).

The WFS project has conducted many trials and on-farm experiments, *e.g.* chemical screening (WFS, 2002c), disc planter evaluation (WFS, 2002d), soil management

(Christodoulou, 2002; Routley, 2002), testing canola (Robertson, 2002), and legume pastures (Robinson, 2002). Many software tools for decision support have been developed prior to and throughout the life of the project which could help improve crop management. They included programs such as Howwet?, Howoften?, Howmuch?, Choices, Choices, and Perfect (Freebairn *et al.*, 2002). In addition, many action learning tools for soil and water management were also developed (WFS, 2002b). Workshops were conducted on water use efficiency, soil moisture management, nutrition, and various other topics in an action learning setting.

Significant achievements and outputs from the project included newsletters and technical articles. The newsletters covered various issues about farming systems such as tillage, planting pasture, weather outlook, stubble cover, rotations, fertiliser application, etc. Technical articles around six main topics including crop rotation, pastures, diseases and weeds, soil and water, nutrition, and economics were distributed.

In 2002, the project team and funding agencies were interested in evaluating local farmers' attitudes towards the project. To gather their impressions of whether the project was making progress, and assess the extent of changes in farming in southwest Queensland, the project was evaluated to consider those aspects and to help plan future activities (Lawrence, 2002).

Over 110 farmers involved in the Western Farming Systems project and the broader farming community were surveyed. From the respondents to the survey (the survey had a 56% response rate), there were some very favourable ratings of the project, including:
- 85% of respondents who stated that the project had been a good investment;
- 91% stated that the project had improved how research and extension was done;
- 91% stated that the project had increased the profitability of farming; and
- 90% stated that the project had a positive effect on helping to reduce land degradation (Lawrence, 2002).

The achievements of the staff and farmers involved in the WFS project have resulted in the continued funding of the project for another four years (third phase). The study reported in this thesis has been recognised for its relevance to some of the project's aims and goals. Consequently, the author was partially supported by the WFS project to work on sub

project 1 'Climate and Risk in the grain and graze industries' of the WFS project, Phase III.

Robinson (2004) noted that, before the implementation of the WFS project, the effects of continuous wheat cropping and alternate methods of production or remedial treatment for land degradation were the dominant themes of scientific investigation in the region. For example, Freebairn and Wockner (1986) studied ground cover versus runoff and illustrated it graphically. Dalal and Mayer (1987) and Dalal *et al.* (1995) reported the rundown of soil organic carbon content and nitrogen content, as well as responses to ameliorative management such as grain legume rotations, fertiliser applications, and pasture leys. Thomas *et al.* (1996) examined the factors that limited wheat yields under zero tillage, while Strong *et al.* (1996) reported wheat crop responses to nitrogen and changes in organic carbon and nitrogen in different cropping systems. Weston *et al.* (1996) investigated the differences in water balance under three different types of pasture leys.

In regard to the use of modelling in the area, Hammer *et al.* (1987) used simulation modelling to assess average wheat yields and annual variability of yield at various locations. The results from their study indicated that crop yields were sufficiently high and consistent to support a permanent grains industry. Probert *et al.* (1996) simulated soil conditions and crop yields in several treatments in the Warra trial. The APSIM model used in their simulations gave satisfactory reproduction of the accumulation of total soil water and total soil nitrate during the summer fallow periods.

Other simulation experiments have defined some benefits of new farming practices, such as reduced tillage and ley farming (Berndt and White, 1976; Littleboy *et al.*, 1992; Scott *et al.*, 1992; Connolly and Freebairn, 1996; Connolly *et al.*, 1998). However, Robinson *et al.* (2001) concluded that wheat yield and protein estimates from the APSIM model involved large errors at low-yielding sites in south western Queensland.

5.3 Chapter summary

In conclusion, this chapter has described the area in which the study was conducted as well as some of the relevant farming systems research that has been done in the area. The study area and its residents still rely heavily on agricultural production as the economic and employment base for the region. The economy of this area is extensively reliant on primary

production, mainly cattle and grain. However, lack of soil moisture is the most troublesome aspect facing farmers in the area, and risk management is extremely important. The next chapter will introduce the various methods employed to investigate the research questions posed in this thesis.

Chapter 6: Methods of inquiry

6.1   Introduction

This chapter consists of three sections and describes the various methods used in this research. After the introductory section, Section 6.2 presents a description of the research methods used in this study including action research, literature review, interviews, focus group discussions, an 'expert' survey, training workshops, and evaluation surveys. Section 6.3 summarises the chapter and opens linkages to Part III of the thesis.

6.2   Research methods

This section sets out the means used to acquire and manage knowledge about the research questions investigated in this study. The methodological framework chosen for this study was action research. The methods chosen for data collection and analysis included interviews, focus group discussions, an 'expert' survey, workshops, and evaluations.

6.2.1   Action research

Throughout its development, different people have come to understand action research in different ways (Whitehead and McNiff, 2006). The earliest action research took place in the 1940s and 1950s, led by Kurt Lewin (Lewin, 1988), an American psychologist. Lewin constructed a theory of action research, which described action research as 'proceeding in a spiral of steps, each of which is composed of planning, action, and the evaluation of the results of action' (Kemmis and McTaggart, 1990). According to McKernan (1991), this description of action research theory by Lewin made action research a method of acceptable inquiry.

In the USA, the idea of action research was taken up vigorously in education during the 1950s (Corey, 1953), but latter attracted criticism from established researchers and declined (McNiff and Whitehead, 2005). In the UK, action research received a new impetus in the 1970s through the work of researchers such as Wilf Carr and Stephen Kemmis (Carr and Kemmis, 1986), Jack Whitehead (Whitehead, 1989), and John Elliot (Elliot, 2001). Whitehead and McNiff (2006) claimed that the work of Whitehead and Elliot has been profoundly influential over the years in presenting action research as a

legitimate educational research methodology. In Australia, a significant base of action research was established by Kemmis, Robin McTaggart and colleagues at Deakin University (Carr and Kemmis, 1983).

In a review, Noffke and Somekh (2005) noted that there has been a resurgence of interest in action research in the USA since the mid-1980s. Of particular importance has been the development of a sustained tradition of teacher research focused on improving learning and teaching (Cochran-Smith and Lytle, 1999; Zeichner, 2003), and more recently a tradition of self-study by teacher educators (Feldman, 2003). Another important strand has been the development of participatory action research in organisational settings and work of non-governmental organisations (Whyte, 1991).

Masters (2000) quoted three of the many definitions for action research:

- A systemic inquiry that is collective, collaborative, self-reflective, critical and undertaken by participants in the inquiry (McCutcheon and Jurg, 1990).
- A form of collective and self-reflective inquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out (Kemmis and McTaggart, 1990).
- Action research aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goal of social science by joint collaboration within a mutually acceptable ethical framework (McKernan, 1991).

There were four basic themes embedded within all of these definitions. They included empowerment of participants, collaboration through participation, acquisition of knowledge, and social change. The process that a research study goes through to achieve these themes is a spiral of action research cycles consisting of four major phases: planning, acting, observing, and reflecting (Zuber-Skerritt, 1993; Cherry, 1999). An extended action research model, which represents these four phases, is illustrated in Figure 6.1.
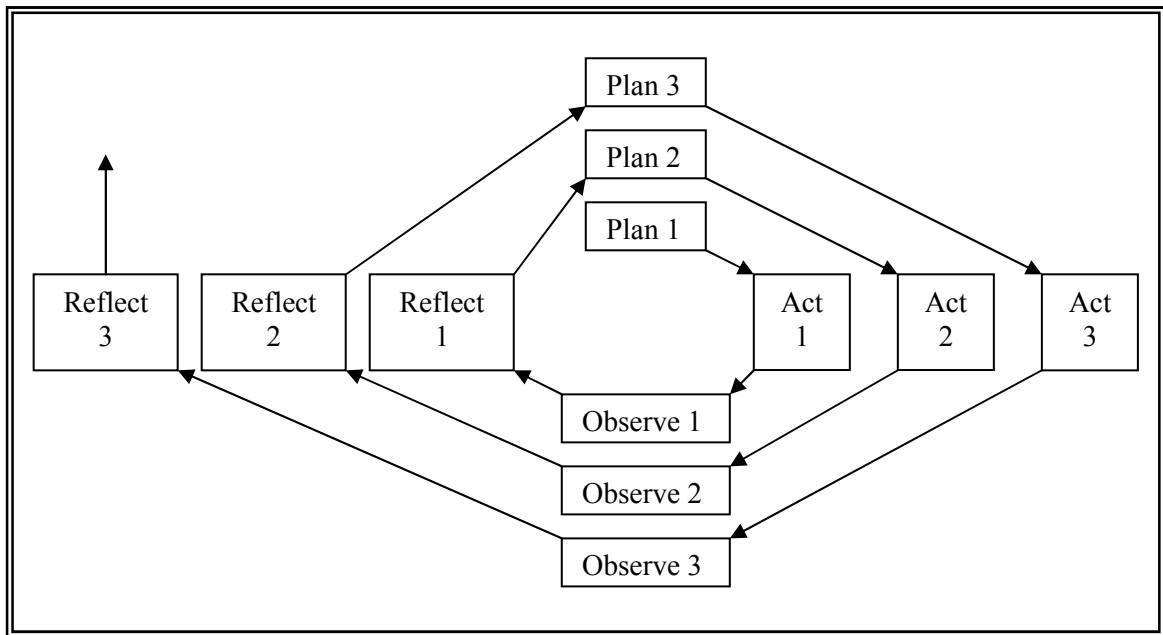
Figure 6.1: An extended action research model

Source: Modified and adapted from McNiff and Whitehead (2002) and Costello (2003)

These major phases were explained further by Zuber-Skerritt (1993):

- Planning: planning precedes the next set of actions and experiences. It may be based on conscious or unconscious thoughts and reactions. Planning often focuses on a particular aspect of the 'doing'.

- Acting: acting is doing something that makes use of prior learning. Acting is an important step for adults to take towards doing something better.

- Observing: What happened because of the action? What physical or systematic changes occurred?

- Reflecting: The conclusion of this process occurs when the 'doer' develops a conceptual model describing what is happening.

Costello (2003) argued that reading a number of accounts of action research is instructive because, in doing so, it becomes clear that there is both agreement and disagreement among authors as to what are its defining characteristics. For example, Denscombe (1998) suggested four such characteristics including its practical nature, its focus on change, the involvement of a cyclical process, and its concern with participation. These characteristics are somewhat similar to the four themes mentioned above.

There are other more concise definitions of action research. For example, Frost (2002) defined action research as a process of systematic reflection, enquiry and action carried out

by individuals about their own professional practice. According to Dick (2002), action research was defined as a family of research methods that pursue the dual outcomes of action (change, improvement) and research (understanding, knowledge) at the same time. He went on to stress that this was one of the reasons why it is particularly suitable for postgraduate students who wish to improve their own work practice while they pursue a postgraduate qualification.

Noffke and Somekh (2005) emphasised that action research directly addresses the problem of the division between theory and practice. They argued that rather than research being a linear process of producing knowledge which is later applied to practice settings, action research integrates the development of practice with the construction of research knowledge in a cyclical process. "Instead of being research *on* a social setting and the people within it, it is research from *inside* that setting carried out either by the participants themselves or researchers working in collaboration with them. It has an immediate impact since it is an integral part of day-to-day work" (Noffke and Somekh, 2005, p.89).

Dick (2000) suggested many literature sources that advance the rigorous achievement of action research. Such sources can be found in the general qualitative literature, *e.g.* the well-reasoned monographs by Kirk and Miller (1986) and Patton (1990), and the papers scattered through the handbook by Denzin and Lincoln (2000).

There is also a considerable body of writing that supports the development of action research, theorises its similarities to, and differences from, other forms of research, and explores the special value of generating theories as an integral part of development work in social settings (Noffke and Somekh, 2005). Much of this has focused upon the nature of practitioner knowledge and the special contribution it makes to research (Cochran-Smith and Lytle, 1993; Elliot, 1994; Winter, 1998).

In addition, the rigour of the action research approach and its application has also been spelled out in many recent publications, such as Dick (1997), Macintyre (2000), Robson (2002), Noffke and Somekh (2005), and Whitehead and McNiff (2006). According to those authors, the choice of action research for this study was justified, relevant, and appropriate because both action and research were its intended outcomes. The cyclic process of action research used in this study will be described later in this chapter.

Generally, there are many methods that can be used in action research. This study involved a literature review, interviews, focus group meetings, workshops, and evaluation surveys. This is consistent with the approach described by well-known scholars writing about action research (Dick, 2000; Stringer and Dwyer, 2005; Whitehead and McNiff, 2006). These authors have noted that the methods most commonly used for data collection in action research are interviewing and focus groups, that is qualitative methods.

6.2.2 Literature review

Reviewing the literature is one of the essential preliminary tasks when undertaking a research study. It is an important step in the process of defining the research problem (Cavana *et al.*, 2001). In general, a literature review has three functions: to bring clarity and focus to the research problem; to improve the methodology; and to broaden the knowledge base in the research area (McBurney and White, 2004).

Reviewing the literature is a continuous process. In this study, it began before the research questions had been formulated and continued until the thesis was finished. The previous chapters of literature review had mostly been completed before the method of inquiry was decided. However, the review has been revisited and revised throughout the study to update relevant and new findings as well as to integrate the findings from this study with those from others.

Generally, a thesis like this includes a 'Review of the literature' as a single chapter. However, the review of literature for this thesis was based on suggestions from some well-known writers on research methods (Kumar, 1996; Burns, 2000; Cavana *et al.*, 2001) who suggested that the literature review should be written around themes that have emerged from reading the literature. The headings displaying themes should be precise, descriptive of the contents, and should follow a logical progression. Thus the review of literature in this study was organised into different chapters (Chapters 2 – 4), progressing from general to specific themes.

6.2.3 Interviews

Interviews may be conducted face-to-face, over the telephone, via a video link, or by email. While there are some minor variations, Cavana *et al.* (2001) suggested that the same

general principles apply, whatever the medium used for the interview. Glesne (1999) gave a readable account of both interviewing and rapport building. In his wide-ranging book, Kvale (1996) mostly treated the interview as conversation, but also addressed its philosophical and scientific context. Taylor and Bogdan (1998) gave considerable attention to interviewing in their general text on qualitative research.

Interviews enable participants to describe their situation. The interview process not only provides a record of their views and perspectives, but it also symbolically recognises the legitimacy of their views (Stringer, 1999). Cavana *et al.* (2001) indicated that the interview provides a unique opportunity to uncover rich and complex information from individual respondents.

Generally, accounts derived from interviews are studied for themes. This data is reported as narrative containing direct quotations from interview statements, field notes, etc. This illustrative data provides a sense of reality, describing exactly what the informants feel, perceive, and how they behave (Burns, 2000).

The interviews conducted in this study included some preliminary interviews with researchers working in the field of agricultural risk management, preliminary discussions with farmers in the study area, and interviews with experts working in the field of agricultural decision support systems. Details of these interviews will be reported in Chapter 7 of the thesis.

6.2.4 Focus groups

Focus groups were developed in the 1930s and 1940s because of perceived limitations with quantitative surveys which could reflect the preconceived ideas of the interviewer as well as the subject (Coutts, 2004). According to Krueger and Casey (2000), many of the procedures that have come to be accepted as common practice in focus group discussions were set out in the classical work by Merton *et al.* (1956). Since then, the focus group has been used frequently to discover consumer attitudes and motivations, and to reveal public attitudes to various issues.

Generally, there is no common definition of a focus group in the literature. For example, Lunt and Livingstone (1996) defined focus group as a research method frequently used in

the social sciences, while Coutts (2004) defined a focus group as a means of rapidly collecting data from a broad grouping of people. In practice, focus groups come in various forms. On the one hand, this variety is a considerable strength, because it can offer many options to conduct focus groups. On the other hand, it is a source of confusion, because it can be difficult to tell what a focus group is and what is not. Conclusively, Morgan (1998) noted four basic defining features that all focus groups have in common. These features were that focus groups are a legitimate research method; they are focused on a particular topic or issue; they provide qualitative data; and focus groups use the facility of group discussions to emphasise the main points about an issue.

Focus groups have many advantages as a method of gathering qualitative data. Basch (1987), cited in O'Brien (1993), stated that group interviews provide a valuable tool for gaining insights into how people think and learn about their personal life situations. In addition, Berg (2001) emphasised that focus group discussions allow researchers to observe a process that is profoundly important to qualitative investigations – namely, interaction.

In practice, researchers have often conducted focus groups to acquaint themselves with new research areas before constructing a questionnaire for a more detailed quantitative study (Converse, 1986). When conducted before a survey, focus groups can be used to facilitate questionnaire design, from the formulation of whole categories of questions to fine-tuning the wording on particular questions (Knodel *et al.*, 1984; Morgan, 1988). Focus groups have also been used before surveys to anticipate survey non-response or refusal problems in hard-to-reach populations, and to explore ways to minimise these potential sources of sampling bias (Desvousges and Frey, 1989). The use of focus groups as a resource for designing a questionnaire was described in detail in the work of O'Brien (1993).

Berg (2001) also implied that focus group research is an innovative and evolving strategy for gathering what might otherwise be fairly difficult-to-obtain information. Focus groups have been found useful prior to, during, and after many programs, events, or experiences. They have been helpful in assessing needs, generating information for constructing questionnaires, developing plans, recruiting new clientele, finding out how customers make decisions to use or not use a product or service, testing new programs and ideas, improving existing programs, and evaluating outcomes (Krueger and Casey, 2000).

In this study, the main objective to be achieved by conducting focus group discussions was to explore the issues that could be studied, to identify the risks that dryland farmers face, and to learn how they deal with those risks. In addition, it was hoped that the author could assess dryland farmers' needs in regard to risk management and decision support tools, and learn how these needs might be met. Results of the focus group discussions will be presented in the next chapter.

6.2.5   Workshops

A series of workshops has been conducted throughout the course of this study. The main objectives for these workshops were to provide farmers with some new knowledge about risk management and decision support tools that are available. Another objective was to assess the usefulness and usability of these tools, as a guide to further work on designing something specific for risk management by these farmers. These workshops were also used as a means to consult and work with a volunteer group of dryland farmers to develop a simple decision support tool that might assist their planting decisions. In addition, the series of workshops were regarded as a vital element to strengthen the action research framework that was chosen as a principal method in this study.

An evaluation survey was used at the end of each workshop to get participants' feedback, as well as to seek ways to improve the next presentation. Chapter 8 provides a comprehensive description and discussion of these workshops.

6.2.6   Action-learning cycles

This study used an action-learning framework and the chosen methods and the justification for their use have been discussed in the previous sub-sections. Figure 6.2 illustrates the cyclic application of the methods used, explains the linkages between them, and describes how this study has progressed.

The first cycle began with the initial research proposal. Action taken in that cycle was to review the literature to examine what had been done in the field of study and to define the primary research questions.

The second cycle consisted of some preliminary interviews with researchers working in the field of agricultural risk management and with some farmers in the study area to refine the research questions as well as to identify the next stage for the study.
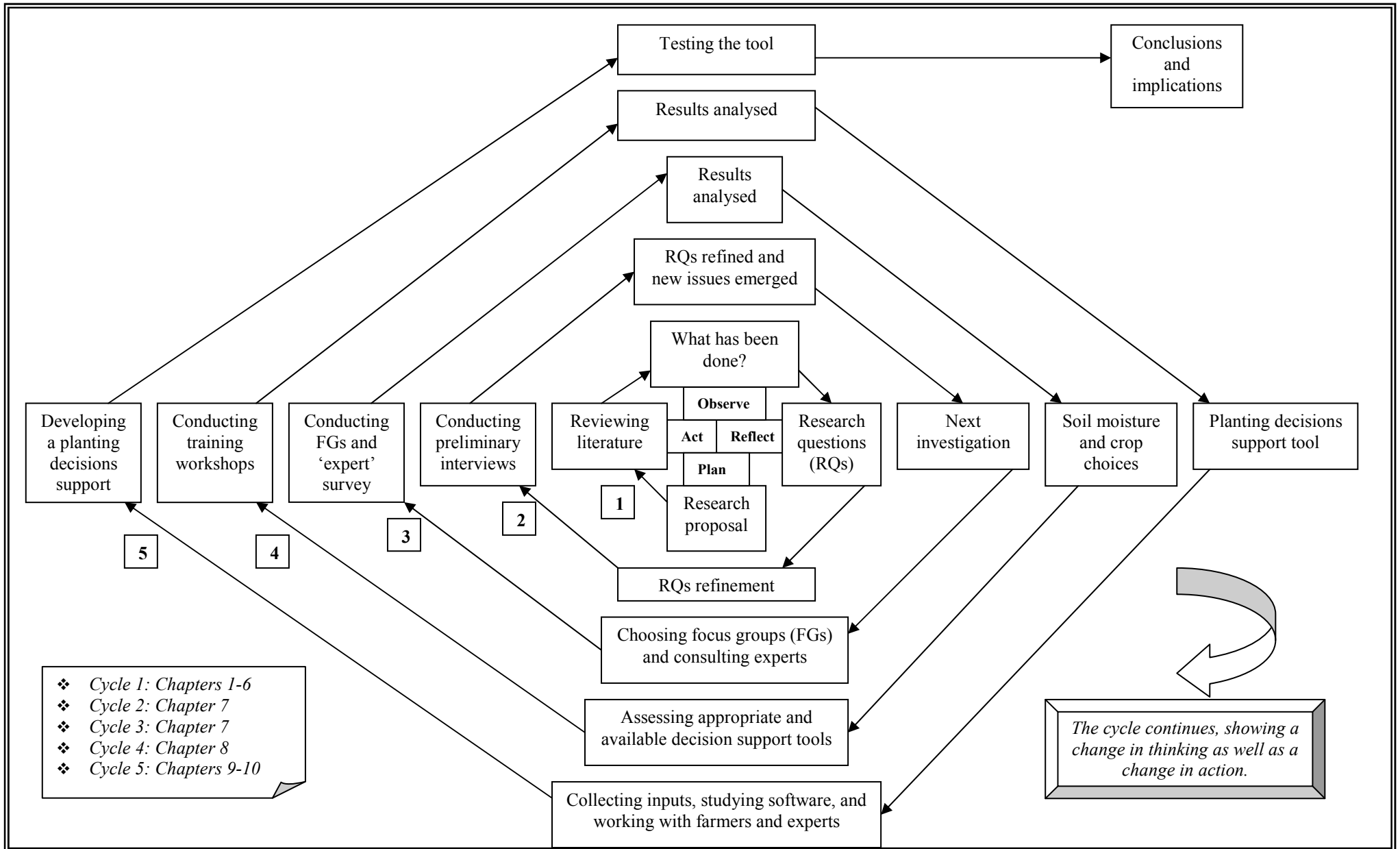
Figure 6.2: Action-learning cycles for the study – An extended action research model

The next cycle included the focus group discussions conducted with dryland farmers in the study area to find out what sources of risk they had to face as well as what risk management strategies they were using. These discussions also aimed to find out whether it might be worth developing something specific to help those farmers make better decisions under risky conditions. Another part of the plan during this cycle was to conduct a survey with experts working in the field of agricultural decision support systems. The survey asked for guidelines and advice from experts before commencing to develop a decision support tool for dryland farmers in the study area.

The fourth cycle included a series of workshops conducted with dryland farmers in the study area. The workshops presented some relevant risk management and decision support tools. Discussions and evaluations carried out through these workshops were designed to consult participants about the necessary inputs to be included in a decision support tool that could be developed for them.

The last cycle entailed the development and testing of a simple decision support tool designed to assist dryland farmers with their planting decisions. This cycle also included a review of the study and indicated some implications for further research and wider application of the results from this study

6.3   Chapter summary

In conclusion, this chapter has introduced the various methods employed to investigate the research questions. Each of the chosen methods was discussed and their choice was justified. The cycles of research used for the study were presented and explained. The following chapters of the thesis will sequentially report on the results generated by each chosen method.

Part III: Inquiry and Consequence

This part of the thesis discusses the various methods used to find answers to the research questions posed. It consists of four chapters. Chapter 7 presents the results of preliminary interviews, focus group discussions, and a survey of experts. Chapter 8 reports the results of a series of training workshops, while chapter 9 describes the design and development of a decision support tool for dryland farmers in southwest Queensland. Chapter 10 brings conclusions to the thesis and proposes some implications for further research.

Chapter 7: Preliminary interviews, focus group discussions, and an 'expert' survey

7.1   Introduction

This chapter describes the second and third cycles of the action-learning research undertaken for this thesis (Figure 6.2, Chapter 6). It reviews how the investigation was initiated and reports on the preliminary inquiries. The chapter covers three main strands of the research methods including preliminary interviews, focus group discussions, and a survey of expert opinion about decision support systems in agriculture. Results and discussions from each strand of the investigation are presented sequentially through the chapter.

7.2   Preliminary interviews

7.2.1   Preliminary interviews with researchers in the field

First preliminary interviews

The first year of this study was spent reviewing literature, preparing the detailed research proposal, and understanding the problem to be investigated. It was recognised from the literature review that the study could benefit from discussions with researchers in the field who might offer constructive comments and suggest refinements to the preliminary research questions. Consequently, in June 2004, some semi-structured interviews were conducted with five staff from QDNR&M, QDPI&F, and CSIRO involved in the APSRU farming systems research group. These researchers had many years of experience working with farmers in risk management or related areas.

Interviewees were given several documents to read before the interviews. These included the study design (as it was proposed at that time) and four preliminary research questions (which had emerged from reviewing the literature). The following questions were used as prompts during the interviews:

1. *What is happening in the field of agricultural risk management?*
2. *Is it feasible and appropriate to examine the four proposed research questions?*
3. *What is the possibility of conducting a risk management survey among farmers?*
4. *Have you any comments about this study topic in general?*

Although the format of the interviews did not always proceed according to the planned questions, they were fairly well focused on the study topic. Most of the discussions were about the APSIM crop simulation model (Keating *et al.*, 2003) or the derived product, WhopperCropper (Cox *et al.*, 2003), and developing a risk management program or model for farmers. The consensus that evolved was that it would be better to build a simple, rather than a complex, model. One respondent commented: "In fact, many software programs and models for farmers have been created but there has not been much response from farmers". It was stated that this occurred because these programs and models were either too complicated or too mathematical for farmers to understand and use. This is consistent with the views reported in the literature reviewed in Chapter 4 about the low adoption rate of decision support systems by farmers.

In supporting the building of a risk management program for farmers, one researcher stated: "Farmers, when making decisions, rely on their memory of recent years; a model, on the other hand, does not have a memory". Unfortunately, there is abundant evidence that memory is a poor tool for the objective recollection of events (Russo and Schoemaker, 1989). According to this researcher, farmers always remember the best crops rather than the poorer ones and the way farmers make decisions is usually based on limited experience. As a result, a risk management program might help farmers make better decisions under uncertain conditions.

The interviewees all agreed that before developing a risk management program, it was essential to conduct focus group discussions or survey farmers to find out how they perceive sources of farming risk and to learn about their current risk management strategies. While meeting with farmers in a focus group discussion was suggested as a possible strategy, the preference seemed to be for a survey and the respondents advised strongly that careful consideration needed to be given to survey design because "It is common that you talk with different farmers and receive no [consistent] response".

The preliminary interviews with researchers in the field did give some useful insights into the direction the study should take, as well as help to refine the research questions. However, there was little new information gained because of the limited time allowed for each interview and some 'first meeting issues' (*i.e.* the author had never met these people before so it took time to 'break the ice' and to get to know each other). Nonetheless, by the

end of the interviews, all interviewees were happy to exchange contact details with the author for further discussion regarding this study.

Follow-up interviews

To gain a better appreciation of the study topic by understanding the various researchers' experience and points of view, more detailed 'email interviews' were subsequently conducted with the same researchers who were interviewed as described in the previous discussion. This occurred during July 2004 when the core question was asked, *'What are the risk management tools and strategies that farmers in southwest Queensland and in other parts of Queensland using?'*. Their responses are summarised and presented diagrammatically in Figure 7.1.
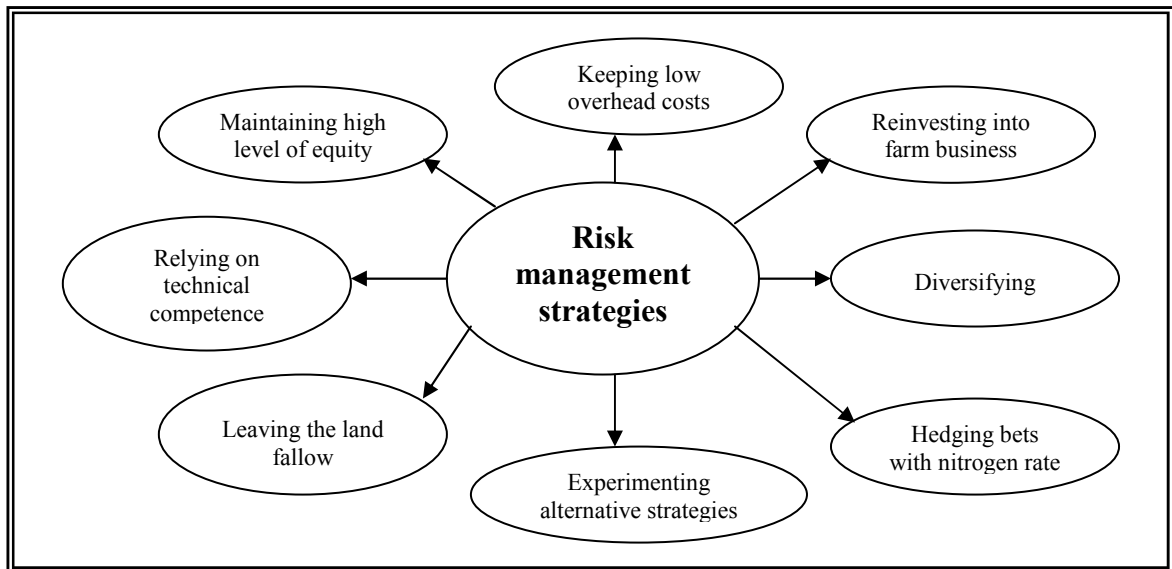
Figure 7.1: **Risk management strategies used by Queensland farmers as suggested by researchers**

Overall, it was concluded that the risk management strategies adopted by farmers were generally similar to those applied by most risk-averse managers. The researchers shared a common understanding that very few formal 'tools' such as models, or information derived from modelling, was used by farm managers to manage risk.

It was generally suggested that such formal 'tools' have influenced a relatively small group of innovative growers. Often the 'innovators' may have the desire to use these sophisticated tools as well as have access to them and the research and consulting staff who can use them. The majority of farmers tend to integrate information from a number of

sources (including other farmers) and experiment carefully within their budget. Farmers will adopt a process when it is perceived to be successful.

There has been some resistance among the farming community to using computerised modelling tools, but this is slowly being reduced as applications and the use of models are increasingly advertised, *e.g.* weather models, financial systems, automotive applications, etc. Budgeting and financial and accounting programs are increasingly available and these tools are being used more frequently by farmers because they have become easier to use. The researchers believed that such tools, if used, might give farmers more confidence in their ability to invest in and expand their businesses.

7.2.2   Preliminary discussions with farmers in the study area

In late November 2004, a meeting of a group of farmers organised by QDPI&F researchers from Roma Research Station was held in Roma (the centre of the study area) to discuss issues relating to the season just finished. This meeting was attended by the author and one of his advisors with the intention of getting to know farmers in the region and starting to understand what they were doing and the problems that they were facing. We also wanted to see whether farmers in this area were interested in risk management and to give a presentation about this study. There was an opportunity to seek potential participants for some subsequent focus group meetings. We were also able to visit some farms and talk with farmers about their farming systems and their risk management.

Several issues emerged from the discussions with these farmers. First of all, it was claimed that risk was very difficult to identify. In addition, farmers normally do not know what probabilities to expect for various outcomes. "Most people don't even know the risk", one farmer said. An added problem is that: "The danger is you don't know what you don't know". Inevitably, farmers, by the nature of their occupation, have to live with risks, usually choosing to stay where they are in an industry with which they are familiar, rather than move into some other venture when income is reduced or risks are increased. "Farming is life-style. What else should I do".

"Getting the timing right" (with respect to farming operations) was emphasized as the essential key in risk management and making decisions. Timeliness was very important as one farmer stressed: "Every time it rains, it brings income opportunities". Other farmers added: "Sometimes doing the right thing is not as important as doing it at the right time".

This is likely to be true because successful ideas must not only be good, but timely – even lucky (Gilovich and Griffin, 2002).

It was largely agreed that experiences and preferences are important in decision making, especially for decisions regarding crop planting. Because of the importance of preferences in decision making, there is no right or even similar answers for the same problem on different farms. "What is right for me may not be right for you", commented one farmer. Another issue regarding decision making is that: "Farmers often do not pay much attention to what they are good at". Moreover, farmers are sometimes inconsistent in their decisions: "What farmers say they do and what they actually do are different".

Production risks were mentioned as the main source of farming risk. Weather variability was claimed to be the biggest problem. Other problems included fallowing ("a lot of money is spent on fallow weed control") and moisture storage ("we need in-crop rain, but rainfall is crazy in this area"). Fertiliser application and seeding rates, drought, kangaroo damage, and poor soil were other risk factors that were mentioned.

Other sources of farming risk identified in the literature review (see Chapter 3) were also mentioned by farmers. Financial issues due to changing interest rates were recognised as a risk and "developing a good financial relationship is very important". The main institutional risk was related to government regulation which referred specifically to the recently-imposed ban on tree clearing in Queensland. Personal risk was also raised in the discussions with farmers: "Farming is a very dangerous occupation, for example, look at how many fingers farmers have lost".

What seemed to concern these farmers most of all was what to grow and when to grow it. There was little mention of marketing, financial, and other similar concerns. One farmer made the comment: "Farmers are better off focussing on improving production outputs". Others added: "Our wheat is sold to the pool at Roma and it is easy. We do not need to study all the marketing stuff such as futures and forward contracts". This suggested that at an early stage of the study, that models such as Risky Business (reviewed in Chapter 4) may not be appropriate to use in this area. However, tools such as the WhopperCropper program (Chapter 4) could be considered further.

Owning or contracting machinery was another issue concerning many farmers. Some farmers like having their own machinery, others like to contract. In addition, the

participants were mixed farmers so they all preferred having "a mix of crops and livestock". These combinations of crops and livestock are inherently difficult to handle in modelling, but they raise some interesting challenges to understand risk management. When asked about their desire for a tool or model to help with risk management, the common response was: "It would be good to have something simple like a spreadsheet model that can combine crops and livestock, and include machinery issues if possible".

Finally, these farmers made several comments in regard to production activities. Cattle were considered a good option. "We are close to Roma cattle market, which is very good for selling cattle". However, it was claimed that the market for cattle was not stable and therefore fairly risky. "Our cattle market relies very much on the USA and Canadian markets, so whatever happens over there will have an impact on us". Considering crops, wheat was given high priority. Chickpeas were said to grow well in low rainfall years and they leave the soil in good condition but there is not much stubble (hence rain in summer can cause erosion). The normal market for chickpeas was said to be in India and Pakistan with few local buyers. Sorghum was regarded as a risky crop, while mungbeans and canola were acceptable. Barley and sunflower were not so good because the price was often high at planting but low at selling time. Lablab was claimed to be a very expensive crop to grow. Hay was good because "the hay market is linked to the cattle market and the feed market, where demand in Queensland is high". Overall, the common strategy regarding production activities was to diversify enterprises to spread the risk.

Figure 7.2: **Visiting one of the Roma farmers at their property**

> *The group includes (front row left to right) Max Aisthorpe (farmer), Dr Malcolm Wegener (UQ), Nam Nguyen (UQ), Kathy Snars (QDPI&F), (back row left to right) Darren Aisthorpe (farmer's son), Prof Ian Morrison (University of Alberta, Canada).*

7.2.3 Section conclusion

In summary, the interviews with researchers in the field of study provided some useful information about risk management tools and strategies used by farmers in Queensland. The discussions with farmers did not necessarily portray the situation in the whole study area since the discussions were conducted with a fairly small group of farmers. However, they did give an indication of what farmers were actually doing as well as describing their problems. As such, their comments could be used to provide guidance for the focus group discussions and design of risk management and decision support tools that were expected to be part of later stages of this study. The observation from these preliminary interviews and discussions revealed that farmers seemed to place a lot of faith in the agronomic package (crop type, soil type, planting time technique, etc) as risk management device.

7.3 Focus groups

7.3.1 Objectives of the focus groups

The main objectives of the focus group discussions (conducted in February 2005) were to explore the issues that could be studied, identify sources of risk the farmers have to face, and learn how they deal with these risks. In addition, it was hoped that we could assess farmers' needs in regards to risk management and decision support tools and learn how these needs might be met.

7.3.2 Focus group design

'Trial' focus group

Ideally, focus group procedures include a trained and practiced moderator who asks a small group of individuals a series of open-ended questions. In the real world, however, inexperienced researchers frequently use focus groups and may themselves act as moderators. This 'real world' situation did apply in this study.

In order to gain some experiences and receive constructive comments, a trial focus group meeting was conducted with staff and postgraduate students in the School of Natural and Rural Systems Management, The University of Queensland, prior to holding the group discussions with the farmers. The meeting had seven participants and all of them were familiar with the use of focus groups in research.

Peer participants in the trial focus group contributed valuable advice on various issues such as getting people to attend focus groups, moderating skills, handling the 'environment' during the focus group discussion, and concluding the discussion. Generally, the comments from research peers indicated that the proposed questions were easy to ask, clear, short, open-ended, one-dimensional, and appropriately sequenced, which are some of the criteria for good quality questions listed by Krueger and Casey (2000). Participants suggested several sources of risk (Figure 7.3) that should be included in a survey of risk management for farmers. These sources are consistent with those reviewed in the literature (Chapter 3).

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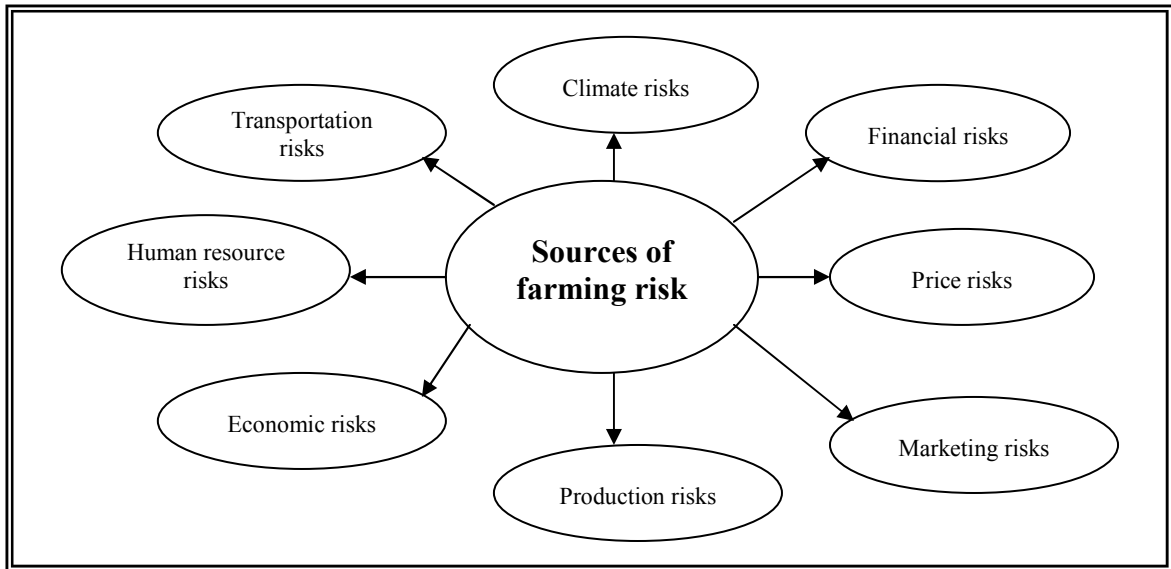
Figure 7.3: **Sources of farming risk suggested by research peers**

Participant selection

Wolff *et al.* (1993) noted that the selection of participants for focus group discussions is typically purposive and based more on suitability or convenience than representativeness. In this study, however, the farmers to be asked to participate in the focus groups were selected from a list of farmers provided by QDPI&F staff at Roma Research Station, and it was presumed on advice of experienced extension staff and WFS team that they were relatively representative of farmers in the study area. Thus the information generated might be considered as generally representative of the wider population and useful in ways suggested by Kennedy (1979). The recruitment procedure included four steps as outlined in Appendix I.

Instruments and material

Like most focus groups, *e.g.* Morgan (1988) and Krueger (1988), the two focus groups had a moderator and were fairly small. The first group had six participants while the second group had 10 participants.

The topics for discussion included concepts such as risk in farming, risk management tools in use, and training needs regarding risk management. The same questions were used in each focus group to find participants' opinions about these research issues. These questions were developed by the process suggested by Krueger and Casey (2000) which includes brainstorming, phrasing the questions, sequencing the questions, estimating time for discussions, getting feedback from others, and testing the questions.

Record of Performance

Researchers in the social sciences often employ a tactic called the extended focus group technique. This procedure includes a questionnaire administered to participants before the group session. The questionnaire generally includes material that will be discussed during the focus group meeting. Information from this questionnaire may assist both group members and the moderator to structure the discussion. The questionnaire allows participants to develop a commitment to a position before any group discussion begins (Sussman *et al.*, 1991). In addition, the information from this questionnaire may help to ensure that the moderator draws out minority opinions as well as more dominant majority ones (Wimmer and Dominick, 1987).

In order to employ some elements of the tactic described above, participants in each focus group were given the list of questions to be discussed, pens, and note paper after the welcome comments and introduction. Participants were then given five minutes to have a 'quick think' about the questions before the discussions began. These questions are listed in Appendix I of the thesis.

The focus group procedure included a sequence of ten steps (see Appendix I). Each group discussion lasted approximately two hours. The discussion was tape recorded and then transcribed. The taping was not a problem for participants and they also agreed for their photographs to be taken and recorded as part of the study. A meal was served before the first group discussion and after the discussion with the second group. A small payment (A$50.00) was also offered to participants towards their travel costs. However, they refused to take the money. Participants all agreed with one farmer who said that:

> "I rarely get paid to attend any of these meetings. I thank you for the opportunity for this. If I knew that you can use that money to further the research that you have indicated in the southwest area, I think that would be more useful than me receiving fifty dollars".

7.3.3 Summary of discussions

This subsection summarises the results of two focus group discussions held at Roma on 18 February 2005. This summary was condensed in accordance with the questions discussed in the meetings and the key themes grouped and highlighted in the transcripts. The detailed discussion of each group is reported in Appendix I.

Definition of risk

Generally, farmers' definitions of risk were not as long or as complicated as those used by scholars (Hardaker *et al.*, 1997; Williams and Schroder, 1999; Just *et al.*, 2003). In the discussions with these farmers, there was general agreement that risk is anything that threatens farm enterprises. "Risk is something that would prevent you from gaining profit or profitable opportunities which you would expect to get". The uncertain future was considered as a source of risk. All participants accepted the fact that farming is risky. "You can't go into farming without risk. In other words, you can't be a 'no risk' farmer".

Sources of risk

As reviewed previously in Chapter 3 of this thesis, the main sources of risk in farming include production, financial, marketing, institutional, and human resource risks (Fleisher, 1990; Hardaker *et al.*, 1997; Kay and Edwards, 1999). These same sources of risk were mentioned by participants in the group discussions, with many additional comments made about how climatic, personnel, business environment, and government policy changes affected the risks they face.

Participants were asked to select three sources of risk that they considered most important. Weather variability was ranked as the most important source of risk in both discussion groups. This was followed by financial and agronomic risks in the first group and institutional and marketing risks in the second group.

Risk management strategies

These two groups of farmers in southwest Queensland, like farmers in other states and overseas, such as South Australian farmers (Nguyen, 2002), New Zealand farmers (Martin, 1996), Dutch farmers (Meuwissen, 2001a), Canadian farmers (AAFC, 1998), and American farmers (Patrick *et al.*, 1985; Jose and Valluru, 1997), use a range of strategies to manage the various sources of risk that they have to cope with in their farming businesses.

Most of the discussion in the focus groups was about strategies used to manage weather variability and production risks such as conserving moisture, using zero till planting methods, and running cattle as well as growing crops. All farmers in the focus groups agreed that conservation of moisture was their most important priority. They said that: "Before we can do anything, we have got to have strategies such as no till or conservation farming to store a little bit of water from the rainfall that we get". The common consensus

among these farmers was that: "Given the water we have available, zero till is the best way to reduce the risk of erosion and water evaporation". They also thought marketing should be "left to experts", and only part of farm production should be sold at any one time. "You'd better not sell all your crops or cattle at one time because you can never be completely right".

Strategies used to manage financial and personal risks were also discussed. However, there was little discussion about how to manage the risk that government policy might change. This source of risk was claimed by participants as something "out of control" (which probably reflected a recent decision by the Queensland Government to ban tree clearing which affected farmers in this area). "Government rules and regulations are risks because we are not able to do anything about it". Others added: "Once you could do whatever you wanted to do with your plot, but now you can't". There was also awareness of the need to educate younger farmers to have good farming skills. "What the young people are learning from agricultural colleges is sometimes quite different with what actually occurs in the field". Participants expressed deep concern that there should be more education in schools about agriculture. "Many kids still think that milk comes from bottles at supermarkets".

Knowledge of existing decision support tools

These farmers questioned the effectiveness of most of the decision support tools and programs that were available and commented on their complex nature. There was a general conclusion that knowing what is available was a problem and learning how to use these new tools could take a lot of time. The cost-effectiveness of these tools/programs was another aspect questioned by participants.

All participants in the focus groups asserted that something simple such as a chart or a tool that could combine soil moisture level with potential crop yields, to indicate the choice of crops to grow, would be of great help to them. They also mentioned that they could use something to do with moisture management, perhaps in conjunction with other available economic research, to assist them in making crop choices.

Figure 7.4: **First group participants ranking sources of risk**

Figure 7.5: **Second group participants discussing the issues**

7.3.4 Section conclusion

There are many problems and many potential answers to the question of appropriate risk management strategies for farmers in the study area. The problem to be addressed in this research is whether to develop something that might address part of the problem very well or whether to try doing something that tries to address the whole problem more comprehensively. However, the whole problem is extremely complex and it may be wise to break it down into parts and try to tackle one or two parts initially as part of this study.

The key messages from the group discussions were that soil moisture management and crop choice were the topics that concerned farmers most in dealing with the risks they face. Overall, it was concluded that it would be useful if these farmers had information that could help them understand ways to store water and utilise it more effectively. Another aspect of this question was choosing the right crop at planting time to make most effective use of available water. There were several options raised as a result of these discussions that were thought to be useful at this stage of the study:

- Design a spreadsheet or decision support tool that makes use of information on cropping history, current soil moisture level, and other factors such as seasonal climate forecasts, to assess crop planting options at various times of the year.
- Put together a training package, which includes appropriate elements to evaluate southwest Queensland weather forecasts or packages and training with some marketing options.
- Conduct a survey among a broader group of farmers to see whether the sort of things discussed in the focus groups reflect what the larger population is thinking.
- Adapt and evaluate products that are available such as the Risky Business program from Western Australia (Abadi, 2003), or tools derived from some of the crop-weather simulation models such as WhopperCroppper (Cox *et al.*, 2004) or Howwet? (Freebairn *et al.*, 2002). It would be feasible to adapt some of these products to meet the needs of farmers in the south west farming zone and work through this process with them.

Irrespective of how the next stage of the investigation might evolve, it was concluded after conducting the focus groups that an appropriate way to proceed would involve taking something back to the farmers and asking them what they thought about it. This would be one way to repay the help and enthusiasm for the study that had already been displayed.

7.4 'Expert' survey

7.4.1 Objectives of the survey

The main objectives in interviewing experts working with decision support systems (DSS) were to ask for advice and suggestions from leading practitioners in the field of DSS about designing a DSS for farmers and to gain a better understanding of the current adoption pattern of DSS in Australian agriculture. It was felt that it would be useful to preview the likely future development of DSS and to assess the possibility and appropriateness of designing something (a decision support tool) to help dryland farmers make better crop choices and more appropriate planting decisions.

7.4.2 Interviewee selection and questions

A questionnaire was emailed to various experts who were familiar with decision support systems in agriculture. This method of data collection was appropriate at that stage of the study, considering all the constraints such as time, location, and budget. Interviewees were chosen on the basis of their publication record in the field of DSS as well as their working experience in this field. In total, questionnaires were emailed to 23 experts. The list of interviewees and their organisations is included in Appendix II.

Three main questions were asked to achieve the objectives described previously. The first set of questions was sent on 12 July 2005 and other emails were sent on the same or following days. The first reply was received on the same day as it was sent and the last reply was received on 17 August 2005. In total, there were 19 responses received. Some of the responses were made in personal discussions and phone conversations.

The response rate (19 out of 23 requests) was impressive, given factors such as the time pressure on respondents, the questions asked were very open-ended, and most of the experts knew very little about the candidate or his PhD study. The following sub-section will report responses to the survey and address some insights and reflections.

7.4.3 Summary and discussion of survey feedback

This sub-section summarises the feedback from those experts who responded to the survey. Generally, respondents agreed that the problems identified by the candidate through his

summary of focus group discussions (soil moisture management and crop choice) were critical issues relating to managing risk in dryland cropping.

The first question asked for the experts' suggestions about designing a DSS for farmers.

1.   What guidelines would you suggest when designing a DSS for farmers?
The following dot-points summarize the concepts that experts suggested as guidelines for the design of DSS for farmers:

- Being relevant to a problem that is causing considerable concern to farmers;
- Working closely with farmers throughout the design phase;
- Trying to take the farmers' point of view;
- Making the DSS very simple and quick to use;
- Having easily accessed information sources;
- Knowing the range of options that the farmer may need to choose from;
- Finding a place for the DSS within a process of communication; and
- Developing it in text form.

Some of these ideas had previously been described in Robinson's work (Robinson, 2004), but respondents generally confirmed that any DSS needed to address issues that were causing considerable concern to farmers. In other words, it needed to help alleviate something that is worrying the farmer or causing some anxiety. "Make sure that the DSS is on a topic that farmers need a DSS for". It should be an issue that farmers are not already making good decisions about, and something that farmers themselves think they are struggling with or need help with. One respondent concluded that "Only if the farmers are struggling with a solvable problem, and the DSS can help solve it more efficiently than the alternatives, can the DSS be relevant".

It is clear that there needs to be close collaboration with farmers throughout the design phase if the DSS is going to be useful. This is to make sure that the DSS really meets farmers' needs, is understandable, and easy to use.

"To be useful to decision makers [when developing a DSS], requires getting into their shoes". For any decision support tool to be useful, it needs to provide information that is relevant to at least one important decision made by farmers. This means that developers need to be explicit about which decision they are trying to address, when this decision

needs to be made, and produce the DSS in a form that is accessible when the decision point arrives. It was suggested that the task needs to be approached from the farmers' point of view, and should not necessarily be considered in the way that researchers would approach the problem.

Respondents shared a common view that unless the DSS is very simple and quick to use, the majority of farmers are unlikely to use it. "The simplest things generally work best, and the simpler the better". It was also claimed that some DSS that are useful are essentially easily accessed information sources (*e.g.* agricultural chemical reference charts and agronomic packages for crop management). Users' preferences for simple DSS have been widely documented in the literature (Knight and Mumford, 1994; Freebairn *et al.*, 2002; Armstrong *et al.*, 2003; Cox *et al.*, 2004).

It was argued that a DSS should support a decision and not merely provide information, so in developing a DSS, it would be useful to consider carefully the decision making process that farmers use to make a particular decision. To do this, the DSS developer(s) needs to consider various issues, including the decision that needs to be made, the range of options that the farmer may have to choose from (assuming that a 'decision' is a choice between a number of potential courses of action), and the economic, environmental, and social factors that might influence the decision or the choice of an option. In this regard, it is vitally important that the objective that the decision-maker has when making his/her decision is actually reflected by the DSS.

To be effective, "Any decision support tool must find a place within a process of communication". It was suggested that developer(s) need to think long and hard about what is being communicated, to whom, and why, before launching into a DSS effort. "It is very important to choose a communication medium and design the tool interface with the communication process in mind".

There were some respondents who favoured paper-based DSS. "The most likely DSS to work is in a text form, posing questions or scenarios and providing some answers or alternatives". Computer driven DSS were generally criticised because they have not been used extensively by farmers.

The second group of questions that respondents were asked were about the adoption pattern of DSS in Australian agriculture.

2.   a) What do you think about the adoption rate for DSS in Australian agriculture? How widely are these tools used?

The views expressed by experts are summarized in the following dot-points:

- The use of DSS is extremely low and they are poorly adopted by farmers;
- The main audience is farm advisors;
- DSS tools for farmers are mostly a waste of time and money;
- Younger farmers and new agricultural graduates are becoming more accepting of DSS; and
- DSS are not widely used by farmers.

The consensus among respondents was that the adoption of DSS by Australian farmers has been very slow. It was also indicated that DSS were not used directly by most farmers. "The main audiences are farm advisors and researchers". Pessimistically, some respondents to the survey claimed that DSS tools for farmers were mostly a waste of time and money. "Adoption is abysmal with many millions of dollars wasted on DSS systems" and "The area of your questions has been well worked by APSRU in recent years. Our experience is that DSS targeted at farmers are not usually that successful". Nevertheless, others respondents were confident that younger farmers and new agricultural graduates are becoming more accepting of the use of DSS.

Experts' responses to this question were similar to what has been reported in the literature (Edwards-Jones, 1992; Lynch *et al.*, 2000; McCown, 2001). Many other scholars have also reported on the low rate of adoption of DSS by farmers in Australia (McCown, 2002a; Nelson *et al.*, 2002; Carberry, 2004; Wensveen, 2004).

However, one respondent pointed out that adoption and influence were related but different. A crude measure of adoption rate (users per unit population) might neglect the possibility that not all users are equal. For example, if users farm larger areas than non-users, then influence will be greater than apparent adoption.

b) What are the main contributions of DSS in agriculture today?

Respondents' answers can be summarized in two dot-points:

- Enhancing the knowledge of farm advisors; and
- As a learning tool in a workshop setting.

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The contribution to better farm management attributable to the development of various DSS in Australia has been the enhanced knowledge of farm advisors/consultants and increased value of information they provide to farmers. These products were also seen to be useful in a workshop setting where discussion can be focused onto decision-making in general or concentrated on making a particular decision that is relevant to a group of farmers. Another contribution would be to research and training. "They might be more useful to the people who build them to structure their knowledge, than to the farmers". The uptake of DSS for educational use has been reported recently in the literature (Daily *et al.*, 2000; Moore, 2005).

c) *What sort of issues limits the usefulness of DSS or their uptake by farmers?*

The answers to this question are summarized in the following dot-points:

- Farmers can make good decisions without using a DSS;
- Many farmers are not computer oriented;
- Most DSS are not well designed and are complex;
- Farmers deal with issues in different ways to researchers;
- DSS are too general and not specific to each farmer's own circumstances;
- Farmers are often short of time [to learn and to use a DSS]; and
- DSS have not been well marketed.

There were many reasons why the slow uptake of DSS by farmers has occurred. Some of these issues are similar to those presented in the review of the DSS literature in Chapter 4 of this thesis. "Farmers can make good decisions without them" was a common response. In addition, many farmers are not comfortable using computers (although this is changing rapidly) and they are not as computer-literate as the DSS developers.

The fact that most DSS are not well designed, or are not focused on appropriate topics, was also criticized and so they do not really reflect how farmers make decisions. Moreover, farmers deal with different components of a decision, and deal with them in different ways to researchers, while "DSS are often oriented to researchers' perspectives". In many cases, DSS are too general and not specific to each farmer's own circumstances. This sometimes requires input data which farmers do not have. Also farmers often mistrust answers which come out of a black box because at times the answers are not appropriate. The 'mismatch' between DSS developers and end-users in their approach to decision making has been

widely documented in the literature (Hochman *et al.*, 1994; Pannell *et al.*, 2000; Robinson and Freebairn, 2000; Keating and McCown, 2001).

Another reason noted for the failure of farmers to use a DSS was that farmers are always busy. "They do not simply have time to learn and use the DSS". Therefore, they usually get their farm advisors to help them with strategic or tactical planning and the software that goes with it. "Farmers do not have time for tinkering with software which they may only need to use twice a year for planning purposes". So they get specialists in for that because consultants or researchers work with many clients using the same software. These service providers earn their living from knowing about these DSS and keeping up to speed with them. From an economic point of view, the marginal cost of DSS software, and the training required to make sensible use of it, is likely to be high for an infrequent user (a farmer) and low for a regular, power user.

Furthermore, DSS generally have not been well marketed. Most farmers do not know that they exist or what they can do. This is consistent with the comments from the group discussions with the farmers at Roma. "There are heaps of programs out there, but knowing what is what and how to use them are really problems". In practice, DSS are developed by researchers as part of their project work and are usually paid for by institutions that do not have a profit motive and usually little customer focus. The project usually achieves its objective of developing the first and possibly even the second version of the software. The funds then run out, the project ends, and the researchers (modellers and developers, and often they are the same) then move on to other jobs abandoning the DSS. "The DSS sits on the shelf and become obsolete in a very short time". No one has the incentive or the inclination to keep it up to date and keep it compatible with changes in computing hardware and software let alone the changes in users' needs.

d) How much are farmers part of the processes of initiating the requirement for, design, and testing of DSS?

The responses can be summarized in two dot-points:

- Not much in many cases – the farmers are often left out of the process; and
- Young farmers with tertiary training are often involved.

Ideally, farmers need a substantial and active role in the whole process from assessing the need for, the design of, and testing of DSS. In reality, however, the users have not been involved as much as they could be in many cases. It was generally concluded that the

farmers are left out of the process. "Scientists seem to replicate their own decision-making processes and believe that is the same way that farmers make decisions". In practice, the farmers who are often involved in testing DSS are part of a small percentage of computer-literate users – often young farmers with tertiary education. "But even then they will mostly play with a DSS tool and possibly learn something useful from it, and not use it again".

The third group of questions asked the experts their opinion about the future development of DSS.

3. a) What are your opinions about the future development of DSS in Australian agriculture?

The responses from experts can be summarised as follows:

- The future for developing DSS is not good;
- The commercial market for DSS is likely to remain small;
- They will continue to be developed regularly on all sorts of issues; and
- Useful DSS would have been, and will be, adopted.

It was generally believed that the future for developing DSS for Australian farmers was not good. Concern was also expressed that the commercial market for DSS was likely to remain small, so there are likely to be few commercial opportunities for private investment in DSS. "Strong competition for scare public R&D funds will see limited investment in DSS in future". A similar future for DSS has been predicted in the literature (Cox, 1996; Freebairn *et al.*, 2002; Hayman, 2004).

The profitability of developing a DSS was questioned. It was also acknowledged that this is a very difficult field to work in. "Please note that I have tried to make, promote, sell, and use DSS. But my experience is still not all embracing on this issue".

There was a comment that DSS will continue to be developed regularly on all sorts of issues, but "… farmers will continue to not use them". Nevertheless, some experts optimistically believed that useful DSS would have been, and will be, adopted. This is in line with conclusions from well-known DSS scholars (Hammer *et al.*, 2001; McCown, 2002b; Robinson, 2004; Matthews *et al.*, 2005). Given the slow acceptance directly by farmers, respondents raised the importance of targeting farm advisors/consultants. In addition, DSS were said to be useful in the training of undergraduate students. Thus

developing and delivering scientific knowledge in a way that supports farmers' decision-making seems a job worth doing.

b) What criteria describe DSS that are widely adopted?

Suggestions by the experts are summarized in the following dot-points:

- Widespread problems need to be addressed;

- These products need to be location specific;

- There needs to be strong support from initial users;

- Relevance, simplicity, effectiveness, and low cost are key attributes;

- Products other than computer-based products should be considered; and

- Users need to be closely involved in the development of these products.

Respondents suggested many criteria that need to be met for broad adoption of a DSS to occur. The DSS needs to focus on a widespread problem or opportunity, which means it meets the needs of a large number of potential users. Also, that opportunity or problem must be sufficiently complex to require a DSS. This might be useful in situations when farmers cannot just phone a friend or a neighbour for the answer.

The returns (losses) from making a 'correct' ('wrong') decision must be sufficiently large to warrant investing in time and resources to ensure the best (not necessarily right) decision is made. "The 'right' decision needs to be location specific". There was a consensus view that things developed close to home were generally the most focused and more likely to be used.

"Initial users of the DSS strongly advocate its use to other farmers". This is very important to increase the adoption rate of DSS. Indeed, many farmers still identify with the old saying 'If something ain't broke, don't fix it' when they come to adopt a new tool or new technology. Therefore, if farmers do not know about the usefulness of a DSS and how its use can help them, they are unlikely to 'give it a go'.

Other essential criteria included ease of use, simplicity, effectiveness, low cost, and user-orientation. Advances in technology, and the accumulation of experience, have changed the DSS landscape in the years since the first attempt were launched. However, it was stated by some respondents that nothing has changed with respect to organisational commitment, *i.e.* "Only the simplest decision calculus will succeed with a short-term

investment". Also, there is a great deal of competition for farmers' time that needs to be taken into account.

Following suggestions made in preceding paragraphs, a DSS does not necessarily have to be computer-based. Rules of thumb, decision trees, or paper-based tools may actually work better than complex computer-based aids in many cases. Easy-to-use models and decision support tools are more likely to be used. "Because seasons, soils, and farmers are so variable, the answers from simple approaches are usually as good as or better than a fancy model".

Close involvement of potential users at all stages in the DSS development process will ensure that the final product will be well accepted. "Test, test, and re-test with real users". It was stressed that the target group needs to be chosen carefully so that it includes mainly people who already have aspirations to do better in the relevant problem domain.

Ultimately, there is no replacement for experts. Without them to interpret the results, models can be dangerous or at best misleading. In most farming systems: "The farmer is clearly the best expert", and expert farmers generally use a range of other experts to support their decision-making.

7.4.4 Section conclusion

This survey contributed many valuable suggestions and insights that affected the direction of this study. The guidelines suggested by experts were considered carefully and applied in developing the 'final product' of this study. The responses from experts consolidated the author's understanding about the current state of DSS in Australian agriculture. The experts' responses have reinforced many points reported in the literature. The future prospect for the development of DSS was generally predicted to be poor. However, the author believes that new DSS, having appropriate attributes and developed according to suggested pathways, could still be widely accepted. The author also believes that farmers' personalities and their attitudes towards risk management and decision making will play an important role in deciding the adoption rate of DSS in Australian agriculture. The intergenerational change underway in Australian farm ownership must also influence the pattern of adoption of computer based technologies (Plowman *et al.*, 2004; Foskey, 2005). Younger and better educated managers are taking over farm businesses as the older

generation moves out. This might be the basis to suggest that the time is coming when DSS might play a greater role in farmers' decision-making processes.

7.5   Chapter summary

This chapter has reported on the preliminary inquiries conducted as part of this study and opened the possibility of undertaking more in-depth inquiries to be reported in the following chapters. Results of the preliminary interviews and focus group discussions revealed that the essential requirement of farmers in the study area was to practise better ways to conserve soil moisture and to choose which crop to sow at planting time. After comprehensive discussion with advisers and experts in the field, it was concluded that a series of training workshops might be conducted with farmers in the study area to bring various existing risk management and decision support tools to their attention. The next chapter will describe details of these workshops and their effect on the farmers involved in them.

Chapter 8: Risk management and decision support tools workshops

8.1   Introduction

This chapter describes the fourth stage of the research undertaken for this thesis (Figure 6.2, Chapter 6). The observations and reflections from the previous stages reported in Chapter 7 identified soil moisture management and crop choice as the critical issues concerning dryland farmers in southwest Queensland as they dealt with farming risks. That discussion led to the possibility of developing a decision support tool to help farmers in the study area assess their planting options. To help clarify what sort of decision support tool would be effective, a series of workshops were conducted with farmers in the study area while farmers in adjacent areas who were also involved in some similar activities were observed. These workshops provided the opportunity for participants to experience some existing risk management and decision support tools. The workshops were also designed to collect inputs to develop whatever potential decision support tool appeared appropriate. This chapter reports on these workshops and discusses what was learned in the process.

8.2   Managing soil moisture and risk management tools workshop

8.2.1   Objectives of workshop

This workshop was held at Roma in August 2005 to introduce two decision making tools, Howwet? and Howoften? (Freebairn *et al.*, 2002), to a small group of local farmers. The main objectives for this workshop were to introduce some basic concepts about soil moisture management and to provide the farmers with knowledge to help them make better planting decisions. Another objective was to assess the usefulness and usability of the Howwet? and Howoften? programs, as a guide to further work on designing other decision-making tools that addressed risk management at crop planting time. Six farmers attended this workshop (Appendix III includes a report on preparations made for the workshop).

8.2.2   Scenario testing

The first half hour of the workshop was used for scenario testing. The main aim of this exercise was to investigate the types of information that participants needed when making

planting decisions. Another aim was try to understand participants' farming conditions and to go through their thought processes when choosing which crop to plant at a particular time of the year. The initial question asked to start the discussion was: *'What is the decision making process you use for planting and crop choices? (For example, take 1st May 2005 as a starting point and consider the decision you made and the information you needed [to choose which winter crop to plant])'*.

Participants listed nine identifiable pieces of information, which they considered were desirable to know when making planting decisions. This information included stored soil moisture, soil conditions (soil type, texture, soil profile), planting window (most critical period to time, 15-20 days, to ensure successful crop establishment), weather outlook (expected rainfall, temperature, SOI phases, frost, etc), rotation (the cropping history of the paddock), weeds present (what sort of weed problem does the paddock in question have), financial considerations (if farmers are under financial pressure, they could take risks that they normally would not), diseases, and influence from other information sources (QDPI&F Notes, farm consultants, neighbours). It is evident that this is not a simple decision: choosing which crop to plant is a complex problem.

In years past, participants have had a strong preference to plant wheat. It has been regarded as the easiest and most forgiving crop to grow. However, other crops, such as chickpeas, mungbeans, and lucerne, have now come into the suite of crops mentioned because of their ability to contribute nitrogen to the soil or break weed and disease presence in the crop rotation. Another favourable option was to grow oats and/or barley as forage crops for cattle.

8.2.3 Presentation of Howwet? and Howoften? programs

To help participants understand the theory of soil water infiltration, storage, and access by plants, some important concepts were introduced and explained at the beginning of the presentation. These concepts included Water Use Efficiency, Plant Available Water Capacity, and Fallow Efficiency.

Figure 8.1: **Demonstration of profile soil water**

The water holding capacity of soil was demonstrated and the dynamics of water movement in a soil profile where water evaporates from the surface layer and is held against evaporation in lower layers was explained. Various aids including sponges, a plastic soft drink bottle with screw cap, plastic tumblers, a bucket of water, and signs representing days of the month, were used to demonstrate the principles.

Most of the time at the workshop was used for the presentation of two decision support tools – Howwet? and Howoften? These tools were introduced and presented to participants by two staff from the Queensland Department of Natural Resources and Mines (QDNR&M) in Toowoomba, Dr David Freebairn, the developer of these tools, and Mr Norman Gurner.

Howwet? and Howoften? programs were reviewed previously in Chapter 4 of this thesis. Basically, Howwet? is a Windows based-program which uses 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? tracks daily evaporation, runoff, and soil moisture using estimates of weather conditions and rainfall input by the user. Accumulation of available nitrogen in the

soil is based on soil moisture, temperature, soil type, and age of cultivation parameters in the program.

Howoften? is another computer-driven program for examining historic rainfall records to determine the likely probability of future rainfall events. The basic question that Howoften? answers is: 'How often does 'x' mm rain fall in 'y' days within a specified time period?'. Further information about these programs is available from the APSRU website (http://www.apsru.gov.au/apsru/). They can be downloaded without cost by farmers.

Throughout the presentation, participants were seated in pairs and provided with a laptop computer to learn how to use these tools. They were shown how to do a range of simple exercises by the presenters. Each participant was then given a CD containing notes on soil and soil water and copies of these two programs. They were encouraged to take these items home and to try the programs themselves. The same material was also sent to the four farmers invited to the workshop but who were not able to attend.

Figure 8.2: **Workshop participants gaining some experience with the Howwet? and Howoften? tools**

8.2.4 Workshop evaluation

At the end of the workshop, participants were asked to fill in a workshop evaluation sheet (Appendix III). This sub-section summarises the evaluation feedback from workshop participants.

1. *I currently/plan to use the following tools on my farm to estimate soil moisture*

Participants at the workshop had used various tools to estimate the amount of moisture stored in their soil (Table 8.1). All of them stated that they had been using and would continue to use rainfall records and the push probe. Half of them had used soil cores to estimate stored soil moisture and one had used neutron probe information. None of the participants was currently using Howwet?, but four of them said that they would like to try the program on their farm in coming seasons.

Table 8.1: **Tools used to estimate soil moisture**

Currently use		In coming seasons	
Rainfall records	6	Rainfall records	6
Push probe	6	Push probe	6
Soil cores	3	Soil cores	2
Neutron probe	1	Neutron probe	1
Howwet?	0	Howwet?	4

2. *Organisation of the workshop*

Questions framed according to a Likert scale (Burns, 2000) was used to allow participants to make an assessment of the workshop, its organisation, and its usefulness (Table 8.2). Generally, all participants said they valued the day, noting that it was well organised, and useful to them (four participants agreed and the other two strongly agreed with this statement). They also stated that similar workshops would be useful to them. The consensus among participants was that attending the workshop had improved their ability to assess and use tools for monitoring soil moisture, calculate how much soil water is stored, and use soil water and climate information in making more informed crop planting decisions.

Table 8.2: **Evaluation of the risk management tools workshop**

Evaluation statements	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a) I thought that the day was well organised and useful				4	2
b) Similar workshops would be useful			1	3	2
c) Attending this workshop has improved my ability to:					
- assess and correctly use tools for monitoring soil moisture				6	
- calculate how much soil water is stored			1	4	1
- use soil water and climate information in making more informed cropping decisions				4	2

3. *Information needed in making a planting decision at a given time in the year*

All participants emphasised the importance of knowing soil moisture and understanding past cropping history when making planting decisions (Table 8.3). Expected yield and expected in-crop rain were also mentioned by most of them (5/6) as being important.

Table 8.3: **Information needed in making a planting decision**

Information	Number of participants agreed
Soil moisture	6
Past crop history	6
Expected in-crop rain	5
Expected yield	5
Expected gross margin	3
Variable costs	2

Only some of the participants indicated the need to consider gross margins and variable costs. The information mentioned here is somewhat limited when compared to what was

suggested in the scenario testing exercise reported previously. This difference might be derived from the different ways that questions were asked (*i.e.* by open-ended questioning in the scenario testing session and a limited set of closed questions in the evaluation sheet).

4. Crops to be included in a program/tool to assist with planting decisions

Workshop participants all indicated that they would like to see wheat and chickpeas included in any program or tool developed to assist their planting decisions. Half of them would also like to see sorghum, barley, and pastures included in the planting support tool. One or two of them mentioned the need to have sunflower, and other legumes (lablab and mungbeans) included in the tool.

5. Do existing products answer participants' needs

Only one participant at the workshop stated that the programs that had been demonstrated met his needs. The other five said they were not sure if the programs could answer their information needs, or not until they tried them more extensively.

Workshop participants then suggested some changes to the products so that they would suit their needs. The first suggestion was that the Howwet? program would be more useful to the farmers if it could include some combination of SOI, MJO, and ENSO predictions. Another suggested change was to allow the program to be able to use a soil nitrogen parameter that was known and examine if it had any effect on nutrient build-up. They also suggested including a greater number of rainfall stations in the Howoften? program.

6. The WhopperCropper program

The WhopperCropper program (reviewed previously in Chapter 4) was mentioned to participants (before they filled in the evaluation sheet) as an existing program which allows a lot of planting scenarios and hypothetical crop choices to be evaluated. Only half of the participants said they had heard of the program; the others could not recall having heard of it. The program had been used by only one of the farmers and it was acknowledged as being useful. The rest of the workshop participants all expressed interest in trying this program.

7. Preference for tools to assist planting decisions

One workshop participant did not express a preference between computer-based or paper-based tools to assist planting decisions. Another one preferred paper-based tools. The four

remaining participants were comfortable with computer-based tools, although they said these tools must be kept as simple as possible.

8. Further involvement in the study

All workshop participants stated that they would be happy to continue to be involved in this study about risk management and decision support tools for dryland farmers in southwest Queensland.

9. Opportunity cost of missing one day in the planting window

Generally, participants claimed that they miss one day's planting in most seasons for a range of reasons. There is little cost if the day missed is at the start of the planting window. If the day missed was towards the end of the planting window, it could mean that up to 50 ha of land might be left fallow. This could cost several thousand dollars in forgone income depending on the potential crop yield and prices.

10. Other comments

There were some additional comments made at the end of the evaluation sheet. Overall, workshop participants regarded the morning was very informative and noted that: "It is a pity that more farmers did not attend". In regard to the programs presented, participants commented that having a program which would output a list of options after considering relevant input data (rainfall, soil type, weather, etc.) would be useful to them.

8.2.5   Section conclusion

This workshop introduced a small group of farmers in the study area to some existing decision support tools. Workshop participants appreciated the usefulness of these tools. They also expressed the view that the workshop improved their ability to manage soil moisture and make planting decisions. The feedback from workshop participants opened the way for another workshop at which the WhopperCropper program would be presented and further discussion about the information needed to design a planting decision support tool would be possible.

8.3 Eastern Faming Systems workshops

8.3.1 Objectives of workshops

The main objective of the series of Eastern Farming Systems workshops, which were conducted by staff from QDPI&F, QDNR&M, and CSIRO in 2005, was to improve farmers and consultants' understanding of soil water management in dryland cropping systems. Another objective was to introduce farmers and consultants to a number of tools that would enable them to undertake their own assessment of soil characteristics and available soil water. The workshops were also aimed to help farmers and their advisers apply soil water information to make more informed cropping decisions (Wockner *et al.*, 2004).

8.3.2 Workshop evaluation

This series of workshops were part of activities of the Eastern Farming Systems (EFS) project[1] funded by the Grains Research and Development Corporation. The EFS project was conducted in a farming area that is adjacent to the study area.

One of the workshop facilitators (Mr Norman Gurner) was a presenter at the managing soil moisture and risk management tools workshop reported in the previous section. He introduced workshop participants to this research and asked them to fill in the evaluation sheet at the end of the workshop.

Although these workshops were not conducted as a part of the PhD study, for consistency, participants at these workshops were asked to fill in the same evaluation sheet that was used in the previously-described workshop (Appendix III). The reason for evaluating these workshops was to see if there was any difference, in terms of understanding soil moisture management and making planting decisions, between farmers in the study area and farmers in the broader farming community. This could provide guidance about the possibility of having wider application of the results from this study as well as having implications of this study.

For the sake of brevity, the evaluation feedback from these workshops is not addressed in this thesis. However, a brief summary of the feedback is included below in the section conclusion.

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[1] : Please refer to this link for more detail of the EFS project: www.apsru.gov.au/apsru/Projects/efs/

8.3.3 Section conclusion

Two groups of farmers attended the EFS workshops. They were similar in many respects to the group of farmers at Roma, and indicated the importance of information such as stored soil moisture, expected in-crop rain, past crop history, and expected yield before making a planting decision. Their dominant crops were wheat and sorghum but chickpeas, barley, and pastures were being considered more often as alternatives.

Most of the farmers who attended these workshops did not know about the WhopperCropper program and some of them said they would like to try it. Most of them preferred computer-based tools to paper-based tools to assist their planting decisions, but they stated that these tools must be simple and easy to use.

In summary, the evaluations of these workshops reported a similar pattern of understanding about soil moisture management and planting decisions among the farmers as those from areas adjacent to Roma. Farmers in the adjacent areas had also used various tools to estimate soil moisture, including rainfall records, push probes, and soil cores. Howwet? was not used by most farmers but almost all of them stated that they would like to try the program in coming seasons. They acknowledged that the organisation of such workshops was useful for them.

8.4 Decision support tools workshop

8.4.1 Objectives of workshop

This workshop was organised as a 'follow-on' from the previous workshops on Howwet? and Howoften? programs. The main objective was to introduce a tool to aid decision making, the WhopperCropper program, and to assess the usefulness and usability of this tool as a preliminary guide to further work on the design of a planting decision support tool. The occasion was also used as an opportunity to introduce some new staff involved in the Western Farming Systems (WFS) project phase III to farmers at Roma. Eleven farmers attended this workshop at Roma on 18 November 2005 (Appendix IV includes a report on preparations made for this workshop).

8.4.2 Workshop discussion

The workshop commenced with an introduction of the new WFS project team formed to carry out a sub-project on 'Climate and Risk in the grain and graze industries' for Phase III of the WFS project. Outcomes from the first two phases of this project (1996–2004) were reported previously in Chapter 5 of the thesis.

After the introduction, participants were presented with a brief summary of the previous focus group discussions and workshop results. For the rest of the first hour of the workshop, participants reviewed their most recent harvesting season and discussed the available summer cropping options. These discussions are summarised in the following paragraphs.

Results from the 2005 winter cropping season

Workshop participants were asked to review the performance of their 2005 winter crops. Generally, they said that the season turned out fairly well even though it was "exceedingly dry at the start". The average yield was two tonnes of wheat per ha. This was better than anticipated. These farmers mostly grew the AWB-preferred variety (Baxter) for the ease of marketing and selling their product.

Having practiced summer fallow, most of them had good soil moisture for planting – about 100 mm (four inches) of soil water before planting. Rainfall was unevenly distributed and below average during the season, ranging from 50 mm on some farms to 200 mm on others. The consensus among participants was that 25 mm of rain could mean adding an extra 200 kg of wheat per ha to their yield.

The most common disease in the winter wheat crop was crown rot. It is principally a disease of the tiller bases or crown of the plant. In addition, lack of in-crop rain had caused a decline in grain quality (a lot of screenings or under-sized grain had to be removed). Another problem was that all grain in the head did not fill because there was no rain when it was still green.

There was a long discussion about applying fertilisers to increase yield. Overall, participants agreed that "25kg N/ha would be the best option". However, they said that this needed to be considered carefully because applying more N would incur more cost. Some participants had applied urea and phosphate fertilisers to their paddocks but they claimed

that no significant yield improvement had been achieved. Some of them also planted mungbeans and chickpeas. These crops were well regarded in terms of improving soil nitrogen.

Workshop participants agreed that the common date for sowing winter crop would be around mid-May. However, some of them stated that "April is the best time to plant", provided that it is not too hot or dry. It was also claimed that the worst paddocks were in 'new ground' (four years or less in cultivation). Participants also said that it was difficult to predict yield: "Those [crops] that looked best did not do so well, and the stuff that started looking bad went two tonnes [of wheat] per ha".

In concluding this discussion, participants appreciated that it was helpful for them to review what they did in the past season. They claimed it would enrich their experience and help them make better decisions in coming seasons. The discussion then moved on to the selection of summer crops.

What are/will be the available summer cropping options?
Workshop participants said that weeds were a big issue with summer crops. The two main weeds included buckwheat (*Fagopyrum esculentum*) and fleabane (*Conyza lencantha*) and they could ruin summer crops, especially in seasons without adequate rain. So it was very important to "kill weeds first" before planting any crop.

Soil moisture was an important consideration before making a planting decision. "We are not going to do anything if we will not have enough moisture". Participants all claimed that they usually did not have enough soil moisture to plant summer crops on their farms and they had to "wait for rain". In the case of having very limited moisture, the strategy would be "cutting the planting rate" [reducing plant density].

These farmers preferred to leave most of their land in summer fallow. This was understandable because they farm in such a dry environment that has low and unreliable rainfall. Summer fallow creates the opportunity to store soil moisture for the start of their winter crops. "Yield [of wheat] will go up on fallow country".

Generally, participants stated that they would use 25-30% of their land for summer crops. The predominant crop for summer planting in this area was sorghum. Some participants said: "Grain sorghum – what else can you put in" while others added: "Graze the sorghum

and store a lot of it for cattle. Back up for grain later on, and do not worry about the price". Other possible summer crops included mungbeans and lablab for fodder. Lablab was regarded as a good crop but the farmers claimed seed was expensive to buy. Late summer (January and February) was believed to be the better time to plant summer crops.

Participants also listed other factors that need to be considered before making a summer planting decision. Those factors included price, SOI phases, and potential gross margins. It was agreed that it is hard to know everything and that "you have to take a risk with farming".

8.4.3   Presentation of WhopperCropper program

The WhopperCropper program (reviewed previously in Chapter 4) was presented to participants by Mr Howard Cox from QDPI&F. Mr Cox was the leader of the 'National WhopperCropper project – delivering risk management to agricultural advisors' (Cox *et al.*, 2004).

The presentation included a review of the wheat crop just harvested and a preview of the coming summer crops. The presentation and discussion took more than one hour and provided participants with the opportunity to ask questions and choose relevant scenarios to test the program. Generally, participants claimed that the model was optimistic because it did not take all potential problems such as frosts and diseases into account. Most of the workshop participants agreed that: "WhopperCropper wouldn't have changed decisions, but it would have provided extra support".

Figure 8.3: **Workshop participants attending the WhopperCropper presentation**

8.4.4 Workshop evaluation

An evaluation was originally planned to be conducted at the end of the workshop, but the discussions and presentations lasted longer than planned so participants were given the evaluation sheet to take home to complete. A copy of this evaluation sheet is included in Appendix IV. A letter enclosed with a return envelope was sent to each participant asking for the return of the workshop evaluation. From the 11 participants who attended the workshop, eight evaluation sheets were returned. The following paragraphs summarise participants' responses to the statements and questions asked in the evaluation sheet.

1. Statements in regard to the organisation of the workshop

A Likert scale (Burns, 2000) was used to gather participants' assessments in regard to the workshop organisation and its usefulness (Table 8.4). All participants stated that the day was well organised and useful for them (five participants agreed and the other three strongly agreed with this statement).

There was only one participant who had a neutral opinion, the rest of them either agreed or strongly agreed that similar workshops would be useful for them. Even though there were some neutral responses, the consensus among participants was that attending the workshop had improved their ability to choose which crop to sow and when to plant it. Furthermore, they recognised the factors influencing crop choice, and were able to analyse different starting conditions and seasonal forecasts.

Table 8.4: **Evaluation of the decision support tools workshop**

Evaluation statements	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a) I thought that the day was well organised and useful				5	3
b) Similar workshops would be useful			1	6	1
c) Attending this workshop has improved my ability to:					
- choose which crop to sow and when to sow it		1	2	5	
- realise factors influencing crop choices			2	4	2
- analyse different starting conditions and seasonal forecasts			2	4	2

2. Which crops should be included in a program/tool to assist planting decisions?
Workshop participants indicated that if they had a program or tool to assist with planting decisions, they would like it to include wheat, chickpeas, and sorghum (Table 8.5). Four out of eight farmers would like to see pastures and barley included in the planting decision support tool. Sunflower, lablab, and mungbeans were mentioned as additional crops by two individual respondents.

Table 8.5: **Crops to be included in a planting decision support tool**

Crop	Number of times mentioned
Wheat	8
Chickpeas	7
Sorghum	7
Pasture	5
Barley	4
Sunflower	1
Lablab	1
Mungbeans	1

3. *Would a crop choice chart (like a wall calendar) to assist planting decisions be useful for you?*

Half of the participants (four out of eight) answered "yes" to this question. Three participants said "no", and one participant answered "don't know".

4. *Is WhopperCropper useful for you?*

Four out of eight participants suggested that WhopperCropper would be useful for them. Among the remaining four participants, one said "no" and three others said "don't know".

5. *Are you going to use WhopperCropper in the future to assist your crop management decisions?*

Only three participants said that they would like to use WhopperCropper in the future to assist their crop management decisions. One participant said "no" and the other four were not sure if they were going to use this program in the future or not.

6. *Other comments about WhopperCropper program*

Generally, participants said that WhopperCropper was another helpful tool to use to assist decision-making. However, there was still reluctance to commit to an assessment of the program because most of them had not been able to experiment with it. It was also acknowledged that it was useful and interesting to hear other growers' views. Moreover, it was claimed that nothing could replace experience.

7. *Further involvement in the study*

All participants emphasised that they would be happy to continue to be involved in this study about risk management and decision support tools for dryland farmers in southwest Queensland.

8. *Factors influencing the choice of summer crop options*

Participants listed many factors that influence their choice of summer crop. In regard to choosing sorghum, the factors influencing the decision included soil moisture, planting window, weather outlook (especially chance of planting rain from the first week of December to the second week of January), price and market outlook (both domestic and export), cash flow, and the need to have a rotation crop to move out of the winter crop sequence to control diseases.

Other crops mentioned were lucerne, lablab, and mungbeans. Lucerne was said to be good to provide a high value crop for animals and to fix nitrogen in the soil. Lablab could be planted any time from October onwards as long as there was some sub-soil moisture and there had been a planting rain. This crop was said to improve nitrogen for the following wheat crop. Some participants said that they would plant mungbeans if they had good late summer rains. Generally, these were regarded as good crops to improve soil fertility and to provide fodder for livestock.

Participants all agreed that summer fallow was essential in the southwest region of Queensland to conserve and store moisture in the sub-soil for the winter crop. Weeds were always a problem and they needed to be sprayed when they were small.

9. *Factors influencing the choice of winter crop options*

Similar to the choice of a summer crop, participants suggested many factors that influence their choice of a winter crop. Wheat was obviously the first choice among the winter cropping options. Wheat was chosen because it was easy and reliable to grow. "Wheat is possibly the easiest, safest, and cheapest crop to grow". Compared with other winter crops, wheat needed little in-crop rain, and it could provide good stubble cover after harvesting to control erosion. The market for wheat was not a big concern because off-farm storage was readily available and delivery points were reliable. Other factors that influenced the choice of wheat included cash flow, the amount of stored soil moisture at planting, and planting window. Wheat could also be used as feed for cattle if it failed to produce a satisfactory grain crop.

Chickpea was regarded as a useful rotation crop. "You can grow a better wheat crop after chickpeas". It was regarded as a good crop to use as a break crop to control crown rot in wheat and it also contributed to the improvement of nitrogen level in the soil. Price, stored soil moisture, and planting rain might also affect the choice. However, it was claimed that potential diseases made it a harder crop to grow than some others.

Barley was said to grow well but marketing was a problem. "If there was a feedlot near, farmers would grow a lot more barley". Barley could leave good stubble for ground cover and stock feed after harvesting. Other factors that might influence the choice of this crop included price, stored soil moisture, market demand, and the need for crop rotation.

Participants mentioned other possible winter crops including oats and lucerne. Oats were mostly grown for cattle feed, stock fattening, and hay production. "Oats for grazing is an important crop and it can be useful for hay". This crop also helped clear paddocks of weeds for summer crop or pasture. Lucerne could be used as a break-crop in the rotation and used for sheep grazing or hay making. This crop could be under-sown to wheat or sown separately. Winter fallow was considered useful to control wild oats and save moisture for summer crop.

8.4.5 Section conclusion

This workshop introduced some more existing decision support tools to the selected group of farmers. They acknowledged that attending the workshop had improved their ability to choose which crop to sow and when to plant it. They had an appreciation of the factors influencing crop choice, and were able to analyse different starting conditions and seasonal forecasts. Participants suggested many factors that influence their choice of summer or winter crops to be planted. These factors are considered essential for further investigation in this study. Workshop participants also noted that the day was well organised and useful for them.

8.5   Seasonal climate risk management workshops

8.5.1   Objectives of workshops

Two workshops were conducted at Roma and St George (two main centres for activities in the WFS project) in April 2006. These workshops were planned activities of the WFS project Phase III. This part of the PhD study was regarded as part of the WFS project and the candidate had been involved in those activities as a member of the project team. The main objective of these workshops was to discuss the 2006 winter climate forecasts and crop outlook. Other objectives were to present the latest findings in climate research in regard to the Southern Oscillation Index (SOI) and the Maiden-Julian Oscillation (MJO) and discuss various issues including soil water, nitrogen, and climate risk with participants. The workshops also presented participants with two decision support tools, WhopperCropper and Yield Prophet, to help them improve their ability to manage climate risk.

Yield Prophet is an internet based decision support system that was developed as part of a commercial joint venture between Birchip Cropping Group[1] and APSRU (GRDC, 2005). Similar to WhopperCropper, this system was based on the APSIM crop simulation[2]. The computer program simulates growth of a range of crops, using up to 100 years of historical weather data, to estimate the yields that might be expected. It uses the farmers' current soil conditions at the start of the season, as the starting point. It can generate reports for outcomes such as expected yields and likely responses to nitrogen fertiliser.

Flyers advertising the workshops were distributed to farmers in the region through QDPI&F regional offices. It did not cost participants anything to attend the workshops and they were provided with refreshments. The workshop at Roma had 14 participants (12 farmers and two consultants) and the St George workshop had 15 participants (10 farmers and five consultants).

8.5.2   Summary of discussions

The workshops commenced with a brief personal introduction by each participant. Workshop facilitators then asked participants to write down their expectations for the day. A presentation on seasonal climate forecasting was given and followed by discussions

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[1] : http://www.bcg.org.au/
[2] : http://www.apsim.info/apsim/

about the use of climate indicators/tools. After lunch, participants discussed the key considerations as they approached the winter crop planting period. Two decision support tools (WhopperCropper and Yield Prophet) were then presented to participants. At the end of the workshops, participants were asked to fill in the workshop evaluation sheet. The following paragraphs report on the discussions of these two workshops.

Expectations of workshop participants

Workshop participants indicated various interests and expectations for the day. Generally, most of them wanted to have a better understanding of weather indicators and the level of accuracy of their forecasts. Some common expectations included "to have an understanding of data available and how to use it successfully", "to use and evaluate better weather forecasts in management", and "to seek accurate climatic indicators for management decisions". Another common expectation was to understand seasonal weather outlooks. Some participants wanted "to see the seasonal outlook for the next 6 months" and "to get an idea of the climate odds for 2006 and further", while others would like "to see what the future holds for our rainfall since seasons seem to be getting less and less rainfall". Participants also expected to be updated with advanced technologies to see if these could help them change their farming practices. Common comments in regard to this point included "to catch up with programs and technology and see if they are appropriate to use", "to see if we can rely on weather outlook [information] to change our farming practices", and "to see if there is anything we are overlooking in the evaluation of our farming procedures". In addition, participants were interested in attending the workshops to improve the information base to "better manage stored soil moisture" and "judge when to plant and when not to". Other expectations included "to learn more about the MJO cycle", "to see what a climate risk workshop involves – never been to one before", and "to listen and learn what you've got to say".

Use and usefulness of climate indicators

Participants at the workshops listed the climate indicators/tools that they were using and discussed their usefulness. At the Roma workshop, most of participants indicated they had looked at the sea surface temperature and other forecasting information. Four out of fourteen participants said they had used SOI and five out of fourteen participants said they had used MJO information. However, it was claimed that the accuracy of these tools was low. "MJO and SOI are really only of academic interest but poor reliability" and "lots of farmers look at SOI and try to utilise it – but very sceptical". It was also claimed that SOI can be more accurate in May, but this would be too late for winter crop planting decisions.

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Participants at the Roma workshop shared a common view that the best indicator of crop performance in the coming season is soil moisture in the field. Some of them said that "stored soil moisture is the key driving planting decisions" and others added "the best indicator of future crop performance is the amount of moisture stored in the soil at seeding time". The majority of participants indicated that they based planting decisions on past experience and used knowledge of local history to make management decisions. However, there were some participants who suggested that "the past is not always a good indicator of the future" and "we should be looking forward in farming".

Generally, participants all agreed that the "sticking point" with forecasting tools is that "accuracy needs to be improved". Comments regarding this point included "we need more reliable indicators of rain", "[put] no reliance on climate indicators: [they] can have a negative effect on practices", "seasonal forecasts are of very limited value", and "if these predictions were 80% correct, they would have a big effect on the decisions about area to plant and fertiliser application".

At the St George workshop, discussion regarding these issues was cut short because of time limits. However, more participants at this workshop were using climate tools than at the Roma one, possibly because there were more consultants attending the St George workshop. Ten out of fifteen participants said that they had heard of MJO before the workshop and seven of them were thinking that MJO could affect some of their tactical decisions. Three out of fifteen participants were looking at the SOI and changing their management decisions accordingly. Similarly to participants at the Roma workshop, participants at this workshop claimed that the SOI did not provide much accurate information until May when it would be too late for them to make planting decisions for winter crops.

Overall, participants at St George also valued stored soil moisture at planting time quite highly. "Soil moisture is the critical thing" and "If you have very poor moisture and a rapidly falling SOI, you'd better go on holiday instead of planting any crop".

Key considerations moving into the planting period
These workshops were held in April and participants discussed their key considerations as the winter planting approached. The three main issues discussed included "to plant or not to plant", "how much moisture is in the soil", and "nutrient application". Generally, all

participants stated that they would plant some part of their land to winter crops. However, they said that they would determine the amount of stored soil moisture before making planting decisions, "got to have moisture to plant". Normally, participants used soil testing and paddock history to find out the amount of stored soil moisture. This also helped to assess the amount of nitrogen available in the soil and to make the decision of whether to apply nitrogen (pre-plant, or in-crop), and how much to apply.

The choice of crop was another big consideration. Participants mentioned the available options included grain crops (wheat and oats), legumes (mostly chickpeas), and forage crops (oats for forage and lucerne). The predominant crop in the area was wheat and the expected wheat yield was around 2.0 t/ha.

Other issues discussed included variety, planting time (early, mid, or late season), diseases, weeds, and stocking rate. "Variety to plant: if getting late, do plant and hope for rain", "how good is the weed control – will they need to be sprayed again before planting?", and "buy more cattle, shear sheep".

In regard to using decision support tools to augment their decisions, most workshop participants said that they based their planting decisions on historical data and their 'gut feel' to make a planting decision. This indicates an inability to articulate the reasoning behind their decisions. The reasons may never have been explicitly considered and rather they look upon the planting decision as something that is akin to an art and probably handed down from father to son. Only a couple of participants in both workshops mentioned that they had used one or more of the available tools to assist their decision making. The rest of the participants claimed various reasons that prevented them from using decision support tools. These obstacles included computer illiteracy, time constraints, irrelevant information, and the fact that these tools were not user-friendly. Generally, participants stated that decision support tools could not make the decision for them. However, they would like the tools to produce information, or some guidelines, that they could use as a basis for making their own decisions.

Figure 8.4: **Participants attending the Roma workshop on seasonal climate risk management**

Figure 8.5: **Participants attending the St George workshop on seasonal climate risk management**

8.5.3 Workshop evaluation

Generally, participants valued the workshops as useful activities and said they provided lots of opportunities to participate and share ideas. They also agreed that the workshops helped them to interact and learn from other people's experience. Participants appreciated that the workshops had improved their ability to make sense of climatic information. However, most of them did not agree that the workshops helped answer their planting questions or helped develop their skills to use decision support systems.

There was a brief discussion after participants completed the workshop evaluation sheets. By and large, most participants were still wondering about outcomes from the workshop. The majority of participants also agreed that the workshop was interesting but they were unsure about its impact on their farming practices. The common comment was that "The workshop was interesting – so what?" Some of them posed questions such as "How are we going to apply these tools?" or "Which is the best system to follow?" Some participants claimed that "Computer programs can never ever take in all the variables that we as farmers have to cope with", and "Your management decisions can never be made by computer programs". Instead, they valued the use of common sense and experience quite highly.

8.5.4 Section conclusion

Various issues regarding planting decisions and climate risk were discussed at the workshops, which overall, were appreciated by participants as useful to them. The workshops presented some tools to help participants improve their ability to manage climate risk. However, at the end of the workshops, participants still questioned what would be the best system to follow. They agreed that the workshop helped them to make sense of climate information, but they still expressed concerns about its accuracy.

8.6   Chapter summary

In conclusion, farmers in the study area, as well as farmers in adjacent farming communities, valued the workshops on climate information and crop planting decisions conducted for them. They appreciated being involved in such an educational process to learn about existing decision support tools that most of them had not heard about previously. However, the majority of this group of farmers was still reluctant to use these tools. Possible causes might be that these tools are complex or they might be regarded as

irrelevant for farmers to use in their specific conditions. This could reinforce the conclusion reported in the previous chapter that a simple planting decision support tool might be more appropriate for and helpful to these farmers.

The next stage of the study explores the factors influencing farmers' choice of a summer/winter crop in more detail. A decision support tool that captures the timing and logic of the decision-making process and incorporates existing sources of information relevant to help make the choice among dryland crop options in southwest Queensland is presented.

Chapter 9: Designing a 'Key to dryland planting decisions'

9.1   Introduction

This chapter describes the design and development of a decision support tool entitled 'Key to dryland planting decisions' for dryland farmers in southwest Queensland[1]. The chapter consists of four main sections in addition to the introduction and conclusion. Section 9.2 introduces the software program used to develop the key. Section 9.3 provides a detailed description of the key and explains how it works. Section 9.4 reports results of a workshop conducted to present a draft version of the key to potential users and seek their feedback. Section 9.5 covers the revision and final development of the key.

9.2   Lucid3 software program

9.2.1   Introduction to Lucid3

After careful examination of different possible software programs, the author and his advisors chose the Lucid3 program as potential software to develop a planting decision analysis tool. At the end of March 2006, a meeting was held between the author, his principal advisor, and the developers of the Lucid program which facilitated the use of Lucid3 for this study. The following sub-section presents an overview of this software and explains why it was chosen.

9.2.2   General description of Lucid3

The Lucid software development team is located at the Centre for Biological Information Technology (CBIT) at The University of Queensland, Australia. The Centre's mission is to develop innovative tools for training and decision support for application in biological research, training, and natural resource management (CBIT, 2006a).

There have been many tools and applications developed using Lucid software. Some of these include 'Aquarium and Pond Plants of the World' (Winterton, 2004), 'Declared Plants of Australia' (Navie, 2004), 'On The Fly - The Interactive Atlas and Key to Australia Fly Families' (Hamilton *et al.*, 2006), 'Key to The Herpetofauna of Fiji'

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[1] : The two terms 'key' and 'tool' will be used interchangeably in this chapter to refer to the 'Key to dryland planting decisions'.

(Morrison, 2006), 'Invasive Mite Identification: Tools for Quarantine and Plant Protection' (Walter, 2006), 'Scale Insects: Identification Tools for Species of Quarantine Significance' (Miller *et al.*, 2006). Various other interactive multimedia tools and products have also been developed using Lucid software. Their names and descriptions are available on the CBIT website: http://www.cbit.uq.edu.au/software/.

Lucid3 is a new version of the Lucid family of products, providing new features requested by Lucid users and improving the handling of many common functions. Written in Java, Lucid3 is a cross-platform implementation, and will run on any Java-enabled operating system (such as Windows, Macintosh, Unix, Linux, etc.). The Lucid3 system comprises a Builder and Player for creating and deploying effective and powerful identification and diagnostic keys. The Lucid3 Builder allows an expert in a group of entities (plants, animals, diseases, minerals, archaeological artefacts, etc.) to create a key that can be deployed via a CD-ROM or over the World Wide Web (CBIT, 2006b).

Users who wish to identify an entity in the group for which the key has been built can 'describe' their specimen to the key by choosing features that match the specimen. The key progressively eliminates entities that do not match the chosen features until only one or a few remain. During the identification process, the user has access to multimedia fact sheets and images that provide further information for making an identification (CBIT, 2006b).

Lucid3 Builder

The Lucid Builder is a powerful software product that allows users to construct multimedia Lucid keys on any topic quickly and easily (CBIT, 2006c). The builder comes with an easy-to-follow tutorial to help users learn the basics of constructing keys with Lucid3.

When the Lucid3 Builder is opened, three panels (Properties, Features, and Entities) will be displayed. The Features and Entities panels hold the feature (character) and entity (*e.g.* taxon) trees to be used in the key. The Properties panel is used to set various properties for items in the other panels. The list of features and states can be used to describe the entities. A matrix of scores is compiled for the features associated with each of the entities, and various image and HTML attachments (images, web pages, etc.) are provided for the entities and features, to provide extra information to users.

The Lucid3 Builder provides all the tools necessary to create the entity and feature lists, encode the score data, and attach information files to items (CBIT, 2006c). Lucid3

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version3.3 Builder Help provides a comprehensive package of explanations and instructions on how to build a key. This can be viewed at the Lucid website: http://www.lucidcentral.org/lucid3/v3_3help/builder/default.htm.

Lucid3 Player

The Lucid3 Player is used to play interactive identification or diagnostic keys created with the Lucid3 Builder. It comes in two forms: as an application for use on a users' hard drive and packaged with CD based keys; or as an applet, which is embedded, and used directly, within a webpage. The Lucid Player provides users with an effective and powerful means of interacting with Lucid keys, enhancing their ability to make identification and diagnostic decisions (CBIT, 2006d).

The identification process facilitated by the Player is extremely effective and involves eliminating taxa or other objects according to characteristics or symptoms associated with the specimen that users are trying to identify or diagnose. This process is supported by photographs, drawings, sound, video and text, which help to confirm that users' choices are correct or most appropriate (CBIT, 2006d).

The Lucid3 Player provides other tools and information to help with the identification. Features in Lucid keys are usually provided with explanatory notes and images to help understanding. Subsets can help organise the list of features to make it easier to manage, and the Player's Best function is a powerful tool to help decide which feature to address next (CBIT, 2006d).

9.2.3   Section conclusion

This section has provided a general description of the software used to create a key for dryland planting decisions. This key was designed to assist dryland farmers with their crop choice decisions. They can use the key to reduce progressively the number of cropping options that are not relevant or applicable to their conditions. Lucid3 was chosen as an appropriate software program for this task because of its strong capacity to identify different entities and choose appropriate diagnostic decisions. The next section will examine the key and its components in detail.

9.3 'Key to dryland planting decisions'

9.3.1 Background information about the key

Results of the interviews and focus group discussions reported in Chapter 7 revealed that the most important source of risk that farmers in the study area said they have to face was weather variability (which translates into production risk). Consequently, the essential management problem for these farmers was to practise better ways to conserve soil moisture and to choose which crop(s) to sow when a planting opportunity arose. A series of training workshops was subsequently conducted with farmers in the study area to bring various existing risk management and decision support tools to their attention (Chapter 8). Evaluation surveys at the end of these workshops identified that a simple planting decision support tool would be appropriate for and helpful to these farmers.

As mentioned previously, the 'Key to dryland planting decisions' was designed to assist dryland farmers with their crop choice decisions. The key captures the timing and logic of the decision-making process and incorporates existing sources of information relevant to helping farmers make decisions about various dryland cropping options in southwest Queensland. A range of factors affecting dryland planting decisions were identified through observations and discussions with farmers in the series of focus group meetings and workshops. A draft of a crop choice chart for dryland planting decisions was constructed before developing the key.

The key provides 12 different cropping options (details of which are given in sub-section 9.3.3 – List of entities). Farmers can choose a crop or crops to plant from the various options presented to them in the input window of the key. The choice will be influenced by their available resources and preferences including amount of stored soil moisture, their expectations about in-crop rainfall, the time of planting, etc. The key will progressively reduce the number of cropping options that are not relevant or applicable to farmers' conditions. In addition, the key provides farmers with a lot of additional information about the advantages and disadvantages of different cropping options (to be found in the attachments, such as the crop management notes) when the key is used.

The following sub-sections (9.3.2 – 9.3.6) provide further background information and description of the key, especially, sub-section 9.3.5 (Scoring matrix) explains why and how the decision options were chosen.

9.3.2 Input data for the key

Guidelines and advice from DSS experts in the survey reported previously (Chapter 7) have been used and applied extensively in designing the key. The key was developed to address planting decisions faced by dryland cropping farmers at Roma, southwest Queensland. These decisions were a 'widespread problem' and 'causing considerable concern' to these dryland farmers[1]. Developers (the author and his advisors) had been 'working closely' with a volunteer group of farmers through the whole process from assessing the need for, to design of, and testing of the key. These farmers contributed significantly to the input data that were used to build the key. This group of farmers could be regarded as a motivated and committed audience (Robinson, 2004).

The key was developed to be a 'very simple' and 'quick-to-use' decision support tool. Even users with very low-level computer skills can use the tool. In addition, most of the input data for the key were either provided by farmers or collected from the QDPI&F website. Therefore, it could be assumed that these data were relevant and applicable to the study area. This would enable the key to be 'location specific'. Moreover, this study had some financial support from the QDPI&F Western Farming Systems project which would enable free distribution of the final version of the key (deployed via CD-ROM and the Internet) to cooperating farmers and QDPI&F staff. It was also believed that the key would gain 'strong support from initial users', the group of dryland farmers who had been involved closely and participated willingly throughout this study.

As mentioned above, input data for the key were provided mainly by the volunteer group of dryland farmers in southwest Queensland. Their data had been collected through a series of group discussions and workshops conducted over the past year (Chapters 7 and 8). Input data applicable to the study area were also selected from other different sources. These included various governments' websites (such as QDPI&F[2], and BOM[3]), the QDPI&F's CD-ROM of Crop Management Notes (Summer 2004 and Winter 2004 editions), and discussions with QDPI&F researchers and experts, etc.

The input data has also been refined with help from a young farmer from Roma, southwest Queensland. This farmer had been involved in all phases of this study from group discussions to training workshops, prior to starting a Bachelor of Agribusiness degree at

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[1] : Words used in inverted commas refer to critical guidelines from experts reported in Chapter 7.
[2] : http://www.dpi.qld.gov.au/
[3] : http://www.bom.gov.au/

The University of Queensland Gatton Campus. The author consulted and worked closely with this young farmer to refine and clarify all of the input data used for the key.

9.3.3 List of entities

The entities list for the key consists of 12 major cropping options considered as being applicable to dryland farming systems in southwest Queensland. The list included wheat, chickpeas, barley, lucerne, oats, winter fallow, grain sorghum, forage sorghum, mungbeans, grain lablab, and forage lablab, as well as summer fallow. Specifically, these were the crops that have been planted by dryland farmers or had been mentioned in the workshops as cropping options that they would like to include in a planting decision support tool.

All entities (cropping options) are illustrated with visual images. Moreover, there are crop fact sheets and comprehensive crop management notes attached to each crop to provide users with more detailed information about planting and managing the crop.

9.3.4 List of features and states

In Lucid3, features and states can be used to describe or identify entities. The key has 13 features including five numeric, one grouped, and seven multi-state features. The numeric features are amount of stored soil moisture, expected in-crop rainfall, expected yield, expected live weight gain for cattle that might be grazed on forage crops, and nitrogen application. Climate outlook is a grouped feature because it includes other features (SOI phases, and expected in-crop rainfall). The multi-state features include SOI phases, planting window, past crop history, market status, risk attitude, other information sources, and other influencing factors.

The multi-state features consist of 35 states that can be used in conjunction with the numeric features to identify and describe the choice of each crop in the entities list. The list of states for the key is included in Appendix V.

These features and states were included in the key because they had been mentioned by dryland farmers through workshops and group discussions as significant factors affecting their planting decisions.

9.3.5 Scoring matrix

Multi-state features in Lucid3 may be scored using seven possible scores:

☐ Absent - the state does not occur in the entity.

☑ Common - the state occurs commonly (or always) in the entity.

☑ Rare - the state occurs rarely in the entity.

☐ Uncertain - it is not known whether the state occurs in the entity or not.

☑ Common and Misinterpreted - the state does not occur in the entity, but it could be commonly misinterpreted that it does.

☑ Rare and Misinterpreted - the state does not occur in the entity, but it could be misinterpreted that it does, though only rarely.

▦ Not Scoped - all states of the feature are not scored and will not be scored for the entity (CBIT, 2006e).

'Absent' is the default score given to all entities for all states, until another score is given. 'Common' is the normal score given in Lucid3 when a state occurs in an entity. It may be used in concert with other scores. 'Rare' is used to record that a state occurs uncommonly or rarely in an entity. 'Uncertain' is used to record that it is uncertain or that the respondent does not know whether a given state occurs, or it does not occur in a given entity. Other scores are explained above yet they are rarely used in Lucid3.

Numeric features in Lucid3 may be scored using four possible scores:

▦ Absent - this feature does not occur in the entity

▦ Normal - the numeric feature occurs normally in the entity

▦ Misinterpreted - the numeric feature does not occur in the entity, but it could be misinterpreted that it does.

▦ Uncertain – the value for the numeric feature for the entity is not known.

▦ Not Scoped - the numeric feature is not scored and will not be scored for the entity (CBIT, 2006e).

The 'normal' score is the most commonly used numeric score in Lucid3. 'Normal' is used when the values entered are normal for the entity being scored. This is equivalent to the 'normally present' and 'rarely present' scores of a multi-state feature. Four values may be entered for the 'normal' score including the outside minimum, normal minimum, normal maximum, and outside maximum. The outside scores are considered as extreme values, rarely occurring, while the inside scores are considered as the normal range.

In developing the key, different scores and numeric ranges were given to states and numeric features for each entity (crop) being scored. The method of scoring these states and numeric features was based largely on the information and knowledge gained from collecting the input data for the key. For instance, in the case of wheat (Figure 9.1), this crop was rarely planted in the last two weeks of April to avoid early frost, nor was it planted as late as in July; therefore 'maybe' or 'rare score' (☑) was given to states '15-30 April', '1-15 July', and '15-30 July'. This implied that wheat was rarely or uncommonly planted in the last two weeks of April, or anytime in July.
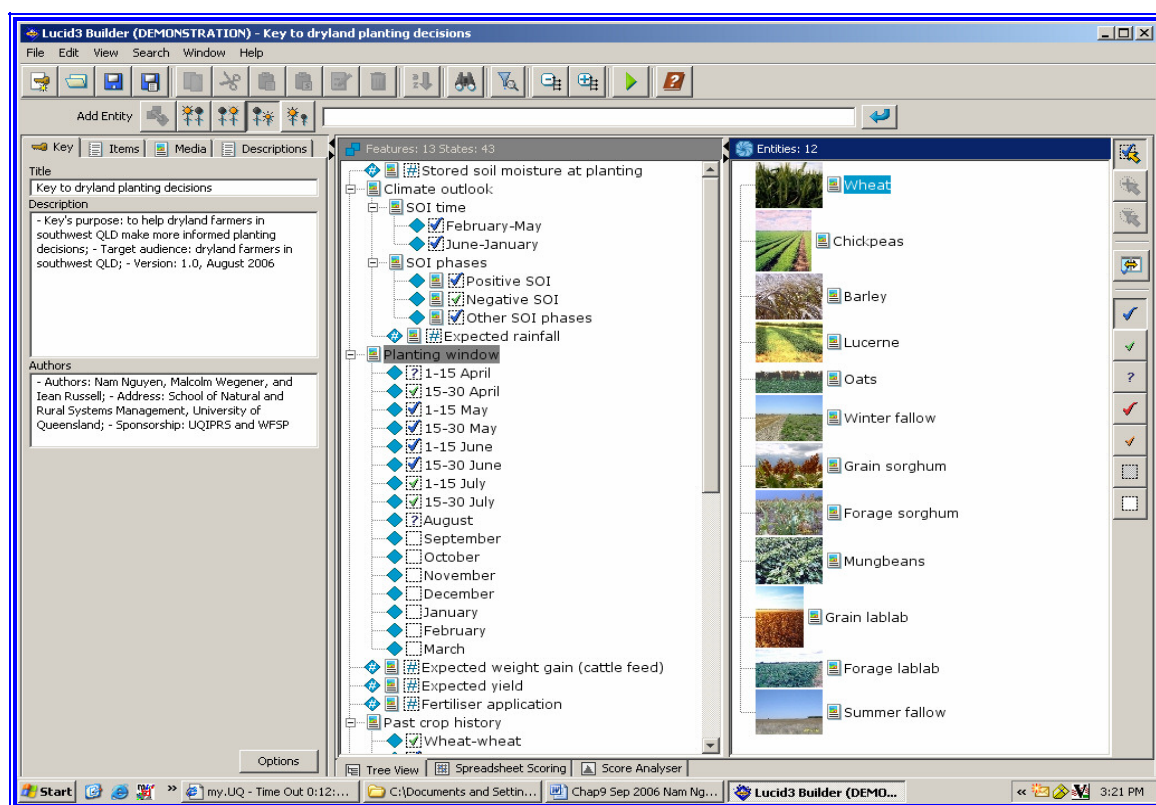
Figure 9.1: **View of the input screen showing multi-state features scored for wheat**

The normal planting time for wheat would therefore be in May or June in the study area, hence any time within that time frame was given 'yes' or 'common' (☑) scoring. This can be interpreted as stating that wheat was commonly planted within this time frame. The first two weeks of April would be too early, and August would be too late, to plant wheat, the 'unsure' or 'uncertain' (☐) score was then given to state '1-15 April' and state 'August'. This indicated that it was uncertain or unsure whether to plant wheat in these time periods. Anytime from September to March would not be a suitable planting time for wheat;

therefore, 'no' or 'absent' (☐) score was given to any state covered within this time frame. A similar procedure was used to score other multi-state features.

In regard to the numeric features (Figure 9.2), the normal minimum amount of moisture to be stored in the soil before planting wheat would be 80 mm, and the normal maximum would be 140 mm. However, there were extreme cases where wheat could be planted outside the minimum, for example on 60 mm stored soil moisture. Likewise, it could sometimes go beyond the maximum of 160 mm stored soil moisture. Therefore, the range given to the numeric feature 'Stored soil moisture at planting' for wheat was 60-160 mm. A similar procedure was applied to score other numeric features. These were initial scores used by the author for later validation. Appendix V provides a more detailed and comprehensive representation of the scoring matrix of the key.

Numeric Scores for Entity: Wheat

Feature Name	Score Type	Outside Minimum	Normal Minimum	Normal Maximum	Outside Maxim...	Units
Stored soil mois...	Normal	60	80	140	160	mm
Expected rainfall	Normal	25	50	100	200	mm
Expected weig...	Normal	0.5	1.0	1.5	1.5	kg/head/day
Expected yield	Normal	0	1.0	3.0	4.0	t/ha
Fertiliser applic...	Normal	0	25	50	70	kgN/ha
Fertiliser applic...	Normal	0	0	0	0	kgN/ha

OK   Cancel

Figure 9.2: **Numeric features scored for wheat**

9.3.6   Images and attachments

Features and entities in Lucid3 keys may be provided with images and web pages to provide further information about the items. For example, features and states may be illustrated with images and notes to help users understand the terms involved, and entities may be provided with access to web pages that include images, descriptions, notes on agronomy, etc.

All the 'technical' terms in the key are linked to the 'Glossary' attachment to help users understand their meaning. In addition, there are various web pages and html files attached

to different features, states, and entities (cropping options) of the key. These attachments provide users with additional information about climate, markets, planting techniques, etc. This information can be viewed when the key is played.

9.3.7   Section conclusion

This section provided a comprehensive description of the key and its components. At the time of writing up this study, there was a draft version only of the key and it needed more feedback from potential users to refine and develop it. The next section will report results of a workshop in which the key was presented to the selected group of dryland farmers at Roma to get their feedback and responses.

9.4   'Key to dryland planting decisions' workshop

9.4.1   Objectives of workshop

A workshop was conducted at Roma in late June 2006 with the main objective to present a draft version of the key to dryland farmers in the study area. Another objective was to consult workshop participants as part of the validation process and gain their agreement on inputs for the key. The workshop was also designed to get dryland farmers' feedback and advice to improve the key.

In mid-June 2006, invitation letters were sent to the farmers who had been involved in the previous phases of this study. The letter invited them to attend a workshop on the 'Key to dryland planting decisions'. After sending the letters, follow-up telephone calls were made to confirm the attendance of 11 farmers, ten of whom attended the workshop.

9.4.2   Presentation

Presentation of the key

After introductions, workshop participants were given a brief presentation about the up-to-date progress of this study. The presentation then led them through the process of developing the key. A sample of crop choices was presented to participants to show them how the key worked. It also helped them to see if the factors chosen were relevant to their conditions or if they would like to change and modify any of these factors.

The following example was chosen to present to workshop participants: stored soil moisture > 100 mm; time of SOI report, June-January; SOI phase, negative; expected in-crop rain, 50-100 mm; planting window, 1-15 June; expected live weight gain for cattle, 0.5-1.0 kg/head/day; expected wheat yield, 1.0-1.5 t/ha; nitrogen application, 0-25 kgN/ha; past crop history, winter crop-summer fallow; market status, reliable and easy access; risk attitude, risk neutral. For other information sources, all states were selected. The result of this selection is illustrated in Figure 9.3.
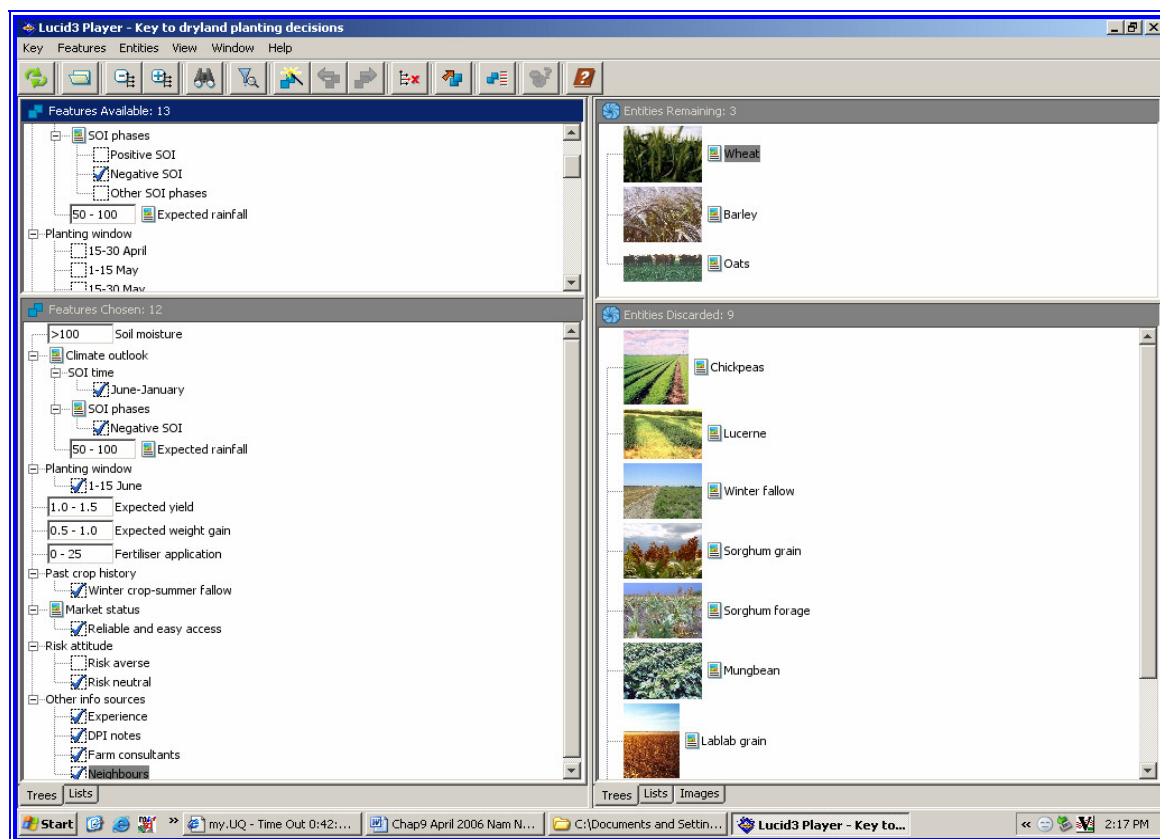
Figure 9.3: **Draft version of the key demonstrated at the workshop**

The presentation also used Internet resources. This enabled participants to view additional information about climate outlook, SOI phases, expected rainfall, commodity market status, etc. The links assessing this information were attached to different features of the key. Crop management notes were provided as attachments to give participants more comprehensive information to choose between the different cropping options. Workshop participants asked many question throughout the presentation to test their understanding of the key and its components as well as query how it worked.

Figure 9.4: **Presenting a draft version of the key to potential users**

Agreement and validation of inputs for the key

The next step in the workshop entailed a presentation of the key using Lucid3 Builder software with relevant explanations of how the scoring matrix works. Participants were taken through the process of scoring features for wheat. They were then asked to comment on and suggest changes if necessary to these original scores. Because of limited time, the author could not go through the whole process of scoring many different crop options with participants. However, an agreement was reached with participants that they would contribute by an alternative mechanism to the exercise of validating input data for the key. This alternative was an input data validation survey and details of this approach and its results are described in Section 9.5 of this chapter.

9.4.3 Workshop evaluation

At the end of the workshop, participants were asked to fill in a workshop evaluation sheet and this sub-section summarises the evaluation feedback from workshop participants.

1. ***How strongly do you agree or disagree with these statements about this workshop?***

A Likert scale (Burns, 2000) was used to get participants to make an assessment of the workshop, its organisation, and its usefulness (Table 9.1).

Table 9.1: **Evaluation of the 'Key to dryland planting decisions' workshop**

Evaluation statements	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
This workshop was a useful activity			2	7	1
This workshop provided lots of opportunities to share ideas				7	3
This workshop helped develop my skills to use decision support tool			3	6	1
This workshop helped answer my planting issues			3	7	
This workshop would help me to make a better crop choice			4	6	

Generally, participants valued the workshop as a useful activity that provided plenty of opportunities to share ideas (seven participants agreed and another three strongly agreed with this statement). Most of the participants also agreed that the workshop helped to develop their skills to use such a decision support tool. Moreover, about two third of participants agreed that the workshop would help them to evaluate their planting options and to make better crop choices.

2. ***How strongly do you agree or disagree with these statements about the presented decision support tool?***

The same Likert scale (Burns, 2000) was used to get workshop participants to comment about the key (Table 9.2).

Table 9.2: **Assessments of the key**

Evaluation comments	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
The 'Key to dryland planting decisions' is simple and easy-to-use			4	5	1
The 'Key to dryland planting decisions' is relevant to local conditions			1	8	1
The 'Key to dryland planting decisions' is user-friendly			2	7	1
The 'Key to dryland planting decisions' is useful for dryland farmers			1	8	1

Six out of ten participants agreed that the key was simple and easy-to-use while another four stated that they were unsure about this until they tried the key themselves. Almost all participants agreed that the key was relevant to local conditions, user-friendly, and useful for dryland farmers.

Some workshop participants had additional comments about the key. "This is a tool which is very much needed in the farming industry" was a statement from one participant. Several other participants suggested that the key "Should be a very useful tool with continuing refinement". They also said that the key "Appears to be a fairly easy program to use with the basic information that may be helpful". One participant mentioned that the key should take other issues such as soil structure and gross margins into consideration. On the other hand, another participant said that: "It has to be simpler for me to use as I am not good on the computer. I will find out if it is user-friendly when I try to use it. I need tick boxes on most things".

3. *Will you be using this tool to assist your planting decisions?*

Seven participants stated that they would like to use the key to assist their planting decisions. Another three participants said that they were unsure whether the key could assist their planting decisions but they would like to try it and see how useful it would be.

4. *Are there any other suggestions that you would like to make to improve the tool?*

Generally, participants mentioned that they might have some suggestions after they had personally used the tool. One participant suggested adding sunflowers to the list of

cropping options while another participant was concerned about maturity ranges for different crop types at various planting dates. All participants promised that they would do the input validation survey to improve its appropriateness and help with validation of input data for the tool.

9.4.4 Section conclusion

A draft version of the key was presented to the volunteer group of dryland farmers in the study area. The presentation received positive feedback from these farmers and they said the key was a useful decision support tool for dryland farmers. Workshop participants all agreed to help with the validation of input data for this tool. The following section will describe the revision process that was subsequently conducted with the key.

9.5 Revision of the key

9.5.1 Input validation

This section describes the subsequent development work on the key after it was viewed by the farmers. Documents were sent to workshop participants within a week after the workshop. These documents included covering letters, scoring tables (Appendix V), and return envelopes. The letter thanked participants for their participation in the workshop and asked them to help check the validity of the key's input data by using the scoring tables. Eight sets of scores were finally returned.

The scoring matrix for the key has been adjusted in accordance with feedback from these farmers in the returned scoring tables. Appendix V details the justification about why some scores were changed while others were kept unchanged. They were described in the sequence of cropping options in the entities list.

In addition to adjusting the scoring matrix, there were some features and components that the author decided to add to the draft version of the key after conducting the workshop and consulting experts. These additional changes included:
- Adding a Glossary to the key to explain 'technical' terms in the lists of features and states;
- Adding multi-state 'SOI time' to include two states 'February-May' and 'June-January'. Since the SOI phase from February-May had little impact on forecasting

rainfall pattern, the feature 'SOI phases' was made dependent on the state 'February-May'. This means that if state 'February-May' is ticked, the feature 'SOI phases' will disappear from the list of available features;

- Adding the state 'Other SOI phases' into feature 'SOI phases' to include SOI rising, SOI neutral, and SOI falling;

- Adjusting the planting window for winter and summer crops. Since the winter cropping season was the dominant interest of farmers in the area, the window for winter crop planting was divided into half month intervals while the window for the summer planting season was specified as whole months;

- Retaining features such as 'Other information sources' and 'Other influencing factors' even though they did not help to differentiate between the different crops. They were regarded as important factors that farmers needed to keep in mind before making a planting decision. Information in regard to these factors is available in the Crop Management Notes attached to each cropping option in the entities list;

- Adding the state 'Varieties' into the feature 'Other influencing factors' reminds users of the importance of this factor;

- Setting dependencies (logical relationships) between features such that a state of one feature controls the presence (or absence) of another feature in Features Available. This helps to keep the list of Features Available looking cleaner and less cluttered when the key is played.

9.5.2 Using the key

Operating the key

Users do not have to answer every question about all of the features when they are describing their cropping options. However the features list was arranged according to the sequence of factors commonly considered when choosing a crop to plant. For example, 'Amount of stored soil moisture', 'Climate outlook', and 'Expected rainfall' were often the most useful features to begin with when choosing which crop/s to plant. Therefore these factors were located at the top of the feature window.

Many of the features, states, and all of the entities (cropping options) have an icon to the left of them that either leads to a glossary item or to attachments. This helps to provide users with clearer understanding and more information.

There are two types of features, multi-state features and numeric features as set out in Figure 9.5.
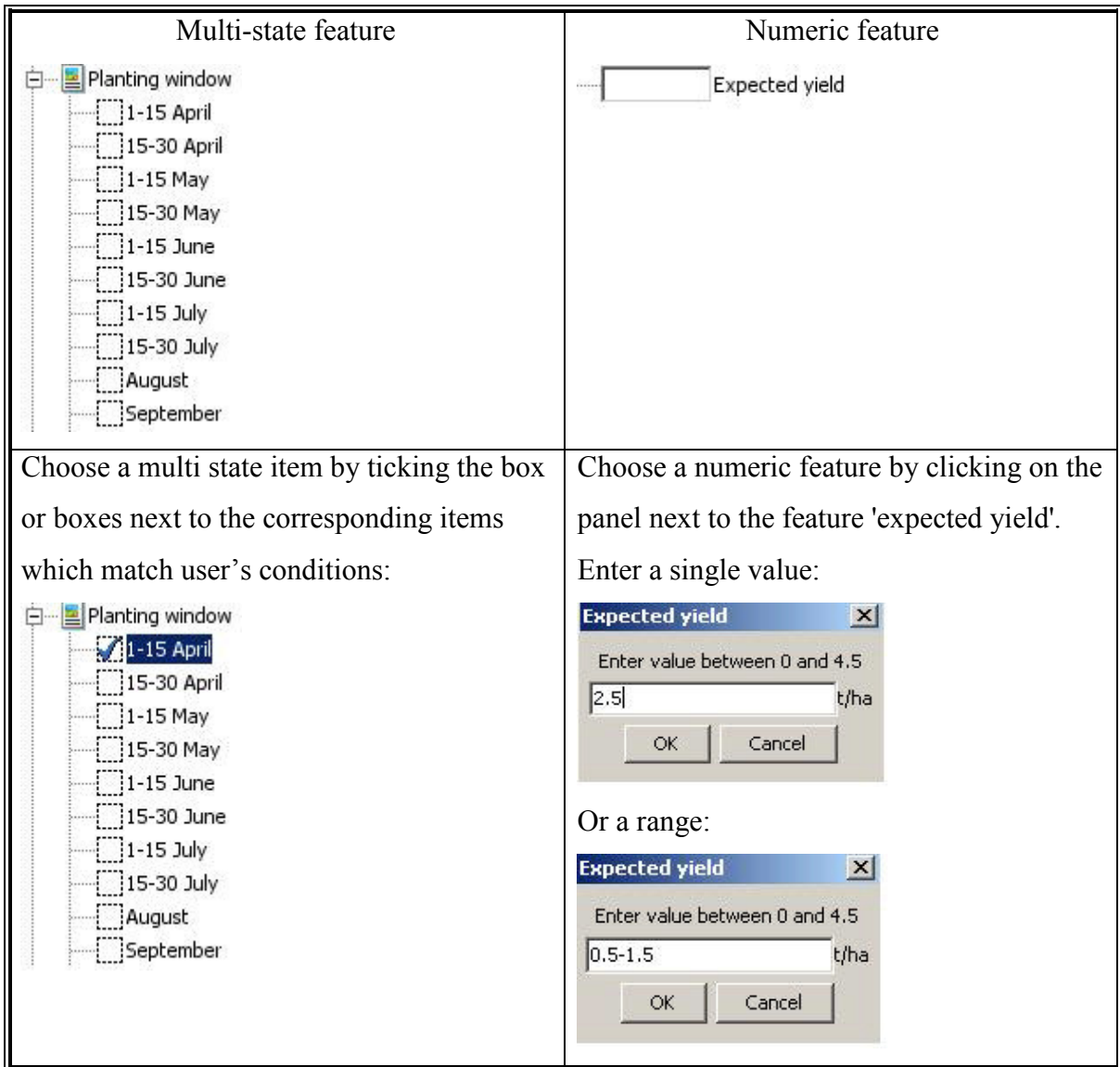
Figure 9.5: **Illustration of multi-state and numeric features**

The users' aim is to choose a crop or crops to plant from the various options presented to them in the input window. The choice will be influenced by their available resources and preferences including amount of stored soil moisture, their expectations about in-crop rainfall, the time of planting, etc. The tool will progressively reduce the number of cropping options that are not relevant or applicable to users' conditions.

After a number of features have been chosen and the Entities Remaining list has been substantially reduced, some features and states may become redundant. A state is considered redundant if it applies to none of the entities remaining, or to all of the entities

remaining (choosing such a state will either leave no entities or remove no entities, so it is pointless to answer). A feature is redundant if all of its states are redundant. The 'Prune Redundants' function will scan the features in Features Available and remove any redundant features and/or states for the remaining entities. This may be useful to 'clean up' the list of features, to make it less likely that a choice will be irrelevant. To activate the 'Prune Redundants' function, choose 'Prune Redundants' from the Features menu, or click the 'Prune Redundant Features' button (⬛✗) on the toolbar.

There is a welcome picture that appears on the screen (Figure 9.6) when the 'index.htm' file of the key is opened. By clicking on the link under 'Viewing the Read me', users are able to read brief information about the key (Figure 9.7).
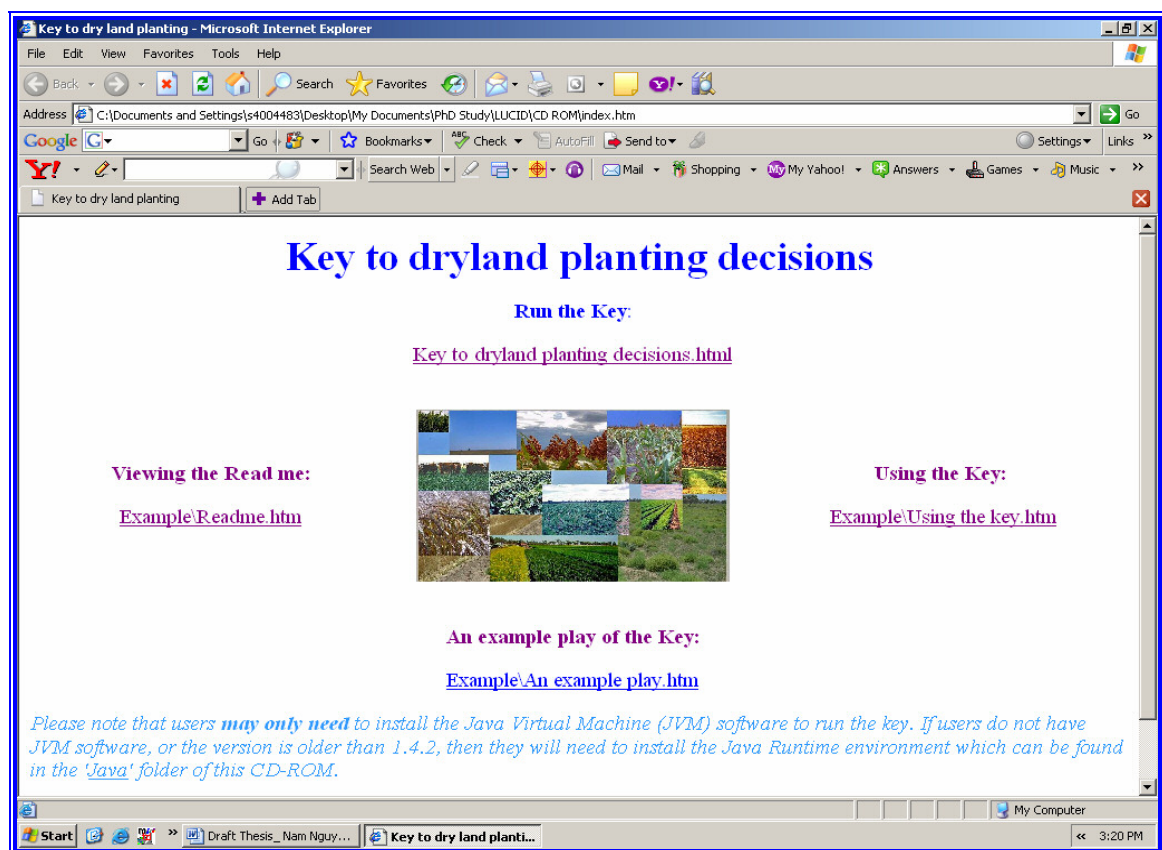
Figure 9.6: **Welcome screen of the key**
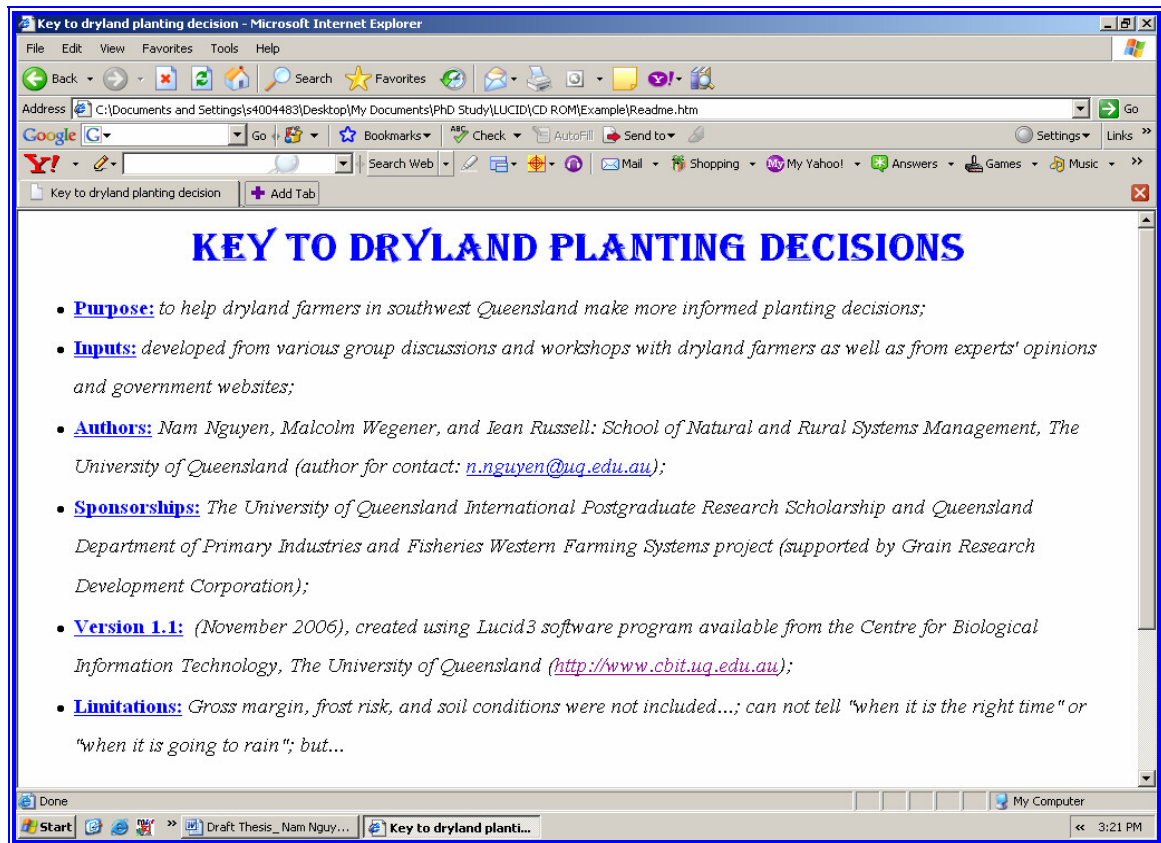
Figure 9.7: **About the key**

Users can run the key by clicking the link under 'Run the Key' at the top of the welcome screen. The selection tool screen (Figure 9.8) is divided into four windows with a menu bar and tool bar. The four windows display four lists:

- Features Available – lists the features that can be selected to describe users' conditions. When users first start the selection tool, 13 features will be displayed. The list of features can be expanded into states by selecting the 'Expand selected list' button ( ) on the tool bar.

- Features Chosen – lists the features as users select them. When users first start the selection tool, this window will be empty.

- Entities Remaining – lists the names of the cropping options that match the features chosen by users. When users first start the selection tool, this window lists all of the 12 cropping options included in the key.

- Entities Discarded – lists all the cropping options that do not match users' descriptions. When users first start the selection tool, this window will be empty.
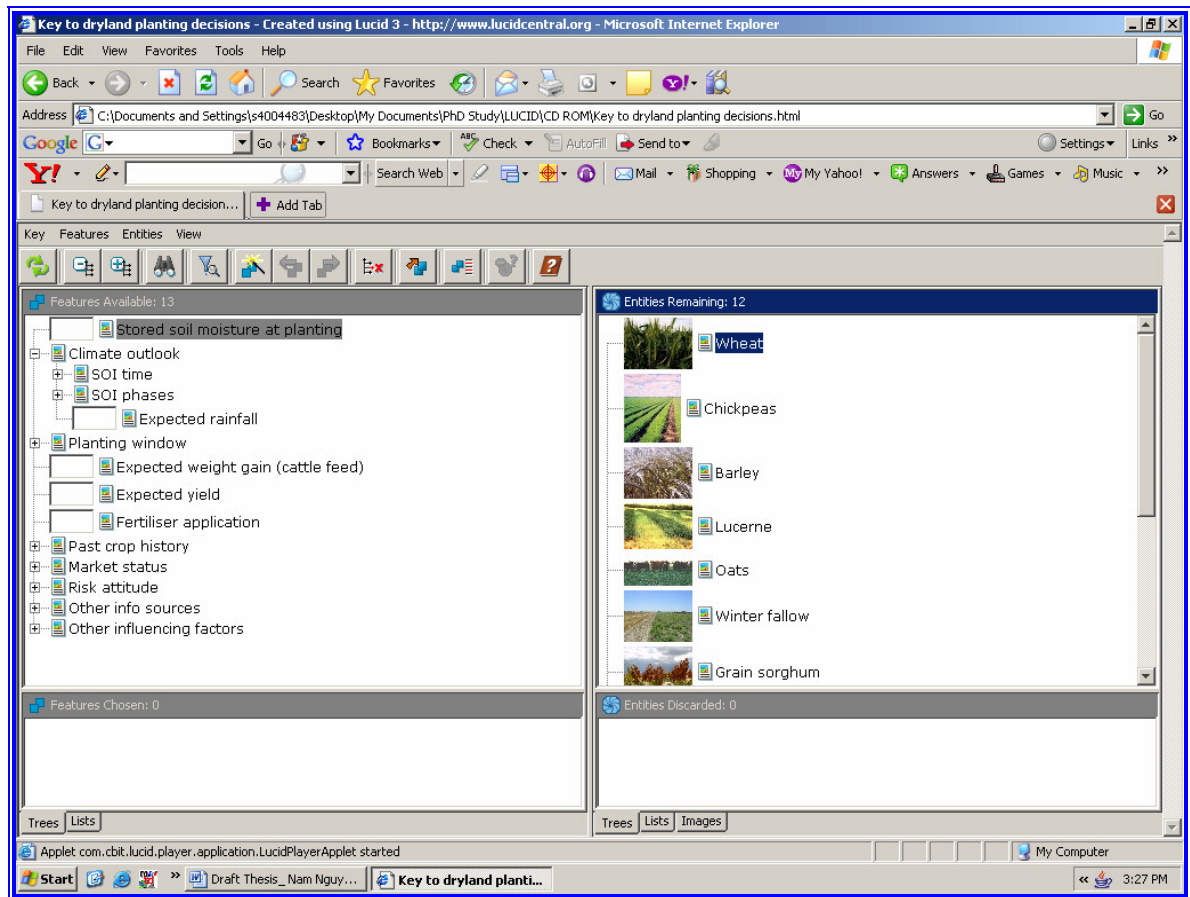
Figure 9.8: **Selection tool screen**

The selection tool has a toolbar that provides a number of tools to help users with the selection process. These include 'Restart Key', 'Find Best Feature', 'Prune Redundant Features', 'View Shortcut Features', 'Calculate Differences', 'Why Discarded', etc. The Lucid help documentation has excellent descriptions of these tools. The Help Menu in Lucid3 Player provides all necessary information about how to use the key.

Two typical examples of using the key

Example 1

Once the selection tool screen is opened, users can use the key to select their choice of cropping options. The following selection is a step-by-step sample to demonstrate how the key works.

Click on the panel next to feature 'Stored soil moisture at planting' and entering '> 100'. This feature will be listed in the 'Feature Chosen' window and two cropping options

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('Winter fallow' and 'Summer fallow') will be discarded from the entities list. These two cropping options are discarded because the key operates on the basis that if dryland farmers have more than 100 mm of moisture stored in the soil, they would think of planting a crop and not leaving the land fallow.

Next, click on the attachment next to feature 'Climate outlook'. This action will take users to the climate information and updates from QDPI&F and APSRU websites. Users can look at this information to see what the outlook or future weather patterns will be for the coming season.

Making the 'Feature Available' window active and clicking on the 'Expand selected list' button on the tool bar will expand the list of features available. All the states included in multi-state features will be displayed.

Feature 'SOI phases' is dependent on the feature 'SOI time'. From February to May, the SOI will have no impact on the prediction of rainfall probability (Alexis Donald, QDPI&F climate expert, *pers. comm.*, 19 June 2006). Therefore, if state 'February-May' is ticked, feature 'SOI phases' will not be shown in the features available list. In this example, un-ticking the box next to the state 'February-May' and ticking in the box next to the state 'June-January' will cause the feature 'SOI phases' to come back into the Features Available list. Users can choose any SOI phase by ticking the box next to the relevant phase. In this example, a tick in the box next to state 'Negative SOI' will choose this phase.

Click on the panel next to feature 'Expected rainfall' to enter the amount of rainfall that is expected during the in-crop period. This amount could range from 25 mm to 200 mm. In this example, we assume the expected amount will be in the range of 50-100 mm.

Four features have been chosen so far and only two cropping options have been discarded. Other cropping options still remain in the Entities Remaining list because they meet the conditions for all the four features that have been chosen.

In the 'Planting window' feature, users can choose any 'window' that matches their planting time. In this example, we choose the first two weeks of June (the box next to the state '1-15 June' is ticked). When this planting window is chosen, five cropping options will be discarded from the Entities Remaining list. They are all summer cropping options

and were discarded because the chosen planting window is not applicable to summer crops.

Click on the panel next to the feature 'Expected live weight gain' and enter '0.0-1.0'. All five winter cropping options will remain in the Entities Remaining list because any of these cropping options would have the capacity to provide cattle with the 'Expected live weight gain' in the 0.0-1.0 kg/head/day range.

Click on the panel next to the feature 'Expected yield' and enter '1.0-2.0'. Lucerne will be discarded from the entities remaining list. Users can follow-on by pointing the mouse at lucerne to make it active and clicking the 'Why Discarded' button ( ) on the tool bar to reveal further explanation. In this case, the key says that lucerne is discarded because feature 'Expected yield' is not scored for this crop. In other words, lucerne is planted solely to feed the cattle and will not produce any yield except 'weight gain' for cattle.

Click on the panel next to the feature 'Fertiliser application' to enter the amount of nitrogen users wish to apply to their crop/s. The common range for applying nitrogen in the area is 0-75 kg N/ha. If '70' is entered in the panel, chickpeas and oats will be discarded from the remaining list. This is because farmers in the area would not apply that much nitrogen to chickpeas or oats. In the example, we try the range from 0-25 kg N/ha. Click on the panel again and re-enter the value '0-25'. Chickpeas and oats will come back into the remaining list.

In regard to past cropping history, the key covers two previous seasons. In the example, choose state 'Winter crop-summer fallow'. This means that the paddock was planted with winter crop/s in the previous season and was left fallow last season.

Users can check the market status of their proposed crop/s by clicking on the attachment next to feature 'Market status'. This action will take users to various websites providing information about market prospects for the crops under consideration. Tick the box next to the state 'Reliable and easy access' (to markets), chickpeas will be discarded from the remaining list. Chickpeas were discarded because the key contains information that says the market for chickpeas is 'Uncertain and unstable'.

In this example, un-tick the feature 'Market status' and go to feature 'Risk attitude'. Assuming that the user is risk-averse, tick on the box next to state 'Risk averse'. Nothing

will be changed (no cropping option will be discarded). However, if we remove the tick in this box and click on 'Key' button on the menu bar, a drop-down menu will appear and un-tick the option 'Retain uncertainties' from this menu. Tick the box next to state 'Risk averse' again. This time chickpeas will be discarded from the remaining list because the key is designed to say that if a person is risk-averse, he or she will be uncertain about the decision to plant a crop which has an uncertain and unstable market like chickpeas.

At this stage, three cropping options (wheat, barley, and oats) are still displayed in the entities remaining list. There are two multi-state features ('Other information sources' and 'Other influencing factors') that have not been chosen. Indeed, these states apply to all of the cropping options and choosing any of these states will not help to discard (eliminate) any cropping options. They are included in the key to remind users to consider their importance when choosing a cropping option. Most of these factors influencing the crop outcome are included and detailed in the Crop Management Notes attached to each cropping option.

In summary, the result (Figure 9.9) was obtained after choosing the steps detailed above for the example. Given the selected states and features, users are presented with the choice of three crops: wheat, barley, and oats. In this particular example, users may choose to plant any one of these crops, or some combination of them.
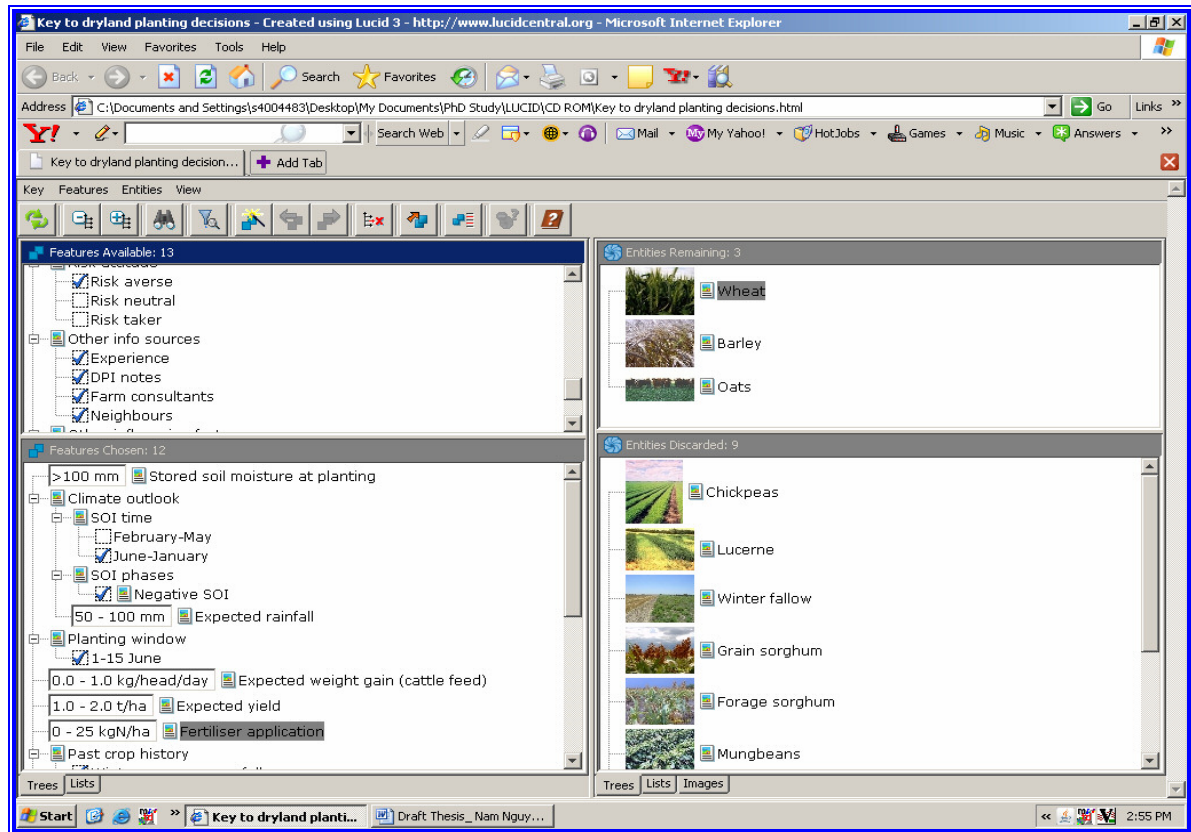
Figure 9.9: **Result of the example with the choice of wheat, barley, and oats**

The key can also help users to evaluate the different features of these crops. They do so by clicking on the 'Calculate Differences' button ( ) on the tool bar. This will open up a screen (Figure 9.10) in which all key influencing features are displayed and the differences among them are listed.
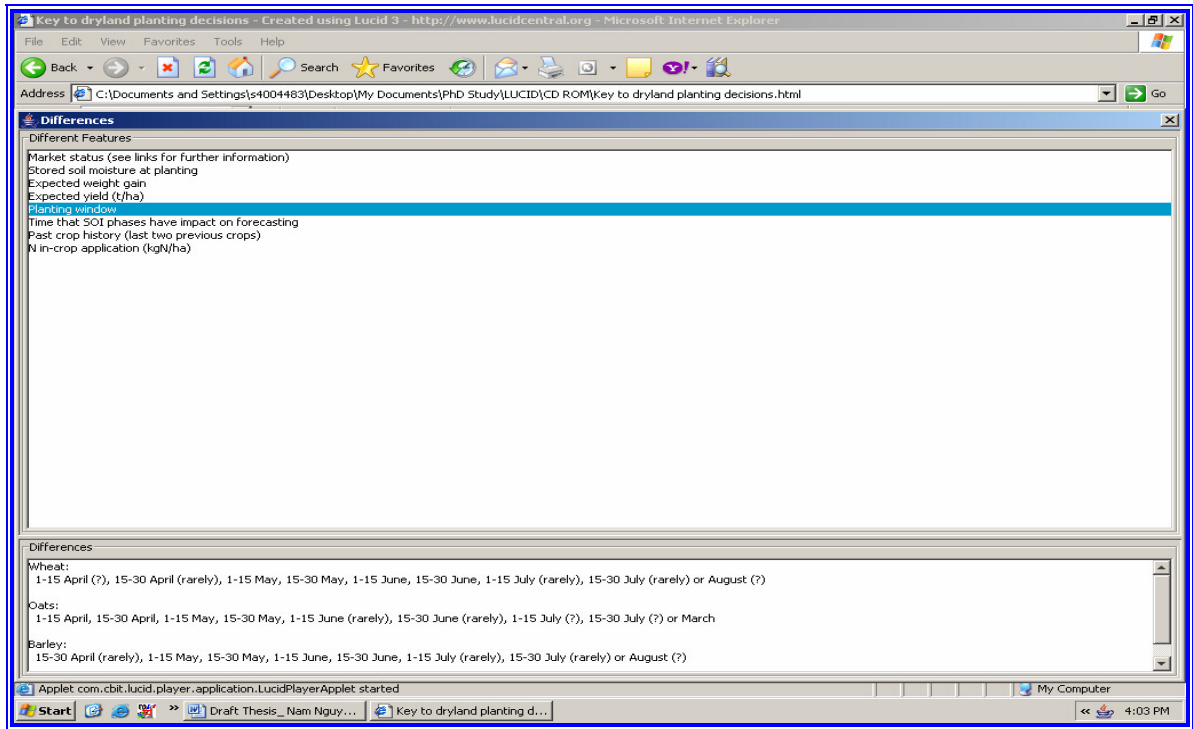
Figure 9.10: **Comparing different features of three remaining crop options**

In addition, users can gain access to further sources of information by clicking on the attachments with each cropping option. This will take them to a crop fact sheet (in this example, Wheat Fact Sheet, Figure 9.11) and a crop management note (is this example, QDPI&F Wheat Management Notes, Figure 9.12).
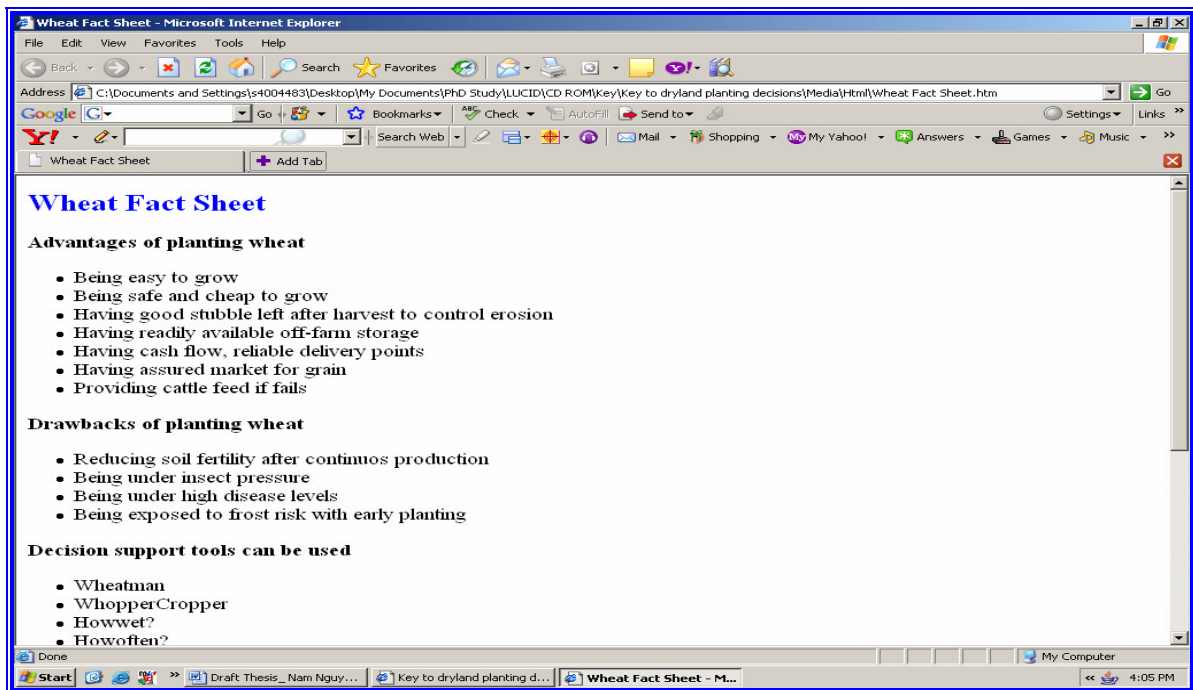
Figure 9.11: **Wheat Fact Sheet**

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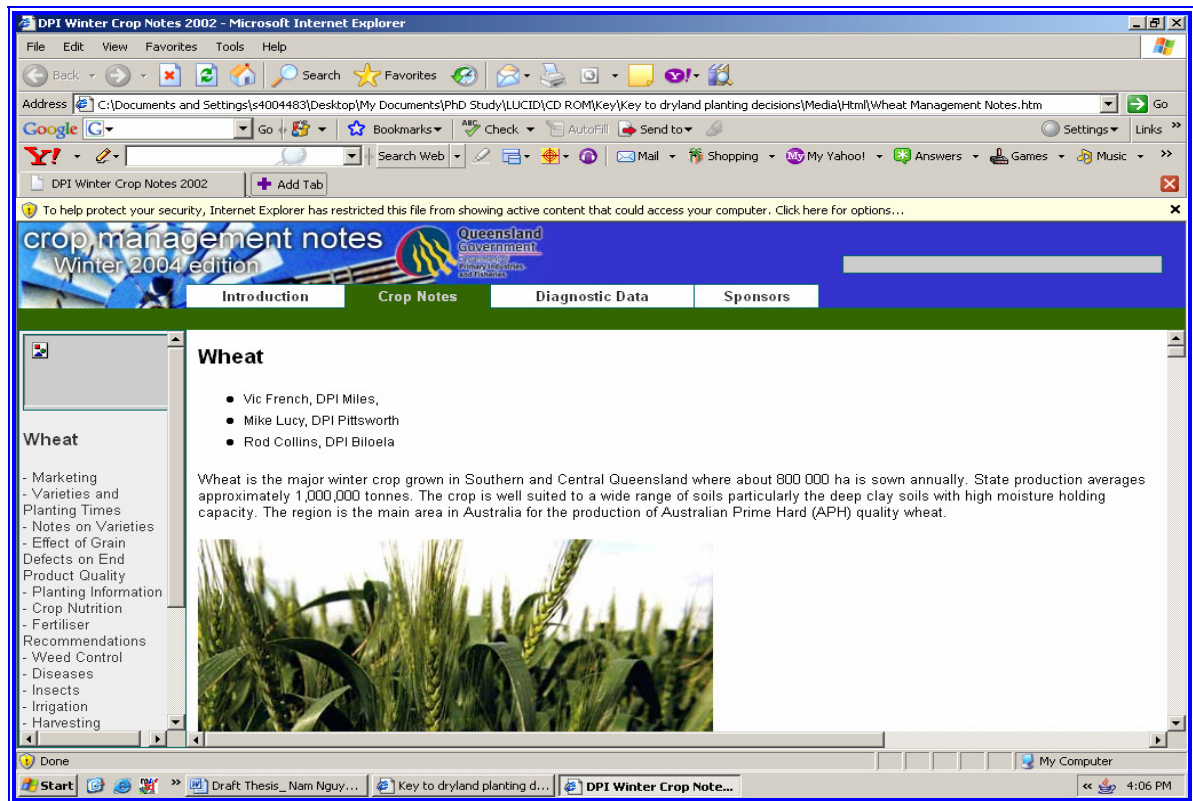
Figure 9.12: **Wheat Management Note**

The crop fact sheet provides information such as advantages and drawbacks of planting that specific crop, decision support tools can be used to help with the planting decision, and provides access to additional information sources. The crop management notes provide extensive information on each particular crop. This includes marketing, variety, planting, crop nutrition, diseases, pests, harvesting, etc. All of the information is available to help users make a more informed decision about which crop/s they are going to plant

Alternatively, the result of this example can be displayed in the format of percentage match value (Figure 9.13). For example, if an entity matches all the selected features it will have a match value of 100% (*e.g.* wheat), and it will appear in the top of the rank of the Entities list. If another entity matches half the selected features (or states) it will have a match value of 50% and will be ranked lower in the list.
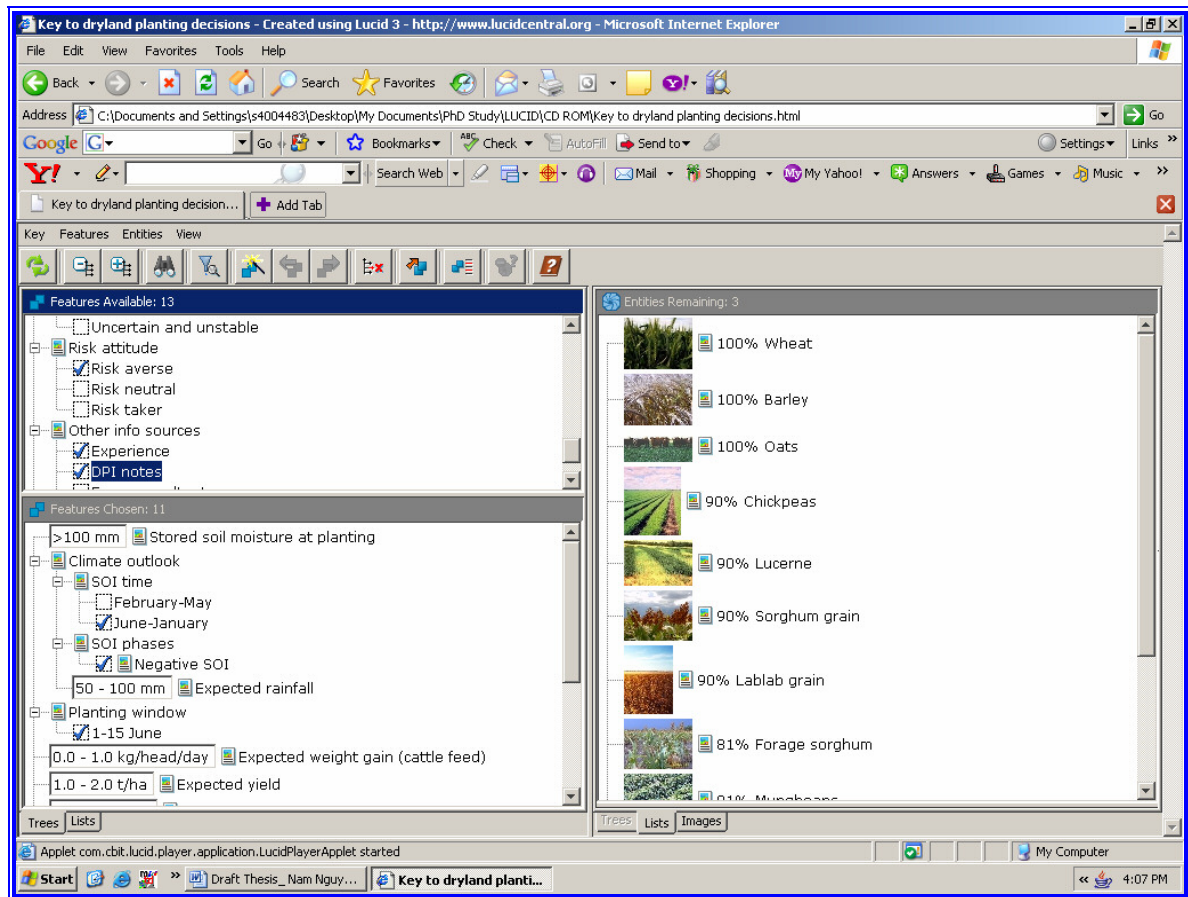
Figure 9.13: **Result of the demonstration example in percentage format**

Example 2

To see the results of some 'what if' questions and test the sensitivity of the key, another example of crop choice is provided. The situation for this example was: 'Stored soil moisture at planting', > 100 mm; 'SOI time', June-January; 'SOI phases', Negative SOI; 'Expected rainfall', 50-100 mm; 'Planting window', 1-15 June; 'Expected weight gain (cattle feed)', 0.0-1.0 kg/head/day; 'Expected yield', 1.0-2.0 t/ha; 'Fertilizer application', 0-25 kgN/ha; 'Past crop history', Winter crop-summer fallow; 'Market status', not chosen; 'Risk attitude', Risk taker. For other information sources and other influencing factors, all states were selected. The result of this selection is illustrated in Figure 9.14.

This selection is quite similar to the previous example. The only difference in this example was the choice of state 'Risk taker' under feature 'Risk attitude', rather than the choice of 'Risk averse' as in Example 1. It can be seen from the results illustrated in Figure 9.9 and Figure 9.14 that, given the same set of conditions, a risk-seeking farmer would consider planting chickpeas while a risk-averse farmer would not consider doing that. This is because the key contains information suggesting that if a farmer is risk-seeking, he or she

might consider planting a crop which has high potential profit like chickpeas, although the market for this crop is uncertain and unstable.
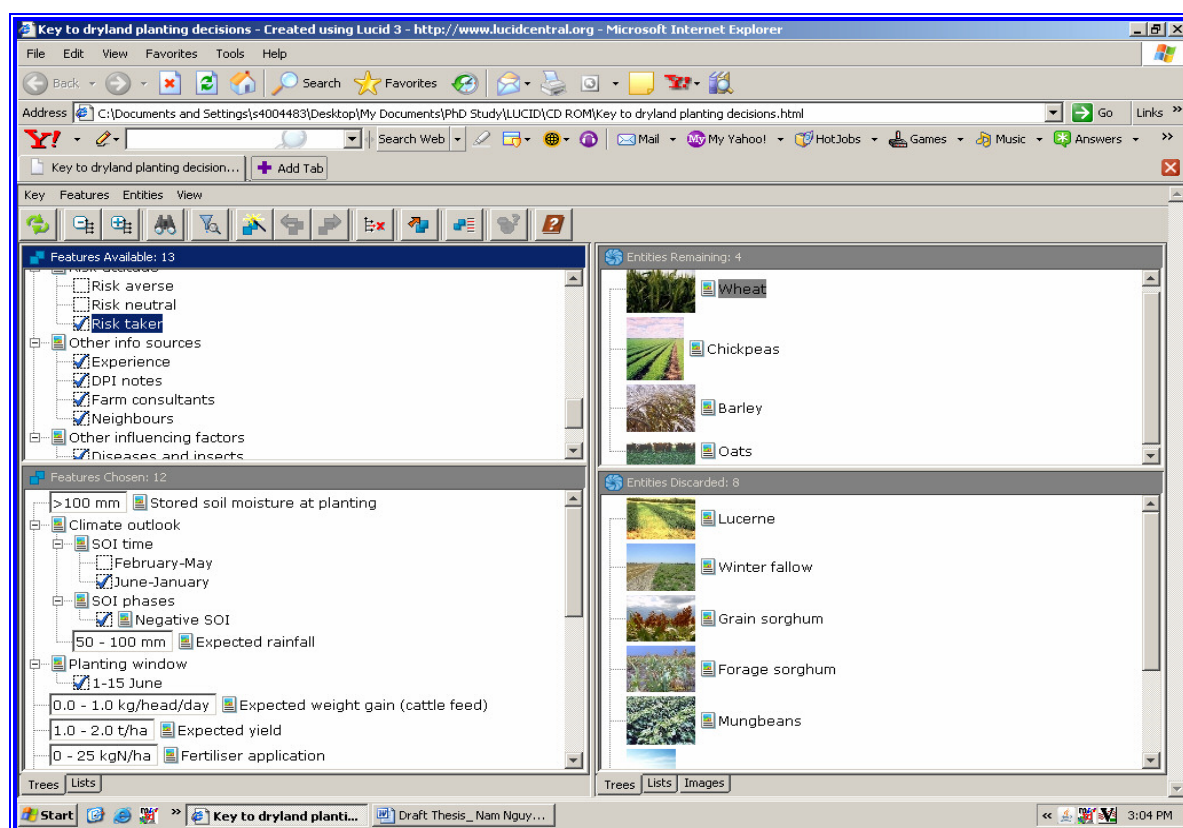
Figure 9.14: Result of an example with a 'risk-seeking' decision

Other examples, such as more or less stored soil moisture at planting time, could be considered.

9.5.3   Deployment and distribution of the key

A revised version of the key (Version 1.1, November 2006) was deployed via CD-ROM and the Internet. A copy of this CD-ROM is attached with this thesis for illustrative and supportive demonstration. The home page address of the key is: www.lucidcentral.org (the key is listed on the front page, under 'Latest Keys'), and its direct link is: http://www.lucidcentral.org/keys/v3/Dry_Land_Planting/. Users can go to the site and use the key without cost. They do not need to install any software, apart from having Java Virtual environment on their computer, to be able to use the key.

9.5.4 Section conclusion

This section reported the developmental work on the key after it was introduced to a group of farmers. An input validation survey was conducted with the volunteer group of dryland farmers and appropriate amendments made to the key in accordance with feedback from the survey. Two examples of the revised version of the key were presented to give readers a better demonstration of the key and how it works.

9.6   Chapter summary

This chapter described the design and development of a decision support tool for dryland farmers in southwest Queensland. This tool captures the timing and logic of the decision-making process and incorporates existing sources of information relevant to making the choice among dryland cropping options in southwest Queensland. A draft version of the key was presented to a volunteer group of farmers in the study area. The presentation received positive feedback from these farmers and they regarded it as a useful decision support tool for dryland farmers. A revised version of the key (deployed via the Internet) has been made available for dryland farmers to access and use, partly as a way of repaying the help and assistance of those farmers throughout the whole life of this project.

Chapter 10: Review, conclusions, and implications

10.1 Introduction

This chapter consists of six sections and presents conclusions to the thesis. After the introductory section, Section 10.2 addresses the limitations of the research. Section 10.3 reviews the research questions, while Section 10.4 suggests some implications for further research. Section 10.5 reports some personal experiences and lessons that the author has learnt through the course of doing this research. Lastly, Section 10.6 brings the thesis to an end with conclusions about the research problem and contributions of the thesis to knowledge.

10.2 Limitations of the research

This study reflects both the limitations and the strengths of qualitative research methods. The study has allowed participants to tell their own stories and through the presentation of the results has allowed their voice to be heard, although inevitably this has been through the interpretation of the researcher, which is a limitation of interpretive research (Lynch, 2003).

From a quantitative point of view, this study was limited by small sample sizes and bias in the selection of participants at different stages of the research. Generally, research reported in agricultural economics and other social science theses would report a larger number of participants. However, the nature of this research made it impossible to have a large number of people involved. This research involved the development of a new product (innovative approach). It therefore required an opportunity to work with a small number of people and incorporate their inputs. It would now be possible for the product to be transferred to somebody else to test it further and proceed with its development and generalisation. In this case, it was also important to work with the more innovative farmers, who were willing to participate in all stages of the study over a period of more than two years.

There were other limitations specific to this study. This study focused on the development of risk management and decision support tools for dryland farmers in southwest Queensland. Some aspects of this study may, therefore, only be relevant to dryland farmers

in that area. Outcomes may be different or may not be relevant for different targeted groups, for example, farmers with access to irrigation. In addition, the study focussed on the cropping side of these farmers' businesses. They were all mixed farms, including both sheep and cattle enterprises as well as cropping, and no attention has been directed at the livestock side of the business, with little consideration of the interaction between cropping and livestock management, although livestock may provide both opportunities and threats in a risk management sense.

This study has identified many sources of risk that dryland farmers in southwest Queensland face. However, the study was not able to develop strategies to manage all of those risks. For example, managing market risks was not dealt with because the farmers claimed that was 'better left to the experts'. This may reflect their stage of development. In time, as they become more competent in managing physical production risks, they may want to become more involved in managing the market risks associated with their respective businesses. It therefore seemed appropriate to work on what was clearly the most important issue to them and develop something to help them deal with crop planting decisions. That meant focusing on the most important source of risk that these farmers said they have to face (production risk – weather variability – crop choice and soil moisture management), and develop a planting decisions support tool.

The planting decisions support tool was not perfectly designed because the author is not an expert in information technology. A similar tool, Tropical Forage (Cook *et al.*, 2005), has been developed using the same software program (Lucid3) as was used in this instance. The output from this study ('Key to dryland planting decisions') cannot compare with the Tropical Forage tool in terms of funding, institutional support, or the number of professional experts involved. However, a prototype has been produced that could be developed further by one of the institutions involved in the Western Farming Systems project.

Another limitation of the key was that it does not include economic factors. It would presumably be 'better' if the key could include economic features such as the gross margin for each cropping option. However, different sets of features when they are chosen produce quite different gross margin values. Lucid3 was not able to handle this complexity and incorporate these values into the selection process. Moreover, the ultimate goal of this study was to help farmers make more informed planting decisions, and not make the decisions for them. Interestingly, gross margins were not rated highly by these producers

as one of the features determining crop choice. Including this and other economic features would be possible but would make the key more complicated and not so easy to use. One of the things that the author aimed to do was to produce a tool to help dryland farmers in southwest Queensland and they were adamant about keeping the aid simple to use.

Finally, it was not possible to evaluate the feedback from a large group of dryland farmers who could have been provided with the revised version of the key. Lack of time and lack of funds prevented this. Because the candidate's scholarship was finishing, it was impossible for a broader evaluation to be conducted. However, the evaluation may still be carried out by the WFS project team because the development of this key was considered as one part of that project.

10.3 Review of the thesis and research questions

This study has required participation by many farmers and experts. A volunteer group of 16 farmers from the study area (Roma in southwest Queensland) was closely involved with the study over a period of nearly two years. These farmers were involved in the initial interviews, focus group discussions, and a series of workshops to assess various risk management and decision support tools. The study also observed and reported on three other groups of farmers (total number of 27 farmers), from areas adjacent to the study area, who were also involved in workshop activities. There were 23 'experts' involved in the DSS survey. In addition, the study involved many other researchers and experts through preliminary interviews, discussions, and consultation.

The research questions addressed in this thesis are restated here. Answers for each of these questions have been found and set out in relevant chapters of the thesis. The following paragraphs review and summarise the key elements of these answers.

Research question 1: What are the current trends in the theory and practice of risk management in general and in agriculture in particular, with a focus on Queensland agriculture?

With respect to **Research question 1**, the study reviewed an extensive literature on risk and risk management in general as well as in agriculture in particular. Major issues involved in research into decision making were also described. Risk in farm management is an area that is receiving more attention than it did previously. Clearly, management of

risk is an important activity for farmers worldwide. Many strategies for managing risk are conceptually possible, including a number of production, marketing, and financial strategies, and the management task facing farmers is to choose a combination of risk management strategies that best suits the unique conditions of their particular farm and their personal circumstances.

The review of literature revealed that most farmers are risk-averse and they often use 'rules of thumb' in making their decisions which tends to limit them to a range of options that they have used before. Experience and preferences (based on precedent) were regarded as very important elements in their decision-making process. In addition, because farmers vary in their attitudes towards risk, risk management cannot be viewed through a 'one size fits all' approach. Different farmers deal with the same situation in different ways, and their preferences towards risk, and their risk-return trade-offs, have a major effect on decision-making in each given situation.

Obviously, managing risk in agriculture does not necessarily involve avoiding risk. It involves finding the best available combination of risk and return given the farmer's capacity to cope with a wide range of outcomes. Indeed, most farmers combine many of the different strategies and tools available to them. In other words, they rely on a mix of strategies to manage risk.

Generally, farmers in the study area of southwest Queensland agreed that they would focus mostly on things that they could control and learn how to manage them. Personal characteristics and preferences were regarded as very important in their decision-making. However, they said that they often based decisions on historical data (precedent) and used 'gut feelings' to make their decisions. These farmers understand that they have to be in a position to take risks: however, they try to keep the risk at a certain, manageable level.

Research question 2: What are the sources of risk that dryland farmers in southwest Queensland have to deal with? How do they perceive and rank these risks?

The farmers in the volunteer reference group mentioned five main sources of risk that they face in their farming business. These included production, financial, marketing, institutional, and human resource risks. These were similar to the main sources of risk in farming commonly identified in the review of the literature (Boehlje and Trede, 1977;

Fleisher, 1990; Hardaker *et al.*, 1997; Kay and Edwards, 1999). This particular group of farmers also made many additional comments about how climatic, personnel, business environment, and government policy changes affected the risks they face.

Climate variability (expressed as production risk) was considered the most important source of risk by the farmers involved in this study. Other important sources of risk included financial, government policy, and marketing risks. The farmers ranked these risks rather differently to farmers in other countries, where climate variability is probably not as significant as a source of risk as it is in Australia. For example, price or marketing risks were perceived as the most important source of risk by a group of Dutch farmers (Meuwissen *et al.*, 2001b). Similarly, a nationwide survey of New Zealand farmers revealed that marketing risks were ranked as very important by all farmers (Martin, 1996). In America, crop price and yield variability were the top-rated sources of risk identified by many farmers (Patrick and Musser, 1997; Knutson *et al.*, 1998; Harwood *et al.*, 1999; Hall *et al.*, 2003).

Research question 3: How do dryland farmers in southwest Queensland manage farming risks?

The group of dryland farmers in southwest Queensland, like their peers in other states and overseas, *e.g.* South Australian farmers (Nguyen, 2002), American farmers (Jose and Valluru, 1997; Hall *et al.*, 2003), Canadian farmers (AAFC, 1998), Dutch farmers (Meuwissen, 2001a), and New Zealand farmers (Martin, 1996), use a range of strategies to manage the various risks that affect their farming businesses.

The farmers in southwest Queensland used different strategies, such as conserving soil moisture, using zero till planting methods, and running cattle, to manage weather variability and production risks. They all agreed that conservation of soil moisture was their most important priority, and "getting the time right" was emphasized as the essential element in risk management and making decisions. This was especially true for decisions regarding crop planting. These farmers focused a lot of their attention on managing the agronomic package (stored soil moisture, cropping options, planting window, etc) as their key risk management strategy.

In regard to financial risk management, it was agreed that good business management was a relevant strategy, and interest rates were regarded as controllable. It was generally

acknowledged that marketing should be "left to experts", and only part of farm production should be sold at any one time. There was also awareness of the need to educate younger farmers to have good farming skills. Diversification and generating off-farm income were other risk management strategies. However, there was little discussion about how to manage the risk that government policy might change. That source of risk was claimed by participants as something "out of control".

Research question 4: What decision support tools or models can be used to help southwest Queensland dryland farmers make better decisions under risky conditions?

A series of workshops was conducted with dryland farmers in southwest Queensland to provide the opportunity for participants to experience some existing risk management and decision support tools including Howwet?, Howoften?, WhopperCropper, and Yield Prophet as well as providing information on the use of some climate indicators including SOI, ENSO, and MJO. Generally, farmers in the study area, as well as farmers in adjacent farming communities, valued the workshops on climate information and decision support tools conducted for them. However, the majority of these farmers were still reluctant to try or use these tools. Reasons claimed that would prevent them from using these tools included computer illiteracy, time constraints, irrelevant information, and the fact that these tools were not user-friendly. These farmers stated that although decision support tools could not make the decision for them, they would like the tools to produce information or some guidelines so that they could use as a basis for making their own decisions. The farmers continued to emphasise that they wanted something to help them make decisions about which crop to plant.

A decision support tool for dryland farmers in southwest Queensland was developed as the main output of this study. Guidelines and advice from DSS experts were used extensively in designing the tool and input data for the tool was provided mainly by the volunteer group of dryland farmers in the study area. This tool captures the timing and logic of the decision-making process as the researcher interpreted it from the farmers' information and incorporates existing sources of information relevant to making the choice among dryland cropping options in southwest Queensland. It uses Lucid3 software to structure the decision-making process to select preferred crop planting options for both summer and winter planting periods and takes into account many of the factors that were identified by the farmers as influencing their decision. The tool was developed to be a simple and user-

friendly decision support tool. Even users with very low level of computer skills can use this tool. While initial reaction to the tool was positive, there was not enough time to evaluate it fully with the volunteer group or with a wider cross-section of farmers.

10.4 Implications for further research

This research has examined several aspects of risk management and decision support tools for dryland farmers in southwest Queensland. The study has successfully used an action research framework and multiple methods for data collection. The results from this study are useful because they advance understanding of risk management and relevant decision support tools in agriculture.

Although several groups of farmers were involved in the study, the number of farmers concerned was not large and they might not be representative of the whole farming population in southwest Queensland. To obtain this wider picture, more workshops or a broader-scale survey should be conducted among farmers in that area, to identify the risks they face and the risk management strategies that they use.

Further work is needed to update and revise the 'Key to dryland planting decisions'. This software would probably be more useful to farmers if it could include some economic factors such as gross margins or establishment costs for most of the cropping options that are available to farmers in the area. In addition, minor modification would be required in order for the key to be applicable to other dryland farming areas.

This study has reviewed five main sources of risk in farming including production, financial, market, institutional, and human resource risks but it concentrated on production risks flowing from variable rainfall in the area. It would be desirable to carry out more research to understand the relevant strategies that farmers use to manage the other sources of farming risk, especially human resource risks. There has been little previous work done in regards to human resource risks faced by farmers and the possible strategies to manage them. As farms become larger, technology more complex, and other risks increase, human resource risks become much more of an issue for farm businesses.

In the presence of the on-going drought in Queensland, further research into alternative farming practices for dryland farmers is essential to help them 'move on' with their farming careers. It would be disasterous for rural areas in Australia to see farmers leaving

their 'beloved' land because their farming businesses are not viable. This could cause a lot of social and economic problems in rural areas.

There needs to be more research to improve the adoption rate of DSS in Australian agriculture. This study reviewed the uptake of DSS by farmers and reported that it has been slow with various issues said to be contributing to this. They include fear of using computers, time constraints, poor marketing, complexity, lack of local relevance, lack of end-user involvement, and mismatched objectives between developers and users. The future prospects for the development of DSS have generally been regarded as poor. Nevertheless, the author believes that new DSS, which embrace appropriate criteria suggested for developing them, could be widely accepted by farmers. These criteria mean that for any DSS to be widely used by farmers, they need to address widespread problems, they need to be location specific, and gain strong support from initial users. They also need to be simple to use, relevant, effective, low cost, and user-friendly, and it is most likely that farmers would have been involved in their development. For existing DSS, it would require more marketing work to promote them because most farmers do not know that they exist or what they can do. In addition, it is also important to keep them up to date and compatible with changes in computing hardware and software, as well as meeting the changes in users' needs.

10.5 Personal experiences and lessons learnt

It has been a challenging, yet interesting, journey to do this research. Cultural interaction was the first experience to mention. Coming from Vietnam to Australia to do a four-year PhD program, the candidate and his family have experienced many changes in life, social relationships, cultural differences, etc and learnt from that experience.

The candidate has gained capacity and flexibility in thinking and doing the research. The application of the Risky Business program was initially proposed for this research but the engagement with the group of farmers early in the field research clearly indicated that managing market risks was not what the farmers wanted. The research plan was then changed to allow the presentation of various other risk management and decision support tools in a workshop setting. Finally, a decision support tool that addressed the farmers' main concern about which crop to plant to make best use of limited stored soil moisture was developed.

Ability to work independently was another achievement. The candidate, with the assistance from his advisors, has been able to conduct many workshops and discussions with farmers and experts. In addition, the candidate, as a very young researcher, has learnt a lot from being exposed to the world of peer researchers and presenting preliminary findings of the study at several national and international conferences. These conferences included the 15th International Farm Management Conference in Sao Paulo, Brazil (Nguyen *et al.*, 2005), the Environmental and Resource Economics Early-Career Researcher Workshop in New South Wales, Australia (Nguyen, 2005), the 2006 APEN International Conference in Victoria, Australia (Nguyen *et al.*, 2006b), and the 26th Conference of the International Association of Agricultural Economists at the Gold Coast, Australia (Nguyen *et al.*, 2006a).

Finally, the candidate has realised and perceived the importance of identifying and working with a volunteer group of farmers, who in this instance were closely involved throughout the field research phase of the study. This close involvement of end-users is so vital, and a poem from a child care centre (GCC, 2006) might be used to describe this:

> "If you tell me, I will forget.
> If you show me, I may remember.
> If you involve me, I will understand."

10.6 Chapter summary

This study enhanced the understanding of risk management and decision support tools in agriculture. Clearly, the management of risk in agriculture is a difficult task. The research reported in this thesis has made a significant increase in the level of understanding about risks faced by a small group of mixed farmers in the dryland cropping area of southwest Queensland and the management strategies they adopt to deal with those risks. It has done this with a knowledge of contemporary risk management strategies (in agriculture and elsewhere), and familiarity with a number of the decision support tools used in agriculture.

Further studies such as this one will help to facilitate research into risk management in agriculture which is so important at the individual farm, regional, national, and global scale, and so may lead to the development of more appropriate tools to support the decision-making processes practised by farmers.

This research has contributed to knowledge in the following ways. First, it has presented a methodological framework for doing research that embraced an action research approach. Thus the methods used included interviews, focus group discussions, a survey among experts on decision support tools in agriculture, workshops with farmers to present new tools that could help their decision-making processes, and evaluation surveys of the products that were presented. The content of these activities was carefully focussed on the farmers' expressed needs. The study used qualitative evaluation methods that allowed each step in the process to be assessed before moving on to the next stage. Thus the clients, as well as the researcher, had considerable influence over the direction of the research, and the outcome was a product that appears to meet the needs of the principal stakeholders.

Second, this study has identified the various risks faced, and the practical risk management strategies employed, by dryland farmers in southwest Queensland. In addition, the study provided these farmers with the opportunity to reflect on how they manage these risks and describe the process to an outside observer. In response, a decision support tool that tries to address their principal concerns has been developed.

Third, the research has introduced those farmers who volunteered to become involved in the study to some existing decision support tools. They appreciated being involved in such an educational process to learn about existing decision support tools that most of them had not heard about. They also expressed the view that attending the workshops had improved their ability to manage soil moisture and make better planting decisions.

Finally, the research has contributed quite specifically by developing a decision support tool that could help dryland farmers in southwest Queensland make informed and more appropriate planting decisions, under the very uncertain and risky conditions in which they farm.

The planting decision key developed as part of this study needs further testing to ensure that it meets the needs of the broader community of dryland farmers in southwest Queensland and it could be enhanced with other features to improve its usefulness to them. These are topics for further research.

<center>*   *   *   *   *</center>

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Appendix I: Focus groups

AI.1 Recruitment of focus group participants

A preliminary invitation letter (AI.2) was sent to each potential participant in the list of farmers provided by QDPI&F staff at Roma Research Station. This letter was sent approximately four weeks prior to the meeting. In total, 22 invitation letters were sent out with the expectation of getting about 70 percent acceptances to have 16 participants in two discussion groups. The second step was making personal contact by telephone. This was done one week after the letters were sent out. The purpose of those phone calls was to check if potential participants had received the letter and whether they would be able to attend the meeting. All potential participants had received the letter by the time of the phone contacts and 20 of them agreed to participate in the discussion. This high rate of response (20 out of 22 invitations) reflects both the nature of the farmers selected and their interest in the study topic. The third step was to send personalised follow-up letters to those farmers who agreed to attend. These letters were sent ten days before the meeting date. The basic content of these letters was to thank participants for accepting the invitation and to confirm the time and date of the meeting. The last step was to call participants to remind them of the meeting. This was done two days before the meeting.

In addition to the invitation letters, participants also received an Information Sheet and an Informed Consent Form as part of the procedure for Ethical Clearance from The University of Queensland. These latter items were given to participants before the discussions started. The Information Sheet explained the justification, objectives, likely output and benefits, contact names, and duration of the study. The Informed Consent Form fulfilled a University of Queensland policy requirement to ensure that participants were given important information about their rights and privacy and had this explained to them. Participants were asked to sign the required forms to record that they had agreed to participate in the study.

> ***Getting people to attend focus group discussions:***
> 1. Set the meeting dates, times, and locations (*Friday, 18th February 2005; 12-2p.m for the first group and 4-6p.m for the second group; Maranoa Club, Roma, Queensland)*;
> 2. Send preliminary invitation letters (*27th January 2005);*
> 3. Make personal contacts by telephone (*around 4-6th February 2005)*;
> 4. Send personalised follow-up letters (*8th February 2005)*;
> 5. Make reminder phone calls (*15-16th February 2005).*

AI.2 Preliminary invitation letter to participants[1]

27 January, 2005

«First Name» «Last Name»
«Address»
«Town» QLD «Postal Code»

Dear «First Name»,

I am writing to ask your assistance with a study on risk management and decision support tools for dryland farmers in southwest Queensland. This study is the basis of my PhD research at The University of Queensland, Gatton Campus. I am working in co-operation with the Western Farming Systems project and Queensland Department of Primary Industries and Fisheries (QDPI&F). Your name was suggested by Kathy Snars, a researcher at QDPI&F Roma Research Station.

We are planning to conduct a group discussion of farmers which will be held:
> *Friday, 18th February 2005*
> *12 to 2 p.m*
> *Maranoa Club*
> *27 Hawthorne Street, Roma 4455*

It will be a small group, about eight people. We will provide a meal and also you will receive a small payment ($50) for your time and travel costs.

I will contact you shortly by phone to confirm your availability. I would be very glad if you could participate in this important exchange of farmers' view.

For more information about these focus groups and their purposes you may wish to contact me on: 07 5460 1604 or my advisors, Dr Malcolm Wegener on: 07 3365 2939, or Dr Iean Russell on: 07 5460 1337.

We are looking forward to seeing you there and hearing your views.

Yours sincerely,   Yours sincerely,

Iean Russell   Nam Nguyen
Lecturer   PhD Student

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[1]: All letters sent to participants in this study were printed officially with The University of Queensland's logo and letterhead. Similar formats as this letter were used to invite farmers to attend various workshops reported in Chapters 8 and 9 of this thesis.

AI.3 Steps of conducting focus group discussions

1. Ask participants to sit according to their name tents on the table;
2. Welcome and give introduction: name, study program, what a project is seeking and how this focus group operates;
3. Give participants an Information Sheet, an Informed Consent Form, a list of discussion questions, blank papers, and pens (*ask them to read and sign the Consent Form; after that allow them 5 minutes to have a quick think about the questions*);
4. Start by asking and discussing the questions in turn;
5. Finish the questions and have a short coffee break;
6. Ask the assistant to write on the board all the sources of risk identified by participants;
7. Add in more sources of risk which were not mentioned by participants and ask them whether these risks apply to their farm operation;
8. Ask participants to add more items that would go under each source;
9. Ask participant to mark on three sources of risk that they think are most important;
10. Conclude the discussion and thank participants for attending the meeting.

AI.4 Details of focus group discussions

Focus group report: Group 1
This group had six participants and all of them were principal decision makers in their farm businesses. They also varied in age.

Question 1   In your words, what is risk?
Farmers' definitions of risk were not as long or as complicated as those used by scholars (reviewed in Section 2.2 of Chapter 2). There was general agreement that risk was anything that threatens the farm enterprises. Another comment was that "Risk is putting anything on the line and being prepared to let something go to get an advantage". All participants in this group accepted the fact that farming is risky. "You can't go into farming without risk. In other word, you can't be a 'no risk' farmer".

Question 2   What are the risks that you have to face in your farm business?
There was a long discussion about risks associated with weather. "I think the biggest risk is weather. If you have rain your crop will come off. If you have storms you may loose your crop. Weather is the biggest single risk". All farmers in this area faced the same problem that was not having enough soil moisture for planting. "We are in a pretty unique situation here. We are growing spring wheat in winter time on moisture that fell last summer. That is one of the risks because growing spring wheat has to rely on last summer's rainfall". Worst sill, rainfall is very unreliable in this area. "We need rain to grow crops; but rain usually comes at the wrong time and it is never enough".

Government policies were another big issue in the discussion. "Legislation, controls, and bureaucracy keep changing and putting a lot of pressure on farmers". "Once you could do whatever you wanted to do with your plot; but now you can't". This was a source of risk that the farmers claimed was out of their control. "Government rules and regulations [create] risks because we are not able to do anything about it".

There was awareness of the changing business environment. "The business environment, *e.g.* taxation, world supplies, and consumers' desire, is changing; therefore it brings more risk into farming". Participants expressed the fear of adverse trade effects as the result of what other nations do. "Some foreign governments want to kill our industry. They can [encourage importers] to bring in a little bit of this and a little bit of that and it is easily being done".

Marketing risk was another issue mentioned specifically in relation to chickpeas. "…if they have a good crop in India or in other areas then when you grow a good crop it may not worth much. That is one of the marketing risks". However, it was generally agreed that this was not a big concern. "Selling a crop is also risky but you can always sell the crop if you have it".

Cattle diseases, planting techniques, nitrogen applications, and water conservation were perceived as agronomic risks. These were sources of risk that participants said they could do something to reduce or minimise the adverse impacts.

Question 3:   How do you manage these risks?
Participants expressed a strong belief that conservation of water was their most important priority. "Before we can do anything, we have got to have strategies such as no till or conservation farming to store [as much water as we can] from the rainfall that we get".

Some of them raised the importance of storing moisture. "With cropping, get the moisture stored and, by using press wheels, be able to plant when you want to. That is a big thing. … With deep planting and press wheels I think that you take one risk out of your farming". There was also strong support for having cattle as part of the enterprise mix. "In this area, at least you can sleep at night when you have cattle. Crops have to rely so much on rain, which is very unreliable here". It was noted that livestock have lower income earning potential to earn money (compared with crops) but with less risk. In addition, running livestock was judged as a good strategy to carry the farm through poor seasons. "Most of us are running livestock (either sheep or cattle or both) and if you miss out on a crop, the livestock usually can tide you over". New ways of conserving hay for feeding livestock were also emphasised. "The introduction of round bales for conserving hay was a big management improvement in livestock. It saves a lot of labour compared with the past".

There was general agreement that marketing of livestock was not a problem. "Animals [predominantly cattle] are doing well here because Roma saleyards always get good prices no matter what the season is". Good road transport and the large scale of Roma saleyards were believed to be advantages for livestock producers in this area. "What happens in Roma, with the number of cattle offered for sale, is that [buyers] can come here and know that they can get a certain number of cattle without having to go from here to Dalby or somewhere else". Another advantage was the way the sale operates. "Cattle are sold on a kg basis and weighed afterwards so the risk is taken out of selling. We've got a rough idea of what they might weigh". In regards to marketing of grain, it was suggested that farmers need to keep an eye on world supplies. "Wheat is a universally [demanded] feed for human and animal consumption".

It was generally accepted that marketing might depend on the individual's financial situation. "Whether you are in the position to store it, hold it and wait, or whether you sell it right after harvesting – there are so many different angles". By and large, marketing did not seem to be a big concern for participants. "You are really getting someone else to do the marketing of grain on your behalf. They are going to sell on futures or whatever".

There were also some points mentioned regarding the management of other sources of risk. "How we manage our properties: Try to think of the right things to teach future generations and that sort of thing". Diversification was appreciated. "You've to have a mixture of enterprises to avoid the boom and bust". The use of new varieties and fertilisers was claimed as a good strategy to reduce the risk associated with product quality (which refers specifically to protein in wheat).

Generally, participants agreed that they would focus most on things that they could control and learn how to manage them. Personal characteristics and preferences were regarded as very important in their decision making. Participants understood that they have to be in position to take risks; however, they would try to keep the risk at a certain, manageable level.

Question 4   Are you aware of or heard about any new ways (programs, strategies, products) that can be used to help farmers make better decisions under uncertain conditions? If yes, what are they?
One of the younger participants commented that "There is heaps of this stuff out there". However, there was a general conclusion that knowing what was available, and learning how to use these new tools, could be problems. Participants also questioned the cost-effectiveness of these products/programs. "How much do you input for the return you will get back".

Question 5   ***What sort of training do you think would benefit farmers like you and help them to improve their risk management ability?***

"It is simple. We can give you the answer but we know that you cannot give it to us: We want to know when it is going to rain". Participants were concerned the most by "How to get the best dollar return out of a limited amount of water". Crop history was regarded as an important factor affecting subsequent crops. "There is an opportunity to try to do something by taking past history into account and [assess] the moisture level in your soil as well as have a little bit of thought about what might come afterwards". Overall, it was concluded that it would be useful if participants had something that could help them understand the best ways to store water or choose crops that can use water more efficiently.

Question 6   ***Could you please rank the sources of risk identified in Question 2 in terms of importance?*** *(apply a red sticky dot to the most important, blue dot to the second most important, and yellow dot to the third most important risk)*

Participants (6 people in total) in this group mentioned seven main sources of risk that they have to manage in their farm businesses. Their ranking of the three most important sources of risk is reported in Table AI.1.

Table AI.1: Ranking of sources of risk – First group

Sources of risk	Most important	Second most important	Third most important	Total
Climatic risks	6 red dots			**6**
Financial risks		1 blue dot	5 yellow dots	**6**
Personal risks				
Business environment risks				
Marketing risks			1 yellow dot	**1**
Agronomic risks		5 blue dots		**5**
Government policy risks				
Total	**6**	**6**	**6**	

Participants in this group stressed that water was the most important input they needed to have for their livestock and their crops. "Water is very important and the conservation of water is the number one issue. If you don't have water, you might get nothing". It was not surprising therefore that all of the farmers put the red dot on climatic risk as the first important source of risk. Financial risks were ranked second (perhaps surprisingly) since the cost of inputs and fluctuating interest rates were regarded as important issues at the time of ranking. Agronomic risks were ranked third because soil moisture conservation was considered as one of these risks.

Focus group report: Group 2
This group had ten farmers including some of the farmers' wives who participated. Farmers' wives were invited because they play an important role in making farming decisions in this area.

Question 1   ***In your words, what is risk?***
"I think risk is anything we do when we can not be sure of the future". Generally, the uncertain future was considered as the source of risk. "Risk is something where you don't know what the end result is going to be. It is like if you start something and you are not sure about the end of it". Things that prevented farmers from attaining profitability were also referred to as risk. "Risk is something that would prevent you, given opportunities,

from gaining profit or [taking advantage of] profitable opportunities which you would expect to get".

Question 2   What are the risks that you have to face in your farm business?
Many sources of risk were mentioned by participants. "The main risks that we have to face are climatic risks, weather conditions, market variations, government policies, personal risks, and interest rates. Anything which impacts upon the profitability of the enterprise is a risk and the extent to these impacts is what we have to try to manage".

Similar to the first group, weather was the first source of risk mentioned by participants in this group. "The weather is the biggest risk and we cannot control it". There was a generally pessimistic view of climatic variability. "The thing we are not sure about is whether the climatic pattern is a temporary thing or whether it is going to be the same next year". Others added that "Regarding climate variability, we have no reason to doubt at the present time that it is going to get a lot worse ...". Concerns were also expressed about the global warming problem. "The earth is warming up itself".

Concern about government policies included vegetation management, water policies, financial issues, and other regulations. Participants claimed that government policy had a huge impact on how they manage their farms. "Now when you want to do something with your farm, or you want to cut the trees down, you've got to do a lot of paperwork. It's unnecessary. The government isn't there to do what they are doing".

In regard to marketing risk, participants agreed that they have no control over the grain market or what prices were going to get at the end of the season. "The big problem is that we are price takers, not price makers". Others added that "…multinational companies are watching the whole world by satellite. They know who grows what and they influence prices in the market". Another marketing concern was the disadvantages experienced by Australian producers in international trade. "We cannot compete with producers in subsidised countries exporting their products". Furthermore, some participants were worried that the increasingly higher quality requirements for agricultural products will make it harder for farmers to compete successfully.

Another big risk was finance, especially interest rates. "The interest rate is something we can only manage to a certain extent. It has a fair influence on what you do and what you don't". Some members of the group expressed disappointment about the "inexperience" of staff in financial institutions. "There are very few rural bank analysts and managers coming from rural background these days. They hardly know anything about the rural industries and the way that bank assistance is set up to help farmers". Similarly to participants in the first group, participants in this group also had fears about the power of some multinational corporations. "We've got to be aware of the control exercised by large corporate entities (especially overseas). They actually have a larger budget than perhaps the Commonwealth Government of Australia has".

There was a fairly long conversation about personal and personnel risks. "Succession planning and things like that are pretty important". Participants agreed to a large extent that now they "don't have enough time to train young people". "Young people such as work experience students who come to your place to do farm work sometimes add more risks, more dramas, and more hassle". There was a discussion but no conclusion about whether buying machinery was better than hiring contractors. It was generally accepted that the need to acquire labour may add to risk. "Untrained or inexperienced contractors cause dramas but it is fairly expensive to pay for skilled ones". Nevertheless, participants agreed

that it was worth employing skilled contractors as long as you could get the necessary return from them. "You've got to be prepared to spend extra money on contracting to save the risk of not planting or harvesting on time".

Question 3:   How do you manage these risks?
All participants agreed that soil moisture conservation was essentially important to them. "Regarding farming, I think we've got to grow wheat on summer rain and whether we use the old tradition of farming or the modern tradition of zero till, they both work. But zero till seems to be a better situation to conserve more moisture. That is what we've got to do: conserve more moisture". Zero till was highly regarded as a good way of farming. "Given the water we have available, zero till is the best way to reduce the risk of erosion and water evaporation". Other strategies included being prepared and being opportunistic. "Spray early, cultivate early, and if you're late you don't get a return". "Be an opportunity farmer, if you've had rain, got moisture, and time, you should put something in because you might get no more of it".

The participants in this group agreed that better medium-range weather forecasting has helped considerably in regards to managing climatic variability. "Although such forecasts have some distance to go in order to become reliable, a study of Pacific Ocean temperatures and the Southern Oscillation Index (SOI) can be a good guide to what will probably happen for some months ahead". Participants claimed that it was regrettable that the time of climatic 'kick over' (from favourable to unfavourable conditions) in the Pacific Ocean does not become very obvious until May in any given year while preparations for planting winter crops must take place considerably before then in order to assure that the soil conditions are right for planting. "About all that a farmer can do is to keep an eye on the sea surface temperature patterns in the Pacific Ocean and follow the movements of the SOI during late summer and autumn, and put in place management strategies to cope with the worst scenario should it occur".

"Getting the price right" was one of the essential strategies in managing marketing risks. However, this was something "very hard to cope with". "Fortunately, now you have got information and advice from agronomists and marketing consultants that can help a lot". Another marketing strategy was selling only part of your production at any one time. "You will be pretty brave here to go out and [forward] sell 50% of this year's crop". Others agreed that "You'd better not to sell all your crops or cattle at one time because you can never be completely right". It was also suggested that the worst time to sell a product was at harvest time and that farmers should try to avoid that as much as they can. "Every farmer should watch market trends carefully in the hope of being able to make the right decision at the right time". Some participants commented that "For example, if market price prospects for cereal grains look poor, chickpeas might be a better option…".

In regards to financial risk management, it was agreed that good business management was a key strategy. "Good business management on the part of the farmers can do a lot to reduce the risk of serious financial losses from either climatic variability or fluctuating market prices". Interest rates were regarded as controllable. "You can lock in interest rates if you want to. If you think the interest rate is going through the roof, you can lock it in for five years at the very least, no drama".

Diversification and off-farm income were other risk management strategies. "It is always wise to be in two industries if you can. That takes the risk out of being in one industry alone because if the cattle industry is having a hard time you can have another source of income from the crop industry … it is wise to diversify your enterprises". While off-farm

income was listed as a risk management strategy, there was some suggestion that off-farm investment may sometimes added to risk. However, the majority of participants agreed that every farmer should consider investing surplus funds (if they have any) in wisely chosen off-farm investments rather than expanding their farming area. "Providing that the off-farm investments are sound, this strategy might increase the chances of overall financial survival".

Some participants seemed to be very prepared for and realistic about managing risk. "There is risk in whatever you do but you can minimise it". For them, the best strategy was getting the best return from every dollar they spend. "We've got to change our thinking. We'd better manage to get the best out of what we've got, instead of talking about the rain and other things". Participants also valued highly the advice they get from sources such as private agronomists, marketing advisers, extension officers, etc.

Question 4   Are you aware of or heard about any new ways (programs, strategies, products) that can be used to help farmers make better decisions under uncertain conditions? If yes, what are they?

Like the first group of farmers, participants in this group also questioned the effectiveness and complex nature of the available programs. "There have been talks and workshops here about the various aspects of climate and we try to understand it … but it is always 'may be' or 'might be' and '40% of the possibility' or 'on average'. It is difficult to know what sort of training we should do to interpret what the science says – very difficult".

Question 5   What sort of training do you think would benefit farmers like you and help them to improve their risk management ability?

There were some pessimistic views about this. "Nothing is possible to be developed to help farmers make better decisions in the face of this enormous weather variability". Nonetheless, the majority of participants said that they would like to have something to evaluate farming options. "Something that helps you to choose the right crop to grow or make better decision at planting time about whether to plant one crop or the other. This would be very useful".

Generally, it was stated that it is difficult to know what sort of training is appropriate. "Any forecasting system needs to be better than 50% right". Participants said that they would like to see a system that works better than other forecasting systems currently available. In addition, international market advice was considered essential. Participants claimed that they lacked information about how overseas markets were performing, reflecting how the prices for their crops and livestock were going to move. "Marketing options should be a very good way to go. The other thing is trying to incorporate some better information there about supplies of products overseas and provide information so farmers can make better decisions about either which crop they should grow or which place to sell their products". There was awareness of the need to educate the young farmers to have good farming skills. "What the young people are learning from agricultural colleges is sometimes absolutely different with what actually occurs in the field". Participants expressed deep concern that there should be more education in schools about agriculture. "Many kids still think that milk comes from bottles at Coles".

Question 6   Could you please rank the sources of risk identified in Question 2 in terms of importance? (apply a red sticky dot to the most important, blue dot to the second most important, and yellow dot to the third most important)

Eight out of ten participants in this group listed climatic risk as the main source of risk that they have to face in their farm businesses. The other two participants listed personnel risk

and market variation as their most important categories. These sources of risk were very similar to those suggested by participants in the first group. Their ranking of the three most important sources of risk is reported in Table AI.2.

In confirming this assessment, one of the participants commented that "I would say without any fear of contradiction that I really believe climatic risk is the most important one". In common with those in the first group, participants in this group considered the value of water was very high. "The biggest problem for all farmers here is water – that is 99.9% of the problem". Therefore, climatic risk was ranked as the most important source of risk. The second greatest risk was the "out of control" source – government policies, and the third one was market variations.

Table AI.2: Ranking of sources of risk – Second group

Sources of risk	Most important	Second most important	Third most important	Total
Climatic risks	8 red dots	1 blue dot	1 yellow dot	**10**
Financial risks		2 blue dot		**2**
Personal risks			2 yellow dots	**2**
Personnel risks	1 red dot		1 yellow dot	**2**
Market variations	1 red dot	3 blue dots		**4**
Agronomic risks			2 yellow dots	**2**
Government policy risks		4 blue dots	4 yellow dots	**8**
Total	**10**	**10**	**10**	

Appendix II: Survey of DSS expert opinion

AII.1 List of survey experts

Table AII.1: List of experts and their organisations

Name	Organisation	Mode of feedback
David Pannell	UWA	Email giving answers
Ross Kingwell	UWA & DAFWA	Email giving answers
Howard Cox	QDPIF & APSRU	Email giving answers
Richard Routley	QDPIF & APSRU	Email giving answers
Malcolm Wegener	UQ & APSRU	Email giving answers
Graeme Hammer	UQ & APSRU	Email giving answers and references
Andrew Moore	CSIRO	Email giving answers and references
Brett Robinson	QDNRM & APSRU	Email giving answers and references
Peter Wylie	Horizon Rural Management	Email giving answers and references
Amir Abadi	DAFWA	Email giving answers and references
David Freebairn	QDNRM & APSRU	Personal discussion providing answers and references
Daniel Rodriguez	QDPIF & APSRU	Personal discussion providing answers and references
Lindsay Ward	Ward Agri Pty Ltd	Personal discussion providing answers
Gus Hamilton	QDPIF & APSRU	Phone conversation providing answers
Teresa Lynch	Central Queensland University	Email providing no answers, but listing references
Peter Hayman	SARDI	Email providing no answers, but listing references
Bob McCown	CSIRO & APSRU	Email providing no answers, but listing references
John Quiggin	UQ	Email providing no answers, introducing Andrew Moore
Holger Meinke	QDPIF & APSRU	Email providing no answers, introducing Daniel Rodriguez

AII.2 Interview introduction and survey questions

Content of interview email sent to experts

Subject of email: Asking for your advice from a PhD student at The University of Queensland

Dear (expert's name),

I am writing to ask for your advice and help with my study.

My name is Nam Nguyen; I am doing a PhD program at The University of Queensland Gatton Campus under the supervision of Dr Malcolm Wegener and Dr Iean Russell. My study topic is 'Risk management strategies and decision support tools for dryland farmers in southwest Queensland'. I am working in association with the southwest Queensland Farming Systems project.

Having done some interviews and focus group discussions with farmers at Roma, I have found that soil moisture management and crop choices are critical issues relating to risk management for farmers in this region. Therefore, I am working on designing a decision support system (DSS) tool (such as a spreadsheet or a model) that makes use of information on crop history, current soil moisture level, seasonal climate forecasts, water use efficiency, and gross margins to assess crop planting options at various times of the year.

As a very beginner in the field of DSS and model design, I would like to ask you, an expert having many years of experience, for your advice. Would you please kindly advise me on the following issues:

1. *What guidelines would you suggest when designing a DSS for farmers?*

2. *What do you think about the current adoption of DSS in Australian agriculture? How widely are these tools used? What are the main contributions of DSS in agriculture today? What sorts of issues limit their usefulness or uptake by farmers? How much are farmers part of the processes of initiating the requirement for, design and testing of DSS?*

3. *What is your opinion about the future development of DSS in Australian agriculture? What will be the likely criteria for the high adoption of a DSS?*

I would deeply appreciate your time and advice! The advice will help me in my work on the development of a risk management tool that is relevant to farming systems in southwest Queensland. I would also like to incorporate a summary of responses to these questions in my thesis, as part of my discussion of DSS, current issues and future directions. I have read a considerable material in this field as part of that background, but would be very grateful for your opinions as an expert in the field. I hope that you will be kind enough to provide responses and to give me permissions to cite these comments in the thesis?

I am looking forward to hearing from you,

Best regards,
Nam

Nam Cao Nguyen
PhD Candidate
School of Natural & Rural Systems Management
The University of Queensland
Gatton QLD Australia 4343
Phone: 07 5460 1604
Mobile: 0423 506 901
Email: n.nguyen@uq.edu.au

Appendix III: Risk management tools workshop

AIII.1 Workshop preparation

In late June 2005, invitation letters were sent to all of the 16 farmers who had participated in the focus group discussions in February 2005. The letter invited them to attend a workshop on managing soil moisture and risk management tools. A summary of the focus group discussions was enclosed with each letter. This enabled participants to comment and make corrections to the summary if necessary. It also helped to check validity of the author's summary of the discussion which raised the importance of addressing the issue of stored soil moisture when farmers have to make planting decisions.

During July 2005, personal phone contacts were made and follow-on letters were sent to potential workshop participants. Initially, 10 farmers had agreed to attend the workshop, which was organised on 3 August 2005. However, only six of them were present on the day and the other four could not come to the workshop because of unexpected reasons.

> *Workshop program:*
>
> | | |
> |---|---|
> | 9.30 – 10.00: | Welcome, informal interaction, and morning tea |
> | 10.00 – 10.30: | Scenario testing: A discussion of planting decisions under various conditions – Nam Nguyen and Iean Russell |
> | 10.30 – 12.00: | Howwet? and Howoften? presentation – David Freebairn and Norm Gurner |
> | 12.00 – 12.30: | Discussion and evaluation – Nam Nguyen and David Freebairn |
> | 12.30 – 13.00: | Lunch |

AIII.2 Workshop evaluation sheet

1. I currently use/plan to use the following tools on my farm to estimate soil moisture (tick more than one if necessary)

Currently use				In coming seasons			
Rainfall records	O	Soil core	O	Rainfall records	O	Soil core	O
Push probe	O	Howwet?	O	Push probe	O	Howwet?	O
Others: …………………………………				Others: …………………………………			

2. Please circle the number that you think relevant to the following statements

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a) I thought that the day was well organised and useful	1	2	3	4	5
b) Similar workshops would be useful	1	2	3	4	5
c) Attending this workshop has improved my ability to:					
- assess and correctly use tools for monitoring soil moisture	1	2	3	4	5
- calculate how much soil water is stored	1	2	3	4	5
- use soil water and climate information in making more informed cropping decisions	1	2	3	4	5

3. In making a planting decision at a given time in the year, what sort of information do you need? (tick more than one if necessary)

Soil moisture   O   *Expected in-crop rain* O   *Past cropping history* O
Variable costs   O   *Expected yield*   O   *Expected Gross Margin* O
Others (Please specify): …………………………………………………………………………………

4. Which crops would you want to include in a program/tool to assist with planting decisions? (tick more than one if necessary)

Wheat   O   *Barley*   O   *Chickpea*   O   *Canola*   O
Sorghum O   *Sunflower*   O   *Pasture*   O
Others (Please specify) …………………………………………………………………………………

5. Do the existing products answer your needs? *Yes   O   No   O   Don't know O*
   If not, what would you like to customise the application of them to suit your needs?
   Howwet?:…………………………………………………………………………………………………
   ………
   ………
   Howoften?:………………………………………………………………………………………………
   ………
   ………

6. Have you heard of the WhopperCropper program?   *Yes   O   No   O*
   Are you using it?   *Yes   O   No   O*
   If yes, is this program useful for you?   *Yes   O   No   O*
   If no, would you want to try this program?   *Yes   O   No   O*

7. Are you comfortable with using a computer-based tool to help you to make better planting decisions? Or would you prefer paper-based assistance?

Prefer Computer-based tool   O   *Prefer Paper-based tool*   O

8. Would you be happy to be involved further in this study?   *Yes*   O *No*   O

9. What would be the opportunity cost of missing one day in your planting window time?
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………
10. Other comments
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………

Thank you very much for your time!

Appendix IV: Decision support tools workshop

AIV.1 Workshop preparation

In September 2005, invitation letters were sent to all 16 farmers who had been involved in the previous phases of this study (focus group discussions in February 2005, and the risk management tools workshop in August 2005). The letter invited them to attend a workshop on WhoppperCropper program, planned to be held on 7 October, 2005. After sending the letters, follow-up personal phone calls were made to confirm attendance of potential participants. Unfortunately, most of the farmers were about to start harvesting their winter crops. This was earlier than expected because the weather was dry and the crops had matured early. Potential participants said they would prefer the workshop to be postponed until some time in the last two weeks of November 2005.

In early November 2005, invitation letters were sent again to these 16 farmers. Personal contacts by telephone were then made to confirm attendance, and 11 farmers said that they would like to attend the workshop. All of them turned up on the day (18 November 2005) to participate in the workshop.

Workshop program:

12.00 – 12.30:	Lunch and informal interaction
12.30 – 12.40:	Introduction (workshop and WFS project team) – Nam Nguyen
12.40 – 13.15:	Discussion (last harvesting season and coming summer crop options) – Nam Nguyen and WFS project team
13.15 – 14.15:	WhopperCropper presentation – Howard Cox
14.15 – 14.30:	Afternoon tea
14.30 – 15.00:	Presentation – WFS project team
15.00 – 15.15:	Evaluation

AIV.2 Workshop evaluation sheet

1. Please circle the number that you think relevant to the following statements

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a) I thought that the day was well organised and useful	1	2	3	4	5
b) Similar workshops would be useful	1	2	3	4	5
c) Attending this workshop has improved my ability to:					
- choose which crop to sow and when to sow it	1	2	3	4	5
- realise factors influencing crop choices	1	2	3	4	5
- analyse different starting conditions and seasonal forecasts	1	2	3	4	5

2. Which crops would you like to see included in a program/tool to assist with planting decisions? (tick more than one if necessary)
    Winter: *Wheat*   O   *Barley*   O   *Chickpea*   O
    Summer: *Sorghum*   O   *Sunflower*   O   *Pasture*   O
    Others (please specify) ……………………………………………………………………

3. Would a Crop choice chart (like a wall calendar to assist planting options) be useful for you?
    Yes   O   *No*   O   *Don't know*   O

4. Is WhopperCropper useful for you?   *Yes*   O   *No*   O   *Don't know* O

5. Are you going to use WhopperCropper in the future to assist your crop management decisions?   *Yes*   O   *No*   O   *Don't know* O

6. Do you have other comments about WhopperCropper?
    ……
    ……
    ……

7. Are you happy to continue to be involved in this study? *Yes*   O   *No*   O

8. Please list the factors that influence your choice of the following summer crops (please list as many factors as you can think of)
    -   *Sorghum:*…………………………………………………………………………………………
        ……
        ……
    -   *Sunflower:*…………………………………………………………………………………………
        ……
        ……
    -   *Pasture:*…………………………………………………………………………………………
        ……
        ……
    -   *Other crop (please specify):* …………………………………………………………………
        ……
        ……

- *Summer fallow:* …………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………

9. Please list the factors that influence your choice of the following winter crops (please list as many factors as you can think of)
    - *Wheat:*……………………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    - *Chickpeas:*………………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    - *Barley:*……………………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    - *Other crop (please specify):* ………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    - *Winter fallow:* …………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………

10. Other comments
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………

Thank you very much indeed for your time and contribution!

Appendix V: 'Key to dryland planting decisions'

AV.1 List of the key's features and states

Stored soil moisture at planting (numeric feature)

Climate outlook (grouped feature)
    SOI time (multi-state feature)
        February-May (state)
        June-January (state)
    SOI phases (multi-state feature)
        Positive SOI (state)
        Negative SOI (state)
        Other SOI phases (state)
    Expected rainfall (numeric feature)

Planting window (multi-state feature)
    1-15 April (state)
    15-30 April (state)
    1-15 May (state)
    15-30 May (state)
    1-15 June (state)
    15-30 June (state)
    1-15 July (state)
    15-30 July (state)
    August (state)
    September (state)
    October (state)
    November (state)
    December (state)
    January (state)
    February (state)
    March (state)

Expected weight gain (numeric feature)

Expected yield (numeric feature)

Fertiliser application (numeric feature)

Past crop history (multi-state feature)
    Wheat-wheat (state)
    Wheat-chickpeas (state)
    Wheat-barley (state)
    Lucerne-wheat (state)
    Winter crop-summer fallow (state)
    Lablab-forage sorghum (state)
    Summer fallow-winter crop (state)
    Summer crop-winter fallow (state)

Market status (multi-state feature)
        Reliable and easy access (state)
        Uncertain and unstable (state)

Risk attitude (multi-state feature)
        Risk averse (state)
        Risk neutral (state)
        Risk taker (state)

Other info sources (multi-state feature)
        Experience (state)
        DPI notes (state)
        Farm consultants (state)
        Neighbours (state)

Other influencing factors (multi-state feature)
        Diseases and insects (state)
        Weeds (state)
        Soil conditions (state)
        Varieties (state)
        Planting rate (state)

AV.2 Input validation for the 'Key to dryland planting decisions'

Table AV.1: Multi-state scores of the key

*This table represents the factors scored for or applied to each crop. If **you agree** with the **given scores**, please **leave them as they are**. If **you do not agree** with **any given score**, please **indicate your new score next to it** (**Y:** *yes/common score*; **M**: *maybe/rare score*; **U**: *unsure/uncertain score*; **N**: no/absent score).*

Influencing factors	Wheat	Chickpeas	Barley	Lucerne	Oats	Winter fallow	Grain sorghum	Forage sorghum	Mungbeans	Grain lablab	Forage lablab	Summer fallow
Planting window:												
- 15-30 April	M	Y	M	Y	Y	U	N	N	N	N	N	N
- 1-15 May	Y	Y	Y	Y	Y	U	N	N	N	N	N	N
- 15-30 May	Y	Y	Y	M	Y	U	N	N	N	N	N	N
- 1-15 June	Y	M	Y	M	M	U	N	N	N	N	N	N
- 15-30 June	Y	M	Y	M	M	U	N	N	N	N	N	N
- July-15 August	U	N	M	N	U	M	U	N	N	N	N	N
- 15-30 August	N	N	N	N	N	Y	U	N	N	N	N	N
- September	N	N	N	N	N	N	M	M	M	M	Y	N
- October	N	N	N	N	N	N	M	Y	M	M	Y	N
- November-December	N	N	N	N	N	N	Y	Y	Y	Y	Y	N
- January-February	N	N	N	N	N	N	Y	Y	Y	Y	Y	M
- March-15 April	N	N	N	N	Y	N	N	M	U	U	M	Y
Paddock history (last two previous crops):												
- Wheat-wheat	U	Y	M	Y	Y	N	Y	Y	Y	Y	Y	Y
- Wheat-chickpeas	Y	M	Y	Y	Y	N	M	M	M	M	M	Y
- Wheat-barley	M	Y	U	Y	Y	N	M	M	M	M	M	Y
- Lucerne-wheat	Y	Y	Y	Y	Y	N	M	M	M	M	M	Y
- Winter crop-summer fallow	Y	Y	Y	Y	Y	N	N	N	N	N	N	U
- Lablab-forage sorghum	M	M	M	M	M	Y	M	M	Y	Y	Y	N
- Summer fallow-winter crop	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y
- Summer crop-winter fallow	N	N	N	N	N	N	Y	Y	Y	Y	Y	Y

Table AV.1: *Multi-state scores of the key (continued)*

*This table represents the factors scored for or applied to each crop. If **you agree** with the **given scores**, please **leave them as they are**. If **you do not agree** with **any given score**, please **indicate your new score next to it** (**Y**: *yes/common score*; **M**: *maybe/rare score*; **U**: *unsure/uncertain score*; **N**: *no/absent score*).*

Influencing factors	Wheat	Chickpeas	Barley	Lucerne	Oats	Winter fallow	Grain sorghum	Forage sorghum	Mungbeans	Grain lablab	Forage lablab	Summer fallow
SOI phases (2 months average):												
- Positive SOI	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	M	M
- Negative SOI	U	U	U	U	M	Y	U	M	M	U	M	Y
- Other SOI phases	M	M	M	M	M	M	M	M	M	M	M	M
Market status:												
- Reliable and easy access	Y	N	Y	Y	Y		Y	Y	U	U	Y	
- Uncertain and unstable	N	Y	N	N	N		N	N	Y	Y	N	
Risk attitude:												
- Risk averse	Y	U	Y	Y	Y	Y	Y	Y	U	Y	Y	Y
- Risk neutral	Y	M	Y	Y	Y	Y	Y	Y	M	Y	Y	Y
- Risk taker	Y	Y	Y	Y	Y	U	Y	Y	Y	Y	Y	U
Other information sources:												
- Experience	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
- DPI notes	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
- Farm consultants	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
- Neighbours	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Other influencing factors:	*The tool includes many crop management notes that provide additional information in regards to these factors*											
- Diseases and insects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
- Weeds	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
- Soil conditions	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
- Planting rate	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	N
- Financial situation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Table AV.2: Numeric scores of the key

*This table represents various ranges of numeric scores applied to each crop. If **you agree** with the **given ranges**, please **leave them as they are**. If **you do not agree** with **any given range**, please **indicate your new range in the underneath box**.*

Influencing factors	Wheat	Chickpeas	Barley	Lucerne	Oats	Winter fallow	Grain sorghum	Forage sorghum	Mungbeans	Grain lablab	Forage lablab	Summer fallow
Stored soil moisture at planting (mm):	60-160	60-160	60-160	60-160	60-160	20-60	50-150	50-150	50-150	50-150	50-150	20-60
Your range: ———————————➤												
Expected in-crop rainfall (mm):	25-200	25-200	25-200	25-200	25-200	25-200	50-200	50-200	50-200	50-200	50-200	50-200
Your range: ———————————➤												
Expected yield (t/ha):	0-4.0	.5-2.8	0-4.0	n.a[*]	.3-1.8	n.a	.5-4.5	n.a	.25-2.7	.5-3.0	n.a	n.a
Your range: ———————————➤												
Expected live weight gain (kg/head/day)[**]:	.5-1.5	0-0	.5-2.0	.5-2.0	.5-2.0	U	.5-2.0	.7-2.0	.5-1.5	.5-2.0	.5-2.0	U
Your range: ———————————➤												
Nitrogen application (kgN/ha):	0-70	0-40	0-75	0-0	0-60	0-0	0-75	0-70	0-40	0-50	0-40	0-0
Your range: ———————————➤												

[*]: *not available*
[**]: *if grain crop fails or if plant forage crops to feed cattle*

Are there any other comments/suggestions would you like to make to improve the tool?

....

....

....

....

....

....

....

....

....

....

Your name: ....

AV.3 Modification of the key's scoring matrix

Y = yes or common score; M = maybe or rare score;
U = unsure or uncertain score; N = no or absent score

Wheat:
- State 'July-15 August': one farmer said M, two farmers said Y, other farmers said U; decided to keep M for 'July' and U for 'August' (it depends on rain, if there is no or little rain from April to June, the farmers may wait until July to plant wheat);
- State '15-30 April': one farmer said Y, others said M; decided to keep M for this state;
- State 'Wheat-wheat': 3 farmers said Y, others said U; decided to change from Y to M for this state;
- State 'Summer fallow-winter crop': 2 farmers said Y, others said N; decided to change from N to M for this state;
- Feature 'Expected yield': only one farmer said '0.0-2.0 t/ha'; decided to keep '0.0-4.0 t/ha' for this feature to be relevant to conditions of other farmers;
- Feature 'Stored soil moisture': one farmer said '40-160 mm'; decided to change the range from '60-160 mm' to '40-160 mm' for this feature;
- Feature 'Nitrogen application': two farmers said '0-50 kgN/ha'; decided to keep the '0-70 kgN/ha' range for this feature.

Chickpeas:
- State '1-15 June': one farmer said Y, others said M; decided to keep M for this state;
- State '15-30 June': one farmer said N, others said M; decided to change from M to U for this state;
- State 'Wheat-chickpeas': three farmers said N, others said M; decided to keep M for this state;
- State 'Lucerne-wheat': one farmer said N, one farmer said M, others said Y; decided to change from Y to M for this state;
- State 'Lablab-forage sorghum': one farmer said Y, others said M; decided to keep M for this state;
- State 'Summer fallow-winter crop': one farmer said Y, others said N; decided to change from N to M for this state;
- Feature 'Nitrogen application': one farmer said '0-0 kgN/ha', others said '0-40 kgN/ha'; decided to keep the '0-40 kgN/ha' range for this feature.

Barley:
- States '30 June-15 July' and '15-30 July': one farmer said Y, others said M; decided to keep M for state 'July';
- State 'Wheat-barley': one farmer said M, others said U; decided to keep U for this state;
- Feature 'Nitrogen application': one farmer said '0-50 kgN/ha', others said '0-75 kgN/ha'; decided to keep the '0-75 kgN/ha' range for this feature.

Lucerne:
- State 'May-July': three farmers said Y; others said M; decided to keep M for this state;
- State 'Lucerne-wheat': one farmer said U, two farmers said M, others said Y; decided to change from Y to M for this state;

- State 'Wheat-chickpeas': one farmer said M, others said Y; decided to keep Y for this state;
- State 'Summer crop-winter fallow': one farmer said M, others said N; decided to keep N for this state;
- State 'Uncertain market': one farmer said Y, others said N; decided to change from N to M for this state;
- State 'Risk averse': one farmer said M, others farmers said Y; decided to keep Y for this state.

Oats:
- State 'June': two farmers said Y, others said M; decided to keep M for this state;
- State 'July-15 August': one farmer said M, others said U; decided to change to U for 'July' and N for 'August';
- State 'Uncertain market': one farmer said Y, others said N; decided to change from N to M for this state;
- Feature 'Expected yield': one farmer said '0.0-1.8 t/ha', others said 0.3-1.8 t/ha'; decided to change from '0.3-1.8 t/ha' to '0.0-1.8 t/ha' for this feature;
- Feature 'Nitrogen application': one farmer said '0-50 kgN/ha', others said '0-60 kgN/ha'; decided to keep the '0-60 kgN/ha' range for this feature.

Winter fallow:
- States 'April-August': one farmer said Y, others said U; decided to keep U for these states;
- Feature 'Stored soil moisture': one farmer said '0-40 mm', others said '20-60 mm'; decided to change from '20-60 mm' to '0-60 mm' for this feature.

Grain sorghum:
- State 'July-August': four farmers said N, others said U; decided to change to U for 'July' and N for 'August';
- State 'September': one farmer said Y, one farmer U, others said M; decided to keep M for this state;
- State 'October': one farmer said N, other said M; decided to keep M for this state;
- State 'Wheat-chickpeas': one farmer said Y, others said M; decided to keep M for this state;
- Feature 'Nitrogen application': one farmer said '0-50 kgN/ha', others said '0-75 kgN/ha'; decided to keep the '0-75 kgN/ha' range for this feature.

Forage sorghum:
- State 'March-15 April': one farmer said N, one farmer said Y, others said M; decided to keep M for this state;
- State 'September': two farmers said Y, others said M; decided to keep M for this state;
- States 'Wheat-chickpeas' and 'wheat-barley': one farmer said Y and others said M; decided to keep M for this state;
- State 'Uncertain market': one farmer said Y, others said N; decided to keep N for this state;
- Feature 'Stored soil moisture': one farmer said '40-150 mm', others said '50-150 mm'; decided to change from '50-150 mm' to '40-150 mm';
- Feature 'Nitrogen application': one farmer said '0-50 kgN/ha', others said '0-70 kgN/ha'; decided to keep the '0-70 kgN/ha' range for this feature.

Mungbeans:
- State 'March-15 April': one farmer said Y, one farmer said N, others said U; decided to keep U for this state;
- State 'Risk averse': one farmer said N, others said U; decided to keep U for this state;
- Feature 'Stored soil moisture': one farmer said '40-150 mm', others said '50-150 mm'; decided to change from '50-150 mm' to '40-150 mm' for this feature;
- Feature 'Expected yield': one farmer said '0.25-2.0 t/ha', others said '0.25-2.7 t/ha'; decided to keep the '0.25-2.7 t/ha' range for this feature;
- Feature 'Nitrogen application': one farmer said '0-0 kgN/ha', others said '0-40 kgN/ha'; decided to keep the '0-40 kgN/ha' range for this feature.

Grain lablab:
- Feature 'Expected yield': one farmer said '0.5-2.0 t/ha', others said '0.5-3.0 t/ha'; decided to keep the '0.5-3.0 t/ha' range for this feature;
- Feature 'Nitrogen application': two farmers said '0-0 kgN/ha', others said '0-50 kgN/ha'; decided to keep the '0-50 kgN/ha' range for this feature.

Forage lablab:
- States 'Wheat-barley' and 'lucerne-wheat': one farmer said Y, others said M; decided to keep M for this state;
- State 'Winter crop-summer fallow': one farmer said Y, others said N; decided to change from N to M for this state;
- Feature 'Stored soil moisture': one farmer said '40-150 mm', others said '50-150 mm'; decided to change from '50-150 mm' to '40-150 mm';
- Feature 'Nitrogen application': two farmers said '0-0 kgN/ha', others said '0-40 kgN/ha'; decided to keep the '0-40 kgN/ha' range for this feature;
- Feature 'Live weight gain': one farmer said '0.5-1.0 kg/head/day', others said '0.5-2.0 kg/head/day'; decided to keep the '0.5-2.0 kg/head/day' range for this feature.

Summer fallow:
- State 'November-December': one farmer said M, others said N; decided to change from N to U for this state;
- State 'Winter crop-summer fallow': one farmer said N, others said U; decided to keep U for this state;
- State 'Summer crop-winter fallow': one farmer said M, others said Y; decided to change from Y to M for this state;
- Feature 'Stored soil moisture': one farmer said '0-40 mm', others said '20-60 mm'; decided to change from '20-60 mm' to '0-60 mm' for this feature.

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