The Adoption of Agricultural Innovations

Geoffrey Kaine

B. Ag Ec. (UNE), M. Ec. (UNE)

Thesis submitted in fulfilment of the requirements of the degree of
Doctor of Philosophy of the University of New England

May 2008
Acknowledgements

This thesis has been several years in the making and I have had the generous support of many people and a number of organisations.

I would like to thank my supervisors, Vic Wright and Ray Cooksey, for their constant support and encouragement. Their constructive suggestions, criticism and advice have been invaluable. Ray has brought a fresh and different perspective that has enriched and ordered my thinking. Vic has been a mentor, colleague and friend to me over many years. He has been steadfast in his encouragement, quick to correct sloppy thinking, and merciless in his teasing.

I would also like to acknowledge Vic and Jim Lees for their contributions to our early work on the adoption of innovations in agriculture. The ideas presented in this thesis had their origins in this work.

A special thanks to Denise Bewsell and Eli Niall who shared the vision of this research and who debated and discussed the ideas expressed in this thesis at length during many long hours on the road when interviewing producers.

I am indebted to all those producers from many agricultural industries across Australia and New Zealand that were kind enough to share their experiences, knowledge and insights with me. I owe my understanding of the practical complexities and pragmatic realities of managing farm systems to them.

I would also like to express my appreciation to the many organisations here in Australia and New Zealand that funded the research projects that have allowed me to develop, test and refine my ideas over the years. I would particularly like to thank the Victorian Department of Primary Industries for providing me with the opportunity to complete this thesis.

I am especially grateful to my colleagues in Practice Change Research, Tatura for their willingness to challenge, discuss and debate the ideas contained in this thesis, and for their patience and forbearance when I have absent, consumed by the task of writing.

This thesis would never have been completed without the generous support of my very dear colleague and friend Fiona Johnson. I am indebted to Fiona for encouraging
me and creating the opportunity for me to complete this thesis by taking on the
difficult and arduous task of managing our team and our projects single-handed
during my absences.

My wife Jean has been inspirational. Jean is my measure of courage, generosity and
self-awareness. She is also my measure of self-indulgence and mischievousness. She
has supported me always and in every way. She has been steadfast in her confidence
in, and her encouragement of, me. Thank you, Jean.

Thanks to Mum, Debbie, Anne and Fred for your love.
Abstract

Technological change and innovation is a fundamental force shaping our lifestyles, our culture and our future. We devote a substantial proportion of our wealth to research activities that span all areas of society, including agriculture. We make this investment, at least with regard to agricultural research, primarily to create wealth and conserve our natural resources.

The return to our investment in agricultural research, the wealth created and the resources conserved depends, in part, on the extent to which primary producers adopt the products of that research. Consequently, maximising the return to our investment in agricultural research involves identifying what research products are likely to be adopted by primary producers and by how many, and determining what processes are required to ensure the diffusion of research products among producers as rapidly as possible. All these depend on an intimate understanding of how the products of research can contribute to better satisfying the needs of primary producers in the conduct of their agricultural enterprises.

The case was made in this thesis that established schools of thinking on the adoption behaviour of primary producers do not provide a rigorous, explicit procedure for discovering how innovations can contribute to satisfying the needs of primary producers as managers of agricultural enterprises. As a consequence, policy makers and investors in research and extension have lacked a rigorous method for identifying the population of potential adopters of agricultural innovations. This means policy making and investment in research and extension has sometimes lacked a thoroughly defensible foundation for setting priorities for agricultural research, and for designing and evaluating programs for promoting the adoption of agricultural innovations.

The aim in this thesis was to describe a framework for discovering how agricultural innovations contribute to satisfying the needs of primary producers as managers of agricultural enterprises. Meeting this objective required describing a method for properly specifying the population of potential adopters of agricultural innovations. Drawing on consumer behaviour theory and farming systems theory a method was described that was based on the assumption that the adoption of agricultural innovations is a highly involving decision for producers and the hypothesis that the
benefits to be had from adopting an agricultural innovation are influenced by particular elements in a farming system that are specific to each innovation. These elements were termed the farm context for an innovation. The method allowed the population of potential adopters to be classified into segments on the basis that producers with different farm contexts obtained different benefits from an agricultural innovation.

The method was tested by application in four case studies in which the population of potential adopters of agricultural innovations was estimated through the identification of the farm context. The case studies included intensive irrigated and extensive dryland agricultural industries, cropping and livestock industries, and perennial cropping industries. The case studies covered innovations with different diffusion characteristics ranging from relatively simple and easy-to-trial innovations to innovations that were more complex and difficult to trial. The case studies spanned the four dimensions of farm context (strategic, labour and lifestyle, technology and practice, and biophysical) and illustrated the ways in which the mix of these dimensions in the farm context differs across innovations.

The results of the case studies supported the hypothesis and demonstrated that the method for identifying and quantifying the population of potential adopters of an agricultural innovation by identifying the farm contexts for an innovation has merit. The results from the case studies also indicated that the method was generalisable across agricultural industries, innovations that differed in their diffusion characteristics, and the different dimensions of the farm system that shaped the benefits to be had from an innovation.
Certification

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

____________________________________
Signature
# Table of contents

Acknowledgements ............................................................................................................. ii
Abstract................................................................................................................................ iv
Certification........................................................................................................................ vi
Table of contents ............................................................................................................... vii
List of tables.................................................................................................................... xi
List of figures................................................................................................................... xiii

## The Adoption of Agricultural Innovations................................................................. 1

1.1 Introduction ....................................................................................................................... 1
1.2 Innovation and adoption defined .................................................................................... 2
1.3 Agricultural adoption research ...................................................................................... 4
1.4 Research objective ......................................................................................................... 9
1.5 Research approach ........................................................................................................ 10
1.6 Outline of thesis ........................................................................................................... 13

## The Adoption of Innovations in Agriculture.............................................................. 15

2.1 Introduction ..................................................................................................................... 15
2.2 Diffusion theory .............................................................................................................. 16

  * Defining the population of potential adopters ................................................................. 25
  * Inappropriate interpretation of diffusion theory ............................................................. 29
  * Inappropriate application of diffusion theory ................................................................. 30

  * The central source model of agricultural research and technology transfer .......... 33
2.3 Capacity building, empowerment and participation ..................................................... 34
2.4 Farming styles ............................................................................................................... 43
2.5 Conclusion ..................................................................................................................... 50
### A Theory of the Adoption of Agricultural Innovations

3.1 Introduction .............................................................. 52
3.2 Consumer purchase behaviour ........................................ 53
3.3 The farm context for an innovation .................................. 62
3.4 Conclusion ..................................................................... 79

### Identifying the Population of Potential Adopters

4.1 Introduction ................................................................... 80
4.2 Knowledge of farm contexts ............................................. 81
4.3 Methods for identifying farm contexts ............................... 84
4.4 Validating farm context as a qualitative construct ................. 94
4.5 Methods for quantifying farm contexts ............................... 101
4.6 Validating farm context as a predictor of adoption ................ 109
4.7 Conclusion ..................................................................... 114

### Case Studies of the Population of Potential Adopters

5.1 Introduction ................................................................... 116
5.2 Case study selection ....................................................... 116
5.3 Case studies ................................................................... 126

#### 5.3.1 Adoption of sub-surface drainage technologies

*Selection criteria* ............................................................... 127
*Background* .................................................................... 127
*Qualitative stage* ............................................................. 129
*Quantitative stage* ........................................................... 131
*Grazing management* ....................................................... 139
*Surface and sub-surface drainage* ....................................... 142
*Extension* ....................................................................... 145
*Conclusion* ..................................................................... 147
5.3.2 Adoption of soil moisture monitoring technologies ......................... 148
   Selection criteria .................................................................................. 148
   Background ............................................................................................ 148
   Qualitative stage ..................................................................................... 149
   Conservation of water ............................................................................ 150
   Irrigation systems, labour and land ......................................................... 150
   Planting techniques ................................................................................. 152
   Irrigation scheduling and soil moisture monitoring .................................. 153
   Quantitative stage .................................................................................... 154
   Adoption of irrigation systems ............................................................... 160
   Adoption of soil moisture monitoring ..................................................... 167
   Extension .................................................................................................. 169
   Conclusion ............................................................................................... 174

5.3.3 Adoption of sheep breeding technologies ......................................... 176
   Selection criteria ..................................................................................... 176
   Background ............................................................................................ 176
   Qualitative stage ..................................................................................... 177
   Risk factors in selecting studs and rams .................................................. 178
   Strategies for countering risk factors in selecting studs and rams .......... 180
   Quantitative stage .................................................................................... 188
   Farm contexts for stud choice and ram selection .................................... 189
   Farm contexts and enterprise characteristics ....................................... 202
   Extension .................................................................................................. 203
   Replication ............................................................................................... 207
   Farm contexts for stud choice and ram selection .................................... 209
   Conclusion ............................................................................................... 216
List of tables

Table 4.1 Components of method for identifying and quantifying farm context.....110
Table 4.2 Criteria for testing external validity of farm context as a theory of adoption ...........................................................................................................................................113

Table 5.1 Listing of studies........................................................................................................118
Table 5.2 The composition of studies with respect to identifying and quantifying farm context ........................................................................................................................................122
Table 5.3 The composition of case studies with respect to testing criteria...........125
Table 5.4 Classification questions for waterlogging of pastures .........................133
Table 5.5 Farm context profiles for waterlogging of pastures ................................135
Table 5.6 Farm context profiles for severity of waterlogging of pastures ..............137
Table 5.7 Farm context profiles for impact of waterlogging on grazing management ....................................................................................................................................140
Table 5.8 Farm context profiles for surface and sub-surface drainage ...............143
Table 5.9 Orchard characteristics by district .................................................................156
Table 5.10 Classification questions for irrigation systems in horticulture ..........162
Table 5.11 Benefit segment profiles for adoption of micro-irrigation .................164
Table 5.12 Characteristics of benefit segments for micro-irrigation .................166
Table 5.13 Extension strategies developed for irrigation system benefit segments ..172
Table 5.14 Extension strategies developed for monitoring farm contexts.........173
Table 5.15 Characteristics of wool enterprises ..............................................................190
Table 5.16 Ranking scenario for ranking affects and fibre diameter .................192
Table 5.17 Respondents ratings of criteria for choosing studs .........................193
Table 5.18 Farm context profiles on criteria for choosing studs .................196
List of figures

Figure 5.1 Classification of farm contexts for waterlogging of pastures .................. 134
Figure 5.2 Classification of benefit segments for irrigation in horticulture .............. 163
Figure 5.3 Classification of contexts for sheep breeding ........................................... 195
Figure 5.4 Classification of contexts for sheep breeding (National) ......................... 210
CHAPTER ONE

The Adoption of Agricultural Innovations

Overall, despite numerous studies, the results of research in this field have been disappointing. Most of the statistical models developed have low levels of explanatory power despite long lists of explanatory variables…. Furthermore, the results of different studies are often contradictory regarding the importance and influence of any given variable.

(Abadi Ghadim and Pannell 1999: 145)

1.1 Introduction

Technological change and innovation are fundamental forces shaping our lifestyles, our culture and our futures. We devote a substantial proportion of our wealth to research activities that span all areas of society, including agriculture. We make this investment, at least with regard to agricultural research, primarily to create wealth and conserve our natural resources.

The return to our investment in agricultural research, the wealth created and the resources conserved depends on the extent to which primary producers adopt the products of that research. Consequently, maximising the return to our investment in agricultural research involves identifying what research products are likely to be adopted by primary producers and by how many, and determining what processes are required to ensure the diffusion of research products among producers as rapidly as possible. All these depend on an intimate understanding of how the products of research can contribute to better satisfying the needs of primary producers in the conduct of their agricultural enterprises.
I shall argue that the established schools of thinking on the adoption behaviour of primary producers do not explicitly provide a rigorous method for discovering how innovations can contribute to satisfying the needs of primary producers as managers of agricultural enterprises. I shall argue that, as a consequence, policy, research and extension agencies lack a rigorous method for identifying the population of potential adopters of an agricultural innovation. Further, I will propose that they therefore lack a defensible foundation for setting priorities for agricultural research and for designing and evaluating programs for promoting the adoption of agricultural innovations.

1.2 Innovation and adoption defined

An innovation is an idea, practice or technology that is new to a decision-maker (Rogers 1995) and may be embodied in new and improved products and processes, new organisational forms, the application of existing technology to new fields, new resources, and new markets (Niosi et al. 1993). Generally speaking, agricultural innovations are conceptualised as being embodied in a physical technology, a practice or technique, or a skill. A practice or technique may be thought of as some kind of management behaviour such as set stocking, or rules governing the timing of management behaviours such as spring calving.

The adoption of an agricultural innovation is an action and is accompanied by the intention to use the innovation for as long as use of the innovation offers an advantage over alternative practices. An agricultural innovation may be a relatively recent discovery or invention, or not, and may have long been known to the producer, or not. Hence, the first use of an agricultural innovation may not occur for some considerable period of time, possibly many years, after the primary producer first becomes aware of the innovation. Consequently, I shall define the adoption of an innovation as the first non-trial use of an idea, practice or technology by a producer. Adoption includes the modification, adaptation and reinvention of a technology or practice but excludes trialling prior to implementation.

Agricultural innovations vary in their divisibility - the extent to which they may be implemented relative to the scale of the agricultural enterprise (Rogers 1995; Doss 2003). The first use of some innovations such as rotary milking systems, drift
lambing, and robotic milking generally occur at the enterprise scale. Consequently, first use and subsequent use of these innovations occur at the same scale and adoption is treated as a discrete state (Doss 2003). Other innovations such as new crop varieties, new planting practices, new livestock treatments or micro-irrigation may be first used at a scale smaller than the entire enterprise and subsequently used more extensively. Consequently, first use and subsequent use of these innovations occurs at different scales. It follows that, for these innovations, adoption is treated as a more continuous state sometimes described as ‘adoption intensity’ (Gebremedhin and Swinton 2003).

The distinction between adoption and adoption intensity creates methodological difficulties as there is no reason to suppose that the factors that influence the first use of a technology or practice are necessarily the same as those that influence any subsequent expansion in the use of the technology or practice (Smale et al. 1995; Smale et al. 2001; Gebremedhin and Swinton 2003). In other words, there is no reason to suppose that the decision-maker seeks the same advantage in their initial use of a technology or practice as they seek in any subsequent expansion in the scale of their use of the technology or practice.\(^1\) These difficulties are avoided by defining adoption as the first use of a technology or practice that is accompanied by the intention to use the innovation for as long as use of the innovation offers an advantage.

The adoption decision encompasses the processes involved in considering the merit of adopting a technology or practice for the first time and includes search activities to obtain knowledge of the innovation. The outcome of the process may be adoption, rejection, or deferment of adoption, of the innovation. Implementation and confirmation of the outcome may be included as stages in the adoption decision (Klonglan and Coward 1970; Robertson 1974; Fishbein and Ajzen 1975; Bandura 1977; Johnson 1986; Chamala et al. 1987; Antil 1988; Davis et al. 1989; Sinden and King 1990; Bagozzi 1992; Rogers 1995; Abadi Ghadim and Pannell 1999; Alvarez and Nuthall 2006). The decision to reject a new technology or practice does not

\(^1\) Furthermore, for the concept of adoption intensity to be commensurable across producers a ceiling must be identified in terms of potential maximal use for each producer. Identifying such a ceiling may be problematic in situations where the ceiling is less than the scale of the enterprise (Smale et al. 2001).
prevent reconsideration from time to time of the merit of adopting a particular technology or practice.

A common theme from several decades of research on technology adoption in agriculture is that the adoption of innovations by producers depends on their believing that the innovation will allow them to better achieve their goals (Lindner 1987; Chambers et al. 1989; Rogers 1995; Frank 1995a; Röling 1996; Abadi Ghadim and Pannell 1999; Pannell et al. 2006). Hence, the population of potential adopters of an agricultural innovation may be defined provisionally as the set of producers for whom adoption of the innovation would create an advantage because the innovation provides a more satisfactory mechanism for achieving their utilitarian, social and hedonic goals. In other words, they constitute the set of producers for whom adoption of the innovation improves the chances of satisfying their self-interest.

Having defined the population of potential adopters of an innovation, terms such as the rate of adoption, penetration of the innovation, and diffusion of the innovation may be defined and distinguished. The rate of adoption is the change in the number of producers that have adopted an agricultural innovation during a period of time. To be commensurable across innovations, rates of adoption should be expressed as a proportion of the population of potential adopters of the innovation. The penetration of an innovation is the total number of producers that have adopted an agricultural innovation at a point in time as a proportion of the population of potential adopters of the innovation. That is, the cumulative proportion of the population of potential adopters that have adopted the innovation. Diffusion is the process whereby an innovation spreads over time through a population of potential adopters of the innovation.

1.3 Agricultural adoption research

The adoption of agricultural innovations by primary producers has been the subject of intense study for some decades. As Abadi Ghadim and Pannell (1999), Chambers et al (1989), Lindner (1987), Röling (1996) and others have observed, when taken as a body of work the results of these studies have been discouraging to say the least. Different studies have produced inconsistent and, often, mutually contradictory results (Feder et al. 1985; Knowler and Bradshaw 2007).
Over the years a number of schools of thought have emerged as to the reasons that explain the decisions of primary producers to adopt agricultural innovations. These include the classical school of technology transfer and the diffusion of innovations that emphasise characteristics relating to the innovativeness of the individual (Rogers 1995), the schools of thought that emerged from farming systems theory that emphasise producer participation in the research process (Chambers et al. 1989), and the schools that emphasise learning and human development (Pretty 1995; Röling 1996). As each school stresses different reasons as being important in the adoption decisions of producers they offer different explanations for the adoption decisions of producers and, consequently, different prescriptions for promoting the adoption of agricultural innovations.

The failure of empirical studies to produce consistent results, and so provide compelling support for any one school of thought, has allowed the different schools to flourish and so offer competing explanations for the adoption decisions of primary producers and competing prescriptions about how to influence those decisions (Douthwaite et al. 2003). This has had a profoundly detrimental impact on research and extension in agriculture.

In the absence of persuasive empirical support for any one school of thought on the adoption of agricultural innovations, investors in agricultural research do not have robust criteria for determining how best to allocate scarce economic resources between projects to develop agricultural innovations. For instance:

> *However, research managers working at the lower levels of the decision hierarchy [...] still lack the practical tools with which to analyse agricultural technology development options in a systematic manner. Specifically, when faced with a range of proposed technology development projects competing for limited resources, they need some means of identifying those that are most likely to have the greatest impact upon the priority groups.*

Reece et al. (2004: 27)

Furthermore, investors in agricultural research do not have robust criteria for determining how best to involve, or not, primary producers in either making investment decisions or in the research itself (Feder et al. 1999; Marsh and Pannell 2000; Vanclay 2004).
Similarly, the absence of empirical evidence clearly favouring one school of thought over the others has meant that investors in extension programs do not have robust criteria for determining how best to allocate scarce economic resources between programs to promote different agricultural innovations. They lack robust criteria for deciding whether to involve, or not, primary producers in making investment decisions about extension programs. Furthermore, investors in extension programs do not have robust criteria for determining how best to design the programs, and consequently, the nature of primary producer involvement in them (Cary et al. 2001; OECD 2001; Boxelaar and Paine 2005; Coutts et al. 2005).

Investors in both research and extension find the issue of judging success and failure of their investments, and what to do about each, problematic. None of the schools can categorically claim success in explaining the adoption decisions of producers. Hence, investors have no reliable criteria for choosing between competing explanations for apparent successes or apparent failures and how, respectively, to repeat or reverse them. Not surprisingly, investors regularly solicit reviews of extension research and practice with aspirations to either identify a favoured school, to integrate the different schools, or to find a framework that systematically places each school and the type of problem they can solve (Coutts et al. 2005).

These are not small matters. There are approximately 3000 full-time equivalent positions in publicly funded extension in Australia (Mullen et al. 2000) and more than $500 million is spent on agricultural research and extension every year in Australia (Anderson and Feder 2003). Worldwide annual expenditure on extension was estimated to be over US$6 billion more than a decade ago (2003: v).

Fulton et al. (2003: 3) describe the following institutions as influencing learning and change in Australian agriculture:

... state and federal departments of agriculture and natural resource management; private extension providers; private agricultural businesses; vocational education and training providers; the national training authority; state training authorities; industry training advisory bodies; research and development corporations; Universities; farmer organisations; and other non-government organisations.

An inadequate explanation of the adoption decisions of producers increases the likelihood of the misallocation of resources among and within these institutions,
resulting in reduced economic growth. Moreover, an inadequate understanding of the adoption decisions of producers in the third world not only increases the likelihood of misallocating resources and reducing economic growth; it increases the chances that well-intentioned efforts to alleviate acute poverty and environmental degradation in those countries will be impeded. As Anderson and Feder (2003: 3) highlight:

Extension helps to reduce the differential between potential and actual yields in farmers’ fields by accelerating technology transfer (i.e., to reduce the technology gap) and helping farmers become better farm managers (i.e., to reduce the management gap). It also has an important role to play in helping the research establishment tailor technology to the agroecological and resource circumstances of farmers. Extension thus has a dual function in bridging blocked channels between scientists and farmers: it facilitates both the adoption of technology and the adaptation of technology to local conditions. The first involves translating information from the store of knowledge and from new research to farmers, and the second by helping to articulate for research systems the problems and constraints faced by farmers.

In my view the continued absence of empirical evidence definitively favouring any one school of thinking on the adoption of agricultural innovations suggests a deficiency in the theoretical frameworks that underpin them. My thesis is that the established schools lack a rigorous method for discovering how innovations can contribute to satisfying the needs of primary producers as managers of agricultural enterprises. As a consequence they are unable to explain the adoption decisions of primary producers sufficiently to identify the population of potential adopters of an agricultural innovation.

The lack of a rigorous procedure for discovering how innovations create benefits for producers as managers of agricultural enterprises means, fundamentally, investors in research and extension necessarily have a limited understanding of the adoption decisions of primary producers (Doss 2003). Consequently, investors cannot explain why producers adopt some innovations and not others. Hence, investors in research cannot but struggle to demonstrate how their decisions to invest in innovation development will match with producers’ decisions as to which innovations they adopt (Reece et al. 2004). And, investors in extension cannot but struggle to demonstrate how their decisions to invest in promoting innovations will inform producers’ decisions as to which innovations they adopt. In short, investors in research and
extension are unable to predict producers’ responses to the outputs of their investment programs (Byerlee 1987). This begs the question as to how investors in research and extension might formulate more meaningful investment strategies. Perhaps it is not surprising that some have gone so far as to argue that extension is in a state of crisis brought on by pressures relating to finance, effectiveness, legitimacy and theory (Vanclay and Lawrence 1995).

The absence of knowledge on the population of potential adopters of an innovation means investors in agricultural research cannot determine the proportion of producers in an industry for whom the innovation is relevant. As a consequence they will have difficulty making accurate judgements about the likely magnitude of the impacts of the innovation on the industry. As a consequence, investors struggle to formulate sensible comparisons between competing proposals for investment in research to develop new innovations.

The absence of information about the population of potential adopters of an innovation means that investors in extension programs cannot ascertain the proportion of the population that have adopted the innovation and so judge the success or otherwise of their programs.

In principle, an innovation might satisfy different needs for different producers. Consequently, different producers might adopt an innovation for different reasons. This suggests the population of potential adopters of an innovation can be classified into segments based on differences in the reasons, or combinations of reasons, for adopting the innovation. The lack of a rigorous procedure for discovering how innovations can contribute to satisfying the needs of primary producers logically dictates the absence of a robust procedure for classifying the population of potential adopters into segments on the basis of the different ways an innovation can satisfy producers’ needs (Reece et al. 2004; Sumberg and Reece 2004).

Ignorance of the different reasons or combinations of reasons that motivate producers to adopt an innovation simply compounds the difficulties investors in extension have in understanding producers’ decisions. This inhibits the design of policies and programs for influencing producers’ decision making.

The lack of a sound procedure for discovering how innovations contribute to satisfying the needs of producers also has repercussions for policy design and
implementation with respect to agricultural production and natural resource management. As Doss (2006: 210) notes:

Without basic descriptive information on who is using the technologies and who is not, it is difficult to know how to formulate policies aimed at improving agricultural productivity.

If policy makers have an incomplete understanding of the adoption decisions of primary producers then they lack a proper basis for formulating policies to change the practices of producers because they cannot anticipate the variety of responses producers may have to those policies (Kaine and Higson 2006).

1.4 Research objective

I have suggested that the absence of a theoretically sound method for discovering how innovations contribute to satisfying the needs of primary producers as managers of agricultural enterprises is a principal cause of the failure of empirical studies into the adoption of innovations to produce a satisfactory body of results. Hence, my objective in undertaking this thesis was to present a framework for discovering how innovations contribute to satisfying the needs of primary producers as managers of agricultural enterprises. In meeting this objective, I shall describe a method for properly specifying the population of potential adopters of an innovation. This method allows the population of potential adopters to be classified into segments on the basis of the different ways an innovation can satisfy their needs. As Sumberg (2005: 9) observes:

Perhaps most importantly, there will need to be much more emphasis on and creative management of the early stages of innovation development – from opportunity identification through to the design and specification of the innovation. Market research must play a major role in these early stages, in identifying groups or segments of potential users, in characterizing the context within which these segments live and farm, and in providing information so that their interests, resources and minimum requirements are reflected in the emerging innovation.

I hope that in achieving this objective I can contribute to more informed decision making in regard to public and private investments in agricultural research and extension, and in the formation of agricultural and natural resource policy. I also hope that my research might contribute to changing the paradigm governing our thinking about agricultural extension.
1.5 Research approach

I have suggested that the different schools of thought that have emerged to explain why primary producers adopt agricultural innovations share a common failing. This failing is the absence of a rigorous method for obtaining an intimate understanding as to how innovations can create advantage for producers. That is, none of the schools has a rigorous method for discovering how agricultural innovations may contribute to better satisfying the needs of primary producers in the conduct of their agricultural enterprises.

The approach I have taken is to characterise the adoption of agricultural innovations as a kind of purchase decision and to draw on thinking from two different disciplines - marketing theory and farm management theory. That the adoption of agricultural innovations is a purchase decision is obvious for agriculture in developed economies where many innovations can only be acquired through markets. However, the adoption of innovations is also a purchase decision even when innovations are freely available. This is because the acquisition and implementation of an innovation necessarily involves the expenditure of resources that have an opportunity cost. The implementation of innovations requires the investment of time and effort in making decisions about the uncertain benefits and costs of reconfiguring the farming system to accommodate the innovation (Dillon and Heady 1958; Norman 1978; Crouch 1981; Collinson 2001; Dorward et al. 2003). Hence, the adoption of any agricultural innovation is a purchase decision.

Marketing theory provides a general conceptual framework for identifying how products satisfy needs. A fundamental proposition of this framework is that needs depend on context. Hence, the benefits to be had from purchasing a product depend on the context of the purchaser. An implication of this proposition is that the benefits to be had from purchasing a new agricultural technology or practice depend on the context of the purchaser, the primary producer. Farm management theory provides a conceptual framework for characterising the specific context of primary producers as managers of agricultural enterprises. Hence, farm management theory provides a framework for identifying the benefits to be had from adopting an agricultural innovation.
In the discipline of marketing an extensive literature has developed about the decision making and purchasing behaviour of consumers. Surprisingly, few of the principles, concepts and constructs in this literature appear in the agricultural adoption and extension literature despite the fact that the technology transfer model (Rogers 1983; 1995) that has dominated in agricultural extension was originally formulated to explain the diffusion of innovations in consumer markets (Black 2000).

There are four reasons for using consumer behaviour theory as the starting point for developing a framework for determining how innovations can contribute to satisfying the needs of primary producers as managers of agricultural enterprises.

First, primary producers are non-specialist purchasers. They are, undoubtedly, specialists in the purchase of agricultural technologies and practices but they are not specialists in purchasing *per se*. A specialist purchaser, such as an organisational buyer, is a purchaser by occupation. They are likely to purchase on behalf of others, to purchase as a member of a group and to purchase on formal product specifications (Assael et al. 1990). Since primary producers cannot be regarded as satisfying these conditions then they must be considered to be non-specialist purchasers. Hence, the literature on decision making by specialists engaged in institutional purchasing is not relevant. The literature on decision making by non-specialist purchasers must suffice. This is the literature on purchasing by consumers.

Second, consumer behaviour theory, like organisational buying theory, recognises that there are a variety of types of purchase decisions and that different decision processes are invoked in different circumstances. This is important as the adoption of a novel agricultural technology or practice is qualitatively different from the routine purchase of familiar, unexceptional agricultural inputs. The former generally entails potential consequences that are significantly more serious than the latter. This difference suggests the way producers might make an adoption decision is likely to be different from the way they make a routine purchase decision.

Third, consumer behaviour theory provides criteria for identifying the type of decision process that is invoked in the circumstance of a particular purchase. In other words, the theory provides criteria for predicting the type of decision making a primary producer is likely to employ when contemplating adopting an agricultural innovation. The construct from marketing that goes to this issue most directly is ‘involvement’.
(Gabbott and Hogg 1999). Adoption decisions, which are novel purchase decisions, can be assumed to invoke higher levels of involvement than do routine purchase decisions.

Fourth, the theory explicitly recognises that different individuals may purchase the same product to satisfy different needs. This recognition follows from the proposition that need depends on context and allows the classification of purchasers of a product into market segments on the basis of the benefits they anticipate from using the product. Hence, the theory provides a conceptual basis for classifying the population of potential adopters of an innovation into segments based on differences in anticipated benefits.

Given that the benefits an innovation offers to a purchaser depends on the purchaser’s context, a conceptual framework is needed which enables those aspects of context to be identified which shape the benefits an innovation creates. Farming systems theory provides such a framework in the case of agricultural innovations.

For ease of expression, I have termed those aspects of a primary producer’s context that affect the benefits an innovation creates for the producer the ‘farm context’ for the innovation. The idea that farm context influences the benefits an innovation creates lies at the heart of farming systems theory, in particular, and participative approaches to extension generally. For example Norman (2002: 4) observes:

*The [Farming Systems Research] approach that evolved was based on the notion that: one had to begin with understanding the problems of farmers from the perspectives of farmers; and that solutions had to be based on a proper understanding of their objectives and their environments, including both biophysical and socioeconomic components.*

Farming systems research used the idea that farm context influences the benefits an innovation offers to develop flexible innovations for farmers (Norman et al. 2000; Collinson 2001). These innovations were flexible in the sense they offered benefits to producers from different farm contexts.

Farming systems research has used farming systems theory to guide the process of developing agricultural innovations. Farming systems research has been used to identify the conditions under which adoption of a prototypical technology is technically and economically feasible (Dorward et al. 2003). This has resulted in an emphasis in farming systems research on identifying the boundary conditions that
limit the feasibility of using an innovation and grouping farms according to similarities and differences in those boundary conditions.

Farming systems theory is used a little differently in this thesis. The theory is employed here to help identify the set of farm contexts within which an innovation creates benefits that suit the needs of primary producers as managers of agricultural enterprises. The emphasis is on identifying the various conditions that give rise to benefits being obtained from an innovation, and grouping farms according to similarities and differences in those benefits. Hence, farming systems theory is used here to help identify, within the boundary conditions that fix the technical feasibility of using an innovation, the set of farm contexts for which an innovation creates benefits that are relevant to the current needs of primary producers. This set may not necessarily be restricted to the conditions for which the innovation was originally developed.

In the thesis I present a theoretical framework for identifying the benefits an innovation creates for primary producers using consumer behaviour theory and farming systems theory. The framework provides the basis for a rigorous method for properly specifying the population of potential adopters of an innovation and allows the population of potential adopters to be classified into segments on the basis of the different ways an innovation can satisfy their needs.

1.6 Outline of thesis

In the second chapter the case is argued that the established schools of thought in adoption and extension lack a rigorous procedure for discovering how innovations can contribute to satisfying the needs of primary producers. In the third chapter a framework for identifying the population of potential adopters of an agricultural innovation is developed drawing on the concept of involvement from social psychology as applied in consumer behaviour theory, and on the concept of the farm context for an agricultural innovation based on farming systems theory.

The fourth chapter is devoted to establishing a method for identifying the population of potential adopters of an agricultural innovation based on the theorising in the third chapter. A set of criteria is also established for testing the merit of the framework and the method.
In the fifth chapter the framework is tested by application in a number of empirical case studies. The case studies span a range of innovations and industries. The case studies have been chosen to illustrate the various facets of a farming system that can form the farm context for an innovation.

The final chapter presents arguments showing how the theoretical framework presented in this thesis integrates with the theoretical frameworks that underpin the established schools of thought in agricultural adoption and extension. The thesis framework is used to reinterpret the findings of empirical studies into the adoption of agricultural innovations and to explain many of the inconsistencies in the results of these studies. The implications of the thesis framework for the design of agricultural research and extension programs are then considered.
CHAPTER TWO

The Adoption of Innovations in Agriculture

One of the main roles of a change agent is to facilitate the flow of innovations from a change agency to an audience of clients. For this type of communication to be effective, the innovations must be selected to match client’s needs. For the linkage to be effective, feedback from the client system must flow through the change agent to the change agency so that it appropriately adjusts its programs to fit the changing needs of clients.

(Rogers 1995: 336)

Instead of starting with the knowledge, problems, analysis and priorities of scientist, it starts with the knowledge, problems, analysis and priorities of farmers and farm families.

(Chambers et al. 1989: xix)

2.1 Introduction

Broadly speaking, theories about the adoption of agricultural innovations can be classified into a variety of schools of thought, most prominently ‘innovation diffusion’, ‘learning and capacity building’, ‘participation and empowerment’, ‘farming styles’ and ‘farming systems’ theories. In this chapter I will describe these schools of thought, excepting farming systems theory, and consider the implications of them for the adoption of agricultural innovations and the design of extension programs.

In considering the implications for the adoption of agricultural innovations of each school, I will pay particular attention to the way in which each school characterises, if at all, methods for identifying the factors that influence producers’ decisions about the
merits of an innovation and, by extension methods for identifying the population of potential adopters of an agricultural innovation.

2.2 **Diffusion theory**

Diffusion is the process by which an innovation is communicated through channels over time among members of a social system (Rogers and Shoemaker 1971). There are three components to the theory. The first component is a description of the process that people follow in making a decision about whether or not to adopt an innovation. The second component is a description of the innovativeness of individuals and the spread of innovation through a population. The third component relates to the characteristics of innovations that influence their relative speed of adoption and diffusion. Diffusion theory (Rogers and Shoemaker 1971; Rogers 1983; Rogers 1995) was the pre-eminent model of the adoption of innovations in agriculture and dominated teaching and research in agricultural extension until relatively recently (Black 2000; Sumberg et al. 2003).

2.2.1 **The innovation decision**

Rogers and Shoemaker (1971) originally proposed a four stage model to describe the process people followed in reaching decisions about an innovation. These stages were awareness, persuasion, decision and confirmation. In the awareness stage the individual is exposed to a new idea and develops some understanding of it. In the persuasion stage the individual gathers sufficient information to form an attitude, either favourable or unfavourable, toward the innovation. In the third stage the decision to accept or reject the innovation is made. Finally, in the fourth stage the individual seeks confirmation that they have made the correct decision. If confirmation is not obtained the individual may reverse their decision.

The original version of the model was criticised for treating producers as passive recipients of innovations and for ignoring the phenomenon of reinvention (Biggs 1990; van de Fliert 2000; Sumberg et al. 2003). The model was extended to include another stage, implementation, which followed the decision stage and was intended to capture the process of installing the innovation and making it operational (Rogers 1983). More recent descriptions of the model explicitly allow for the modification, adaptation, reinvention and abandonment of innovations as well as active information
seeking and problem solving by decision-makers during the implementation stage (Rogers 1995; Sumberg et al. 2003).

The model of the adoption decision proposed by Rogers and Shoemaker (1971) is one of many models of behaviour change proposed by different authors (Klonglan and Coward 1970; Ajzen 1971; Robertson 1974; Fishbein and Ajzen 1975; Bandura 1977; Napier et al. 1985; Johnson 1986; Chamala 1987; Antil 1988; Davis et al. 1989; Bagozzi 1992; Rogers 1995; Abadi Ghadim and Pannell 1999; Venkatesh and Davis 2000; Alvarez and Nuthall 2006; Pannell et al. 2006). These models vary in their complexity, the stages in the change process they distinguish, the sophistication with which they describe the processes at work in particular stages, and their generality. However, they are all similar in proposing that the adoption of an innovation is a function of the decision-maker’s perception of the degree to which the innovation contributes to the achievement of their goals – be they utilitarian, social or hedonic (Lindner 1987; Pannell 1999b).

These decision process models are also similar in that they recognise that the elements in the context of the decision-maker that influence the contribution of an innovation to the goals of a decision-maker vary from innovation to innovation. However, these decision models are constructed on the assumption that these elements can be identified using a process of discovery that is external to them. That is, while some of these models offer extensive suggestions as to the various elements in the context that may influence decisions, they do not contain mechanisms for identifying precisely which elements are influential for a particular innovation. Consequently, these models of the adoption decision process cannot be used in isolation to identify the population of potential adopters of an innovation.

For instance, the Theory of Reasoned Action (Fishbein and Ajzen 1975; Ajzen and Fishbein 1980) proposes that the intention to act depends on attitudes and social norms about behaviour. This model, and its variants, has proved to be popular as a model of the adoption of agricultural innovations (Lynne et al. 1995; Parminter et al. 1997; Bergevoet et al. 2004; Garforth et al. 2006; Hattam 2006; Rehman et al. 2006) but identifying precisely which attitudes and norms are relevant to the decision-making about any particular agricultural innovation depends on using methods of discovery that are external to the model. Consequently, although these models are descriptions of an adoption decision process they cannot be used alone to predict the
outcomes of a specific decision. To predict the outcome of the decision process a theory of the merit of agricultural innovations that is external to the model of the decision process is required. Hence, the population of potential adopters of an agricultural innovation cannot be identified using models of the adoption decision processes alone.

The focus of research using diffusion theory has been on identifying the variables that influence progress through the various stages of the adoption decision process in order to understand the spread or diffusion of innovations through a population. In particular, there has been an emphasis on understanding the influence of the characteristics of decision-makers on the diffusion of innovations through a population and the influence of the characteristics of innovations on differences in their rate of adoption (Ruttan 1996).

2.2.2 **Adopter categories and the diffusion of innovations**

According to Rogers (1983) there are two reasons for the differences that occur among individuals in the timing of their adoption of an innovation. First, in principle, differences arise simply due to variations in the speed with which promotional messages and information can be disseminated through a network. Recognition of this principle underlies the formulation of most mathematical models of the diffusion of innovations (Bass 1969). Second, differences arise because individuals vary in characteristics such as their capacity to cope with uncertainty, to form relationships with peers, and to emulate opinion leaders and peers. These differences in capacity to cope with uncertainty, form peer relationships and emulate others underpin Rogers and Shoemaker’s (1971) classification of the adopters of an innovation into five categories.

Rogers (1983; 1995) proposed that innovativeness be defined as the degree to which an individual is earlier in adopting new ideas than other members of a social system. Given this definition and empirical evidence that the rate of adoption of an innovation is typically and approximately normally distributed through time (Rogers 1995), the population of adopters of an innovation could be partitioned into five standardised categories based on standard deviations from the mean of the distribution.

Rogers (1995) argued that the first category consists of a small proportion of individuals, termed ‘innovators’, who would be constantly alert to the appearance of
new ideas and novel technologies and would be the first to adopt innovations. These individuals would actively seek information on an innovation, would independently form attitudes towards it and reach a decision. These individuals were often characterised as venturesome and able to cope with a high degree of uncertainty. These individuals may have little or no influence over others (Rogers 1995; Mahajan et al. 2000).

The ‘early adopters’ are the next category to take up the innovation. These individuals are respected by their peers and act as role models for others (Rogers 1995). Hence, the individuals in this category were thought to have the strongest influence on the opinions of other adopters because other adopters looked to these individuals for information and advice (Mahajan et al. 2000).

The third category of adopters is the ‘early majority’. The individuals in this category are characterised as deliberate and interact strongly with their peers. The individuals in this category share their opinions about an innovation but will seldom hold any influential position in terms of opinion leadership (Mahajan et al. 2000). The individuals in this category provide an important link in the diffusion process between those who adopt very early and those who adopt later (Rogers 1995).

The ‘late majority’ are the next category to adopt the innovation and the individuals in this category are characterised as cautious and unlikely to adopt until there is widespread evidence that others have successfully done so. Rogers (1995) argues that peer pressure is necessary to motivate adoption among the ‘late majority’. Individuals in this category were sometimes characterised as adopting because of economic necessity or peer pressure (Mahajan et al. 2000).

The final category of adopters is the ‘laggards’. Individuals in this category were often characterised as isolated from the social system, traditional and suspicious of new ideas and change (Rogers 1995). These individuals are the last to adopt an innovation.

In Rogers’ (1983; 1995) framework the diffusion of an innovation is initiated by raising awareness of the innovation among the relatively small numbers of ‘innovators’ and promoting the innovation to the ‘early adopters’. The rate of adoption increases over time as individuals in the other adopter categories, such as the ‘early majority’, whose attitudes towards the innovation are assumed to be influenced
by the success of ‘early adopters’, take up the innovation. Eventually the rate increases to the point where enough individuals have adopted the innovation for the rate of adoption to become self-sustaining through word-of-mouth communication (Swanson et al. 1984).

Rogers and Shoemaker (1971) summarised the research on innovativeness and concluded that earlier adopters were more likely to be better educated, literate, have larger enterprises, and have higher social status and socially mobility than later adopters. Earlier adopters were more likely to have greater empathy, be less dogmatic, more favourable to change, less fatalistic and have a greater ability to deal with abstractions than later adopters. Finally, Rogers (1995) found evidence to suggest that earlier adopters were more likely to have more social participation, be highly interconnected through social networks, have more contact with change agents, have a higher degree of opinion leadership and be more cosmopolitan than later adopters.

2.2.3 Characteristics of innovations and their rate of adoption

Rogers and Shoemaker (1971) proposed that differences arise in the rate of adoption between innovations due to differences in the characteristics of the innovations themselves. The rate of adoption is the relative speed with which an innovation is adopted by members of a social system. Rogers (1995) identified five characteristics of innovations that influence their rate of adoption.

The first of these was ‘relative advantage’ which is the degree to which an innovation is perceived to be superior to the practices and technologies it supersedes (Rogers 1995). Relative advantage is a subjective, comparative measure of the benefit of adopting an innovation and may be expressed in economic, social and other dimensions. The nature of the innovation determines the specific type of relative advantage that is important to potential adopters, though this may be influenced by the characteristics of potential adopters (Rogers 1995). Consequently, the perception of relative advantage requires, first, that individuals perceive that the innovation offers a ‘technical improvement’ in that the innovation is superior in some way to the practice or technology it supersedes and, second, that individuals perceive that the technical improvement provides a more satisfactory mechanism for achieving their utilitarian, social and hedonic goals. The rate of adoption of an innovation is positively related to relative advantage.
The second characteristic of innovations that influences their rate of adoption is ‘compatibility’ which is the degree to which an innovation is consistent with the values, experiences, and needs of potential adopters (Fliegel et al. 1968; Rogers 1995). The characteristic of compatibility may influence the rate of adoption of an innovation in that the decision-maker’s beliefs, past experience and practices result in: them being aware, or not, of the innovation; more or less informed about the principles, purpose and consequences of the innovation; more or less able to implement the innovation correctly (Rogers and Shoemaker 1971; Pannell et al. 2006). In principle, the rate of adoption of an innovation is positively related to compatibility. Note that an innovation that is completely incompatible with the values, experiences and needs of a decision-maker would seem unlikely to offer relative advantage in a dimension of relevance to the decision-maker. In practice, relative advantage and compatibility have been found to be correlated (Rogers 1995).

The third characteristic of innovations that influences their rate of adoption is ‘complexity’ which is the degree of effort needed to understand and use an innovation (Rogers 1995). The more complex innovations are, the more difficult are the tasks of understanding the principles underpinning them, implementing them and of anticipating the consequences of adopting them. Hence, more complex innovations place greater demands on the learning and implementation skills of decision-makers. The rate of adoption of an innovation is negatively related to complexity.

The final two characteristics of innovations that influence their rate of adoption are ‘observability’, which is the ease with which the results of the innovation can be seen and evaluated and ‘trialability’, which is the degree to which an innovation can be tested or sampled before being fully adopted (Rogers 1995; Pannell et al. 2006). Both of these characteristics are positively related to the rate of adoption.

The rate of adoption of innovations may also be influenced by variables other than the characteristics of innovations such as the type of the innovation decision, type of communication channels used and the promotional efforts of change agents.

In short, proponents of diffusion theory propose that innovations that are judged to possess a high degree of relative advantage and are relatively simple to understand are likely to be adopted more rapidly than innovations that are judged to possess little or no relative advantage and are complex. Innovations that are compatible with the
values, needs, past experience and ideas of a decision-maker are likely to be adopted more rapidly than innovations that are incompatible. Innovations that can easily be trialled and produce benefits that are easily observed are likely to be adopted more rapidly than innovations that are difficult to trial and produce benefits that are difficult to observe.

2.2.4 Implications for extension

There are some fundamental implications in diffusion theory with regard to the purpose and conduct of agricultural extension. The first is that, in principle, extension activities may alter producers’ perceptions of the benefits of innovations and thereby influence their adoption in two essentially different kinds of ways. One way is for encounters between producers and change agents to provoke a reconfiguration of the goals of producers such that they align more closely with the consequences of innovations. Such an outcome would expand the population of potential adopters. However, this would involve modifying producers’ aspirations and values, a task that is widely acknowledged as extremely difficult given the enduring nature of values and their role in defining self-identity (Kamakura and Novak 1992; Schwartz 1994; Stern et al. 1998; Frost 2000; Pannell et al. 2006).

The other way is for encounters between producers and change agents to change producers’ perceptions of the contribution innovations may make to the achievement of their goals, the goals themselves remaining constant. This implies a change in producers’ perceptions of the interaction between innovations and the environment in which innovations are to be embedded. This kind of encounter changes the rate of adoption of innovations but leaves the size of the population of potential adopters of innovations unchanged (Pannell et al. 2006). The difficulty of modifying producers’ aspirations and values, compared to changing their perceptions, implies that extension activities are most likely to influence the rate of adoption of innovations rather than the scale of adoption (Vanclay 2004).

The second implication is that extension may influence the rate of adoption of an innovation by accelerating the initiation of the adoption decision process (Pannell et al. 2006). This involves promoting awareness and knowledge of the innovation among the population of potential adopters. In this regard the change agent:
Third, extension may influence the rate of adoption of an innovation by accelerating the progression of individuals through the stages of the adoption decision process. Efforts to reduce uncertainty about the benefits of the innovation, and enhance the perceived compatibility of the innovation with values, needs and experiences of the decision-maker, may speed progression through the awareness and persuasion stages of the decision process. Similarly, activities such as field days and farm demonstrations provide means of trialling the innovation and demonstrating the benefits of adoption. Farm demonstrations also provide a context for demonstrating the application of the innovation that is familiar thereby promoting emulation by peers (Rogers 1995).

Fourth, change agents in extension are encouraged to focus their efforts on identifying individuals that are members of the ‘early adopter’ category in the population in order to maximise change agent effectiveness. The individuals in this category are expected to be opinion leaders and role models. Rogers (1995) characterises the individuals in this category as respected by their peers and as being the embodiment of successful adroit users of new ideas. These individuals are expected to have a more favourable attitude towards science and be highly interconnected in their social system. Consequently, change agents may accelerate the diffusion of an innovation through the population of potential adopters by influencing ‘early adopters’.

Fifth, extension may influence the rate of adoption through the judicious choice of mass media and inter-personal communication channels and messages. For example, the choice of different types of mass media, direct targeting of opinion leaders, audience segmentation, demonstrations and farm visits will depend in part on the stage of the adoption decision process the change agent wishes to influence. Relatedly, the framing of promotional material to ensure consistency with the selective exposure and selective perceptions of the target audience is critical to maximising attention to, and appropriate interpretation of, the material (Rogers 1995).
Finally, the influence of extension on the rate of adoption of an innovation will be constrained by characteristics of the innovation. The more complex an innovation, the less compatible the innovation with the values, needs and experiences of producers, the more difficult will be the task of accelerating the rate of adoption. Similarly, the smaller and less obvious the benefits of the innovation and the more difficult the innovation is to trial, the more difficult will be the task of accelerating the rate of adoption.

Given these considerations, Rogers (1995) proposed that the roles of a change agent were raising awareness of the potential for beneficial change, developing rapport with clients, diagnosing problems for the client, persuading the client to change, encouraging action, reinforcing change once implemented, and building the capacity of the client for autonomous change (Rogers 1995).

Diffusion theory indicates that agricultural innovations may fail to spread through the population of potential adopters for a variety of reasons that relate to the design and implementation of extension programs. These include inadequate promotion of the innovation, poor selection of communication channels or poor design of promotion materials, inappropriate choice or design of demonstration activities, inadequate effort or insufficient skills on the part of the change agent, inadequate identification and targeting of ‘early adopters’, and so on.

These putative reasons for the failure of innovations to diffuse have led to a focus in agricultural extension research on subjects such as understanding how producers learn and identifying the factors that influence their learning, identifying the characteristics of opinion leaders and understanding interpersonal networks, the use of communication channels, the characteristics of successful change agents and their training, and the design of promotion activities (Swanson 1984; Byerlee 1987; Chamala 1987; Saito and Weidemann 1990; Rosenberg and Turvey 1991; Guerin and Guerin 1994; Wadsworth 1995; Petheram 1998; Trompf et al. 1998; Petheram 2000; Trompf and Sale 2001a; Hagmann and Chuma 2002; Fulton et al. 2003; Coutts et al. 2005; Stone 2005; Llewellyn 2007).

In the absence of a reliable means for assessing the population of potential adopters the success of extension programs is generally judged on the participation of producers in programs and on participants’ evaluations of their experiences rather
than on behaviour change (Petheram 1998). Low levels of participation in extension programs tend to be equated with low rates of adoption and program failure. High levels of participation in extension programs tend to be equated with high rates of adoption and program success. The designs and extension techniques used in an apparently successful program with an innovation in one industry are often copied and employed in programs for other innovations, and other industries, with the expectation that similar levels of participation, and therefore high rates of adoption, will follow (Jeger 2000).

2.2.5 Discussion

Defining the population of potential adopters

Diffusion theory is a theory about comparative rates of adoption. Fundamental to any such theory is a definition of the population of potential adopters since such a definition is a requirement for ensuring that rates of adoption are measured in ways that are commensurable. Rogers and Shoemaker (1971) did not appear to provide an explicit definition of the population of potential adopters in their writings. They defined diffusion as the process by which innovations spread to members of a social system over time and the rate of adoption as the relative speed with which an innovation is adopted by members of a social system (Rogers and Shoemaker 1971; Rogers 1995). They then defined a social system as a collective of entities which are functionally differentiated and engaged in joint problem solving with respect to a common problem or goal and that the social system constituted a boundary within which an innovation diffuses (Rogers and Shoemaker 1971). This suggests that the social system could be treated as defining the population of potential adopters of an innovation because the members of a system, as defined by Rogers and Shoemaker (1971), share a common problem for which, presumably, the innovation offers a solution. Unfortunately, there are some difficulties with such a definition.

First, there is no reason to expect that any single innovation will necessarily provide the solution to a particular problem experienced by the members of a social system given that the members of a social system are heterogeneous in their goals and circumstances – this is especially the experience in agriculture (Byerlee et al. 1982; Collinson 2001; Norman 2002; Dorward et al. 2003; Sumberg et al. 2003).
Second, some innovations may offer solutions to more than one problem and these problems need not necessarily be common to the same set of decision-makers. This is recognised by Rogers (1995) in a discussion of reinvention and Shih and Venkatesh (2004) in a discussion of use variety. Third, this definition requires that the members of the social system recognise the presence of the problem in order to be a member of the system. This raises difficulties in the treatment of individuals who only become aware of the problem when they become aware of the innovation and the benefits it promises. In practice the population of potential adopters is equated with a social collective such as a community, regional, professional or occupational grouping, or is quantitatively estimated using data on actual adoption (Griliches 1957; Fliegel et al. 1968; Rogers and Shoemaker 1971; Pomp and Burger 1995; Marsh et al. 2000; Chaves and Riley 2001).

An alternative is to define the population of potential adopters in terms of the proposition, embodied in models of the adoption decision process, that the motivation to adopt innovations is a function of the decision-maker’s perception of the degree to which the innovation contributes to the achievement of their utilitarian, social and hedonic goals. Hence, the population of potential adopters of an innovation could be provisionally defined as the set of decision-makers who would perceive an innovation to offer the prospect of better achieving their goals given sufficient knowledge of the consequences of adopting the innovation. In describing the population in terms of the achievement of goals this provisional definition allows for variety in the problems that an innovation solves for decision-makers and excludes those decision-makers for whom the innovation does not offer a solution. Furthermore, this definition does not require that the decision-maker recognise the presence of a problem in order to be treated as a member of the population of potential adopters.

This definition of the population of potential adopters seems broadly consistent with the definition of adoption as the degree of use by producers in the long run when those producers have full information about a technology and its potential (Griliches 1957; Feder et al. 1985). It also complements the definition of a ‘good farmer recommendation’ proposed by Byerlee (1987: 233) as ‘that practice which farmers, given their objectives and resources, would employ if they had all the information available to the researchers.’
Given this definition, the rate of adoption of an innovation may be defined as the proportion of the population of potential adopters that have adopted the innovation during an interval of time where the interval is some fraction of the time the innovation has been available. The cumulative proportion of the population of potential adopters that have adopted the innovation at a point in time defines the penetration of an innovation.

In terms of the concepts used by Rogers and Shoemaker (1971) this definition limits the population of potential adopters to the set of decision-makers that would perceive an innovation as offering a technical improvement of a type that is relevant to their needs and that is sufficiently compatible with their values, experiences and needs to merit adoption – given accurate information on the consequences of adoption. Hence, the population of potential adopters of an innovation may be defined as consisting of the set of decision-makers who would perceive the innovation as offering a relative advantage, given sufficient knowledge of the consequences of adopting the innovation.

This definition properly excludes from the population of potential adopters those decision-makers who perceive an innovation as generally compatible with their values, experiences but offers a technical improvement of a type that is not relevant to them. For example, a new agricultural practice may be acknowledged as superior to present practice by offering a productivity improvement but judged irrelevant in the absence of a desire to increase profitability (Frank 1995b). Such an innovation lacks merit for the producer on the grounds of offering a technical improvement they perceive to be irrelevant. In other words the producer does not perceive the innovation offers them a relative advantage.

This definition also excludes from the population of potential adopters those decision-makers who perceive an innovation as offering a technical improvement of a type that is relevant to them but perceive the innovation to be incompatible with their values and experiences. Such an innovation lacks merit for the producer because, being incompatible with their values and experiences, it does not offer a perceived relative advantage.

---

2 This does raise the vexing question as to the definition of the needs of the decision-maker. In this instance the important point is that the innovation is not incompatible with needs of the decision-maker – simply irrelevant to them at the particular point in time.
This definition includes in the population of potential adopters those decision-makers
who perceive an innovation as offering a technical improvement of a type that is
relevant to them but is not fully compatible with their values, experiences and needs.
This suggests that the innovation is assessed by the decision-maker as contributing to
the achievement of one or more of their goals but detracting from one or more other
goals. Whether adoption of the innovation is justified will depend on the extent to
which the decision-maker believes the values, experiences and needs that are relevant
to the decision are commensurable and therefore allow the use of compensatory
decision rules and, if this is the case, whether the innovation is then judged to offer,
on balance, a relative advantage (Payne et al. 1993). 3

Where the decision-maker believes the values, experiences and needs that are relevant
to the decision are non-commensurable then the innovation is unlikely to be perceived
as offering a relative advantage. This is because the decision-maker is not prepared to
compromise on a relevant value, experience or need with which the innovation is
incompatible.

The definition of the population of potential adopters I have proposed draws attention
to the importance of the innovation itself in defining the population of potential
adopters. The population of potential adopters of an innovation is the set of decision-
makers who would perceive the innovation as offering a relevant and compatible
technical improvement given sufficient knowledge of the consequences of adopting
the innovation. Since the decision-maker is fully informed of the consequences of the
innovation then the population of potential adopters cannot, by definition, be changed
by repositioning the innovation with the respect to goals of the decision-maker to
increase relevance, or by repositioning the innovation with respect to the values and
goals of the decision-maker to increase compatibility. This means, in short, that the
population of potential adopters of an innovation can only be changed by changing
decision-makers goals, a difficult proposition given that the values and goals of
decision-makers are relatively enduring and stable (Frost 2000), or by changing the
innovation itself.

3 See Sall et al (2000) for an example of needs in regard to an innovation being explicitly treated as
commensurable.
Reinvention (Rogers 1995), on the other hand, may be interpreted as modifying an innovation to increase relative advantage of the innovation, to create or improve the relevance of the technical improvement embodied in an innovation, or to create or improve the compatibility of the technical improvement embodied in the innovation. In the latter two instances reinvention increases the population of potential adopters. The theoretical and empirical evidence suggests that independent experimentation, adaptation and reinvention of agricultural innovations by producers is pervasive (Sumberg et al. 2003; Kaine and Higson 2006).

The theory of innovation diffusion has attracted criticism from a variety of sources (Röling et al. 1976; Norman 1978; Norman 1980; Chambers et al. 1989; Kloppenberg Jr 1991; Vanclay and Lawrence 1994; Thrupp and Altieri 2001; Sumberg and Reece 2004). However, many of these criticisms stem from an inadequate understanding of the theory, incorrect application of the theory to understanding decisions to adopt innovations, and the improper interpretation of the theory in the design of innovation development and extension policies and programs in agriculture. These are discussed below.

**Inappropriate interpretation of diffusion theory**

The criticisms that stem from an inadequate understanding of diffusion theory largely concern the inappropriate interpretation or application of the components of the theory that relate to the diffusion of innovations and the rate of adoption of innovations. This is partly because critics have confused the model of the innovation decision process with Rogers’ (1995) definitions of the diffusion process and the rate of adoption of innovations. In essence, many have either treated diffusion theory as a theory of adoption rather than a theory about the rate of adoption, or failed adequately to distinguish between adoption and the rate of adoption (Napier et al. 1985; Guerin and Guerin 1994; Vanclay and Lawrence 1994; Pannell 1999b; Black 2000; Cary et al. 2001; Vanclay 2004; Boxelaar and Paine 2005; Pannell et al. 2006; Miller et al. 2007).

The classification of the members of a social system into adopter categories on the basis of elapsed time between awareness and adoption of an innovation necessarily presupposes eventual adoption of the innovation by all members of the system.
Hence, the classification of the members of a social system into adopter categories can only logically apply to those members of the social system for whom adoption of the innovation would contribute to the achievement of their goals. In other words, the classification of the members of a social system into adopter categories only applies to the members of the system that constitute the population of potential adopters.

Similar reasoning applies with respect to the characteristics of innovations and their rate of adoption. The rate of adoption of an innovation is the relative speed with which the innovation is adopted by the members of a social system. Logically, for rates of adoption to be commensurable across innovations, rates must be calculated with respect to the population of potential adopters; that is, those members of the social system for whom adoption of the innovation would contribute to the achievement of their goals.

Consequently, while diffusion theory necessarily requires some model of the adoption decision process in order to allow inferences to be made concerning the diffusion of innovations and rates of adoption, those inferences only apply to potential adopters of the innovation of interest as defined by the model. Hence, criticisms levelled at diffusion theory, such as that the theory assumes that awareness and knowledge of agricultural innovations will always filter through to all sections of the farming community, are understandable given the ambiguity of Roger’s writings, but are mistaken (Vanclay and Lawrence 1994).

**Inappropriate application of diffusion theory**

The criticisms that stem from the incorrect application of diffusion theory to understanding decisions to adopt innovations largely relate to the design of quantitative studies of adoption. Most studies of the adoption of agricultural innovations usually involve the identification of statistically significant associations between adoption of an innovation as the dependent variable and a variety of explanatory variables using cross-sectional data (Feder et al. 1985; Lindner 1987; Rogers 1995; Doss 2003; Marra et al. 2003; Knowler and Bradshaw 2007). The dependent variable in these studies, adoption of the innovation by an individual, is a non-linear, contingent function of the variables defining the rate of diffusion of the
innovation and the variables defining the relative advantage of the innovation. Such a function may be specified as follows.

Let \( Pr(a) \) denote the probability that a decision-maker has adopted an innovation at time \( t \), let \( Y_t \) denote the number of decision-makers that have adopted the innovation at time \( t \), and let \( \hat{Y}_t \) denote the population of potential adopters. Let \( X_t \) denote a set of variables that indicate whether an innovation offers a perceived relative advantage at time \( t \). Let \( Q_t \) and \( Z_t \) denote the set of diffusion characteristics of decision-makers and the set of innovation characteristics that influence the rate of adoption of the innovation respectively at time \( t \). Let \( f \) and \( g \) denote functions. Then the population of potential adopters at time \( t \) is given by:

\[
\hat{Y}_t = g(X_t) \quad \text{where } g(X_t) > 0
\]

The probability that a decision-maker has adopted the innovation at time \( t \) is given by:

\[
Pr(a) = f(Q_t, Z_t) \quad \text{if } g(X_t) > 0
\]
\[
Pr(a) = 0 \quad \text{if } g(X_t) \leq 0
\]

The proportion of the population of potential adopters that have adopted the innovation at time \( t \) is given by:

\[
Y_t / \hat{Y}_t = f(Q_t, Z_t)
\]

Hence, the number of adopters of the innovation at time \( t \) is given by:

\[
Y_t = f(Q_t, Z_t) \cdot \hat{Y}_t
\]
\[
Y_t = f(Q_t, Z_t) \cdot g(X_t) \quad \text{where } g(X_t) > 0
\]

The expressions above reveal that quantitative studies of the adoption of innovations will be misspecified to the extent that the contingent interaction between the variables describing the population of potential adopters and the characteristics of decision-makers and innovations is ignored. This means that the results of quantitative studies of the adoption of innovations that assume linear relationships between adoption and (a) the variables defining the rate of diffusion of the innovation, and (b) the variables defining the relative advantage of the innovation will be misspecified and therefore biased (Dimara and Skuras 2003).
Few, if any, quantitative studies of the adoption of agricultural innovations appear to have recognised this potential source of bias.\textsuperscript{4} This may be one explanation for the fact that, despite numerous studies, the identification of reliable systematic relationships between producers’ characteristics and their adoption of agricultural innovations has proved elusive. It may also contribute to explaining the difficulty in identifying reliable relationships between factors that influence relative advantage and the adoption of agricultural innovations (Feder et al. 1985; Abadi Ghadim and Pannell 1999; Knowler and Bradshaw 2007).

In addition, Doss (2003) notes that the results of cross-sectional studies must be interpreted with some care. The results of such studies should only be interpreted, in the absence of information on the direction of causality, as indicating an association between the explanatory variables and current use of a technology, not adoption of the technology.

The difficulties that have been experienced in obtaining reliable associations in adoption studies may also be the result of differences across studies in the penetration of the innovation among the population of potential adopters. Where all, or nearly all, of the potential adopters in a sample have adopted the innovation, the process of diffusion becomes irrelevant to understanding differences between those individuals in the sample that have adopted the innovation and those that have not. In these circumstances the variables relating to the diffusion of the innovation should be excluded from the analysis and those defining relative advantage should be retained.\textsuperscript{5}

Where all, or nearly all, of the sample are members of the population of potential adopters of the innovation then the characteristics of the innovation are not relevant to understanding differences between those individuals in the sample that have adopted the innovation and those that have not. In these circumstances variables relating to the diffusion characteristics of individuals should be retained in the analysis and variables defining the characteristics of the innovation such as relative advantage and compatibility should be excluded, except where there are individual differences in the

\textsuperscript{4} For instance, Feder and Umali (1993) and Feder et al (1985) do not recognise this source of bias in their review of econometric modelling of adoption and diffusion.

\textsuperscript{5} This may explain results such as those reported by Adesina and Baidu-Forson (1995) and Adesina and Zinnah (1993).
The intensity of relative advantage, as is usually the case (Loy Jr 1969; Pomp and Burger 1995; Chaves and Riley 2001).  

The central source model of agricultural research and technology transfer
The criticisms of diffusion theory that stem from the improper interpretation of the theory in the design of innovation development and extension policies and programs in agriculture largely relate to the association of the theory with the ‘technology transfer’ or ‘central source’ model of agricultural research and technology dissemination (Biggs 1990; Röling 1996; Collinson 2001; Sumberg et al. 2003). In this model innovations are identified for development at the discretion of a centralised system of formal research institutes, developed by technical and subject matter experts within that system using scientific principles and processes, and disseminated using the principles of diffusion theory (Rogers 1995).

Notwithstanding some notable successes, this model has attracted a variety of criticisms such as producing innovations that did not suit the needs of the target audience, producing innovations that contributed to social inequality, and producing innovations that degraded natural resources (Goss 1979; Norman 1980; Buttel et al. 1990; Vanclay and Lawrence 1994; Thrupp and Altieri 2001; Sumberg and Reece 2004). As a result of these shortcomings the central source model has been judged a failure (Norman 1980; Chambers et al. 1989; Biggs 1990; Vanclay and Lawrence 1994; Röling 1996; Collinson 2001; Thrupp and Altieri 2001; Norman 2002).

An important reason for the failure of the central source model was the belief, on the part of those responsible for the design and implementation of research and extension programs, that suitable innovations could be identified, developed and disseminated with limited consultation with members of the target audience (Chambers 1989; Malik 1991; Röling 1996; Collinson 2001; Norman 2002). A variety of reasons have been advanced for this belief. These include, among others, a perception that traditional agricultural practices and technology were unsound and should be replaced...

6 Musser et al (1986) provide an interesting case where they attempt to estimate regressions for the diffusion of IPM amongst peanut farmers in Georgia using variables measuring perceptions of relative advantage but omit diffusion variables relating to education, age, and extension contact and so on. The performance of the regressions was poor.
rather than preserved (Norman 1980; Gupta 1989; Chambers 1994b; Vanclay and Lawrence 1995; Thrupp and Altieri 2001), a belief that the scientific method could be used to understand the complex reality of producers’ production environments and identify solutions to production constraints (Pretty 1995; Vanclay and Lawrence 1995; Collinson 2001; Douthwaite et al. 2002), and a view that innovations could be refined and adapted to local circumstances using a program of limited on-farm testing prior to release (Sumberg and Okali 1989; Douthwaite et al. 2002). In short, the central source model treated producers as passive recipients of innovations and emphasised the transfer of knowledge and technologies from research centres to producers (Biggs 1990; Malik 1991; Röling 1996; Norman 2002; Sumberg et al. 2003; Vanclay 2004).

There seems little doubt that diffusion theory was the principal theoretical basis for the central source model (Biggs 1990; Röling 1996; Sumberg et al. 2003) and the perceived failure of the model has resulted in widespread disenchantment with diffusion theory. Arguably, however, diffusion theory was misinterpreted and misapplied in the central source model. Diffusion theory is simply a theory concerning the spread of innovations among populations of potential adopters. Crucially, the theory does not contain a definition of the population of potential adopters of an innovation that allows a rigorous method to be formulated for identifying the population of potential adopters of an innovation. In the absence of such a definition and method, diffusion theory cannot be treated as a theory about the process of designing an innovation for a population of potential adopters, or as a theory about the design of institutional systems to produce innovations, or even as a theory about the organisation of research and extension systems. Hence, the association of diffusion theory with the failure of the central source model of agricultural research and technology dissemination is unfortunate and ironic as a proper appreciation of the theory may have pointed to some of the weaknesses of the model.

2.3 Capacity building, empowerment and participation

The failure of the central source model of agricultural research and technology dissemination generated research in a variety of areas such as understanding the
operation of knowledge networks and the institutional organisation of agricultural research and extension (Wolf and Zilberman; Röling 1985; Röling 1996; Carney 1998; Anderson and Feder 2003). In particular, the failure of the central source model intensified research into participative methods for engaging producers in the identification of priorities for agricultural research and extension programs and engaging them in the process of designing, developing, adapting and disseminating agricultural innovations (Röling 1996; Black 2000; Norman 2002; Sumberg et al. 2003). This included research into methods for understanding the complex reality of producers’ production environments and identifying solutions to constraints in those environments: farming systems research (Norman 1978; Byerlee et al. 1982; Collinson 2001; Norman 2002; Dorward et al. 2003).

In this section theories about the adoption of agricultural innovations in terms of learning and capacity building, participation and empowerment are considered.

2.3.1 Diffusion theory and learning
Diffusion theory suggested that extension could influence the rate at which innovations spread through populations of potential adopters by promoting awareness and knowledge of innovations and by accelerating the progression of individuals through the stages of the adoption decision process. For example, efforts to reduce uncertainty about the benefits of an innovation and enhance the compatibility of an innovation with the values, needs and experiences of individuals could, in theory, accelerate the progression of individuals through the awareness and persuasion stages of the adoption decision process. As a consequence, understanding how producers learn and identifying the factors that influence their learning were strategically important subjects for research and practice in extension (Kilpatrick et al. 1999; Andrew et al. 2005; Coutts et al. 2005).

The resulting research investigated a range of issues such as learning styles, processes and sources of information used by producers (Kilpatrick et al. 1999; Trompf and Sale 2001a; Fulton et al. 2003; Kilpatrick and Johns 2003), the influences on producer participation in formal and informal education and training (Kilpatrick et al. 1999; Murray-Prior et al. 2000; Andrew et al. 2005), the social, family, business and geographic circumstances that influence producers’ participation in learning activities and their experiences of learning (Saito and Weidemann 1990; Reeve and Black 1998;
Kilpatrick et al. 1999; Kilpatrick and Bell 2000; Andrew et al. 2005; Llewellyn 2007), processes for facilitating learning (Revans 1980; Petheram 2000; Hagmann and Chuma 2002; Andrew et al. 2005; Coutts et al. 2005), and the impact of learning, education and training on technology adoption and farm performance (Foster and Rosenzweig 1995; Reeve and Black 1998; Kilpatrick et al. 1999; Kilpatrick 2000; McCown 2002). This research drew on a variety of theories of learning such as action learning, adult learning, experiential learning, social learning and double loop learning (Argyris 1976; Bandura 1977b; Bandura 1977a; Kolb 1984).

In short, the focus in extension research and practice was on designing programs to facilitate learning among producers. The emphasis originally was on learning to promote the transfer of agricultural technology and practices to accelerate the diffusion of innovations among producers. Over time and with the growing disillusionment with the central source model of innovation this has increasingly shifted toward an emphasis on building the capacity of producers to learn, plan and make decisions (Chambers 1989; Black 2000; Macadam 2000).

2.3.2 Capacity building and participation

The importance of learning as a subject for study in extension was reinforced with the perceived failure of the central source model of agricultural innovation and the emergence of the multiple source model (Biggs 1990). The multiple source model of innovation broadened the objectives of agricultural extension to explicitly include equitable community development and sustainable agricultural development. In addition, the participation of producers in the identification of priorities for agricultural research and extension programs and their participation in the process of designing, developing, adapting and disseminating agricultural innovations is fundamental in this model (Biggs and Clay 1981; Byerlee et al. 1982; Pachico and Ashby 1983; Ashby 1987; Chambers et al. 1989; Biggs 1990; Saito and Weidemann 1990; Röl 1996; Dorward et al. 1997; Black 2000; Riley and Fielding 2001; Norman 2002; Sumberg et al. 2003; Joshi et al. 2007).

This change in objectives reinforced a trend in agricultural extension towards viewing learning as a lifelong process of personal development and the role of extension as one of building the capacity of producers to learn and to manage change rather than simply being a vehicle for the transfer of technical knowledge (Escalada and Heong
1993; Petheram 2000; van de Fliert 2000; McCown 2001). Hence, proponents of this view of the role of extension advocate extension activities that build knowledge and skills in observation, experimentation, analysis, reflective thinking, consultation, decision-making, planning, and so on, rather than technical knowledge about the principles, properties and consequences of particular innovations (Macadam 2000; Andrew et al. 2005; Coutts et al. 2005; Nuthall 2006).

The participation of producers in the setting of priorities and their involvement in designing, developing and adapting innovations increases the possibility that participatory research programs will generate innovations that offer a relevant and compatible technical improvement to producers, even though these processes have their disadvantages (Ridgley and Brush 1992; Vanclay and Lawrence 1994; Pretty 1995; Black 2000; Sumberg et al. 2003; Orr and Ritchie 2004). This is because participatory approaches to agricultural research and extension recognise local knowledge and experience, support local innovation and adoption, accommodate diversity, promote local capabilities, and facilitate the sharing of knowledge and experience among producers (Chambers et al. 1989; Chambers 1994b; Pretty 1995; Black 2000; Sumberg et al. 2003).

Participatory approaches are also claimed to provide an environment that allows complex agricultural and environmental problems to be understood and resolved and encourage producers to have ownership of these problems and, as a consequence, be motivated to implement solutions to them (Chambers et al. 1989; Malik 1991; Guerin and Guerin 1994; Chambers 1994c; Pretty 1995; Martin and Sherington 1997; Black 2000). These claims are based on the propositions that participants have identified a problem of mutual concern, have a shared desire to take action to find a solution to the problem, and have agreed to work together to reach a solution through a process of co-learning (Chambers 1994a; Pretty 1995; Petheram and Clark 1998; Petheram 2000). For example, as articulated by Petheram (2000: 8)

An important principle … is that success in changing behaviour relative to management of complex problems is more likely to occur if the farmers (or other participants) have ownership of the problem and the possible solutions. So, for success, an R&D process must allow farmers to be involved in defining their problems and hence in owning these. The farmers must (in the process) first learn about the existence, nature and gravity of their problem(s), but also need to feel some responsibility for finding solutions. The process should allow
farmers to use their own experience and knowledge, but also encourage them to access expertise and hence knowledge from other sources.

The emergence of the multiple sources model of innovation, together with the reconceptualisation of agricultural extension as building the capacity of producers to learn and to manage change, coincided with a growing recognition that learning and change are complex processes that are contextually dependent and socially constructed through the interactions of the individuals involved (Schön and Martin 1994; Weick 1995; Röling 1996; Leeuwis 2003; Vanclay 2004; Andrew et al. 2005; Boxelaar and Paine 2005; McCown 2001). One implication of this recognition is that the outcomes of learning can be inherently unpredictable. Consequently, the outcomes of participatory activities intended to identify priorities for research and extension, or to contribute to designing, developing, adapting and disseminating agricultural innovations, cannot be anticipated. This has raised critical issues for public policy and institutional design with respect to agricultural research, extension and evaluation (Martin and Sherington 1997; Marsh and Pannell 2000; Murray 2000; Orr and Ritchie 2004).

The failure of the central source model of agricultural innovation and the emergence of the multiple source model of innovation has had a profound effect on the conduct of agricultural research and extension. The focus in extension research and practice has shifted away from designing programs to facilitate learning among producers and toward an emphasis on building the capacity of producers to learn, plan and make decisions (Chambers 1994b; Pretty 1995; Macadam 2000). This has been accompanied by a shift towards participatory approaches to agricultural research and an appreciation of the concept of co-learning among producers, scientists, change agents and policy makers (Foale et al. 1996; Petheram and Clark 1998). With these shifts extension has been reconceptualised as a mechanism that actively influences the identification of problems and the setting of priorities for research and the identification of solutions to problems, and facilitates the personal development of producers. This is a marked contrast to conceptualising extension as merely a mechanism for the transfer of information between agricultural scientists and producers.
2.3.3 Discussion

From the perspective of diffusion theory the knowledge and skills that producers acquire through capacity-building activities do not intrinsically alter the relative advantage that an innovation offers a fully informed producer. Knowledge and skills may be necessary to permit adoption of the innovation but the acquisition of them does not, in itself, justify adoption of the innovation. Only the perception of a relative advantage justifies the adoption of an innovation.

Capacity-building activities create knowledge and skills that enable producers to commence, and progress through the various stages of, the adoption decision process more efficiently and effectively. If an innovation does not provide a better means of satisfying the utilitarian, social or hedonic goals of a producer in the presence of the knowledge and skills acquired through capacity building, acquisition of these skills does not justify adoption and therefore their acquisition is not relevant to defining the population of potential adopters. Conversely, if an innovation does provide a better means of satisfying the utilitarian, social or hedonic goals of a producer, and the presence of the knowledge and skills acquired through capacity building is necessary to permit adoption, then the acquisition of these skills will influence the rate of adoption and penetration of the innovation among the population of potential adopters.

For capacity building to change the population of potential adopters the process must create the perception among producers that an innovation offers a relevant and compatible technical improvement by fundamentally changing their values and goals. As mentioned earlier, this would entail modifying producers’ aspirations and values, which is extremely difficult given the enduring nature of values and their role in defining self. Moreover, it is not clear where the moral authority to embark on such a cause might be sourced. In short, the process of capacity building, like the process of raising awareness, largely serves to accelerate the diffusion of an innovation through a population of potential adopters.

The participation of producers in the setting of priorities for research programs and their involvement in processes for selecting, designing, developing and adapting innovations creates the possibility that a research program has a greater chance of generating innovations that offer a relevant and compatible technical improvement to those producers. Hence, capacity building that improves the capacity of producers to
engage in participative research programs should be distinguished from capacity building that improves the capacity of producers to evaluate and implement innovations as the former influences the generation of innovations while the latter influences their diffusion and rate of adoption.

The participation of producers in the setting of priorities for research programs and their involvement in such programs increases the chances of generating innovations that offer a relative advantage to producers in a variety of ways. First, there is a greater likelihood that research priorities will align with the problems encountered by producers and so the resulting research will create innovations generating technical improvements that are relevant to producers. Second, there is a greater likelihood that research will create innovations generating technical improvements that are compatible with producers’ values, experiences and needs because of the involvement of those producers in the design and development of innovations (Chambers et al. 1989; Martin and Sherington 1997). In effect, the involvement of producers in the setting of research priorities and the design and development of innovations increases the population of innovations that offer relative advantage.

Third, in principle the participation of producers in research programs may increase the chances of generating innovations with characteristics that offer greater opportunities for adaptation and reinvention (Chambers et al. 1989; Douthwaite et al. 2002; Sumberg et al. 2003). Fourth, the participation of producers in research programs may increase the likelihood that innovations will be released as prototypes thereby increasing the potential for adaptation and reinvention (Collinson 2001; Douthwaite et al. 2002; Sumberg et al. 2003). These have the effect of increasing the population of potential adopters of an innovation by creating opportunities for expanding the range of contexts in which the innovation may offer a technical improvement that is relevant and compatible with the values, experiences and needs of producers. In effect, the involvement of producers in the design and development of innovations may increase the population of potential adopters of innovations by improving the chances that innovations will be produced that offer relative advantage across a greater variety of producer contexts.

The characterisation of learning and innovation as complex processes of social interaction between producers, researchers, change agents, investors and other stakeholders was a paradigmatic shift from the characterisation of learning and
innovation in the central source model of innovation (Chambers et al. 1989; Biggs 1990; Pretty 1995; Röling 1996; Murray 2000). However, the recognition that learning is a context-dependent, social process is entirely consistent with diffusion theory to the degree that participatory agricultural research and extension activities must be instrumentally and strategically rational if not always communicatively rational (Röling 1996; Leeuwis 2003).7

For participatory research and extension activities to be instrumentally rational requires admitting the existence of structural coupling mechanisms that permit congruent adaptation between the producer’s environment and the producer (Röling 1996). These coupling mechanisms impose constraints on the socially-constructed realities and consequent actions that can be judged adaptively congruent and therefore instrumentally and strategically rational.

Such a perspective means that relative advantage is not a purely relativist concept but must be interpreted as a socially-constructed indicator of adaptive congruency between the producer and their external environment. Consequently, the adoption of an agricultural innovation that is perceived to offer a relative advantage is an instrumentally and strategically rational action. Conversely, it is instrumentally and strategically rational to reject agricultural innovations that are not perceived to offer a relative advantage. Logically, producers possessing similar utilitarian, social and hedonic goals and inhabiting similar environments should exhibit similar behaviour in regard to the adoption of agricultural innovations if they are to be instrumentally and strategically rational.

The characterisation of learning and innovation as complex social processes means that the interaction between producers and other participants when engaged in participative extension activities necessarily alters their socially-constructed reality. If the change in perceived reality of producers prompts them to modify their goals then the participative process may have influenced the population of potential adopters of the innovation because producers’ perceptions of the relative advantage offered by an

---

7 In other words, participatory research and extension activities involve negotiated agreement among stakeholders (communicative rationality) as to the strategic sense of differences in individual actions (strategic rationality) taken in regard to person-innovation relationships (instrumental rationality).
innovation may have altered. If the change in the perceived reality of producers prompts them to modify their perceptions of the relative advantage offered by an innovation without altering their goals then the participative process simply influences the rate of adoption of the innovation.

Interestingly, engagement in extension activities that change producers’ perceptions of the relative advantage of an innovation by changing their beliefs about the instrumental interaction between their goals and the innovation is precisely the purpose of the traditional perspective on extension (Rogers 1995). The difference between the traditional diffusion perspective and the constructivist participatory perspective is the explicit recognition in the participatory perspective that the realities of the change agent and the producer are socially-constructed and the interaction between them may modify the socially constructed reality of the change agent as well as the producer. Consequently, the characterisation of learning and innovation in the constructivist participatory perspective as complex processes of social interaction between producers, researchers, change agents, investors and other stakeholders represents a more realistic and complete description of research and diffusion processes (Chambers et al. 1989; Guerin and Guerin 1994).

If the constraint of adaptive convergence leaves limited scope for variety in the socially-constructed realities that permit the perception that an innovation offers relative advantage, the criteria for judging the size, relevance and compatibility of the technical improvement offered by an innovation are comparatively few and the task of identifying the population of potential adopters should be feasible. In contrast, if the constraint of adaptive convergence leaves ample scope for variety in the socially-constructed realities that permit an innovation to be perceived as offering relative advantage, the criteria for judging relative advantage may be diverse and highly idiosyncratic. In these circumstances the innovation may be potentially appealing to most members of a social system; however, the task of classifying the population of potential adopters according to differences in perceptions of relative advantage may be problematic.

8 Taking ‘ownership’ of a problem entails the problem become expressive of producers’ values and goals. Some problems may require a change of some kind in producers’ utilitarian, social or hedonic goals for this to occur (Frost 2000).
In conclusion, the emergence of the multiple source model of agricultural innovation encouraged and legitimised the use of participatory approaches to agricultural extension. Participatory approaches to extension are founded on a more realistic and complete theoretical description of the process of agricultural innovation and dissemination and are largely complementary to traditional diffusion theory (Chambers et al. 1989; Guerin and Guerin 1994; Röling 1996; Black 2000). These descriptions recognise that, through participatory processes, extension is a mechanism for increasing the population of agricultural innovations that are created which offer relevant and compatible technical improvements to producers, as well as a mechanism for influencing the diffusion of agricultural innovations among a population of potential adopters.

However, the participatory approach to extension does not offer a method for identifying the population of potential adopters of an innovation once the innovation has been developed. In other words, participatory theories of innovation development and adoption lack a method for identifying the members of a social system for whom adoption of an innovation, once developed, would be instrumentally and strategically rational, given sufficient information about the innovation. The absence of such a method, together with the inherent unpredictability of the outcomes of participatory approaches, partly explains the difficulties the participatory approach to extension and research has experienced with the dissemination of innovations – the ‘scaling out problem’ – and program and policy evaluation – the ‘scaling up problem’ (Hagmann and Chuma 2002; Dorward et al. 2003; Douthwaite et al. 2003). In short, participatory theory and diffusion theory have at least one shortcoming in common: the absence of a sound method for identifying the population of potential adopters of an agricultural innovation.

2.4 Farming styles

The failure of the central source model of agricultural innovation and the disillusionment with diffusion theory encouraged research into other approaches to understanding and systematising the complex reality of producers’ production environments. The theory of farming styles is based on the proposition that farming is a context-dependent, social process (van der Ploeg 1985; van der Ploeg 1993;
Vanclay and Lawrence 1994; Howden and Vanclay 2000; van der Ploeg 2000; Vanclay 2004; Schmitzberger et al. 2005; Brodt et al. 2006; Vanclay et al. 2006). Farming styles theory concentrated on classifying producers into groups based on similarities in their technical, market and social context with a view to providing a framework for targeting extension activities.

2.4.1 **Farming styles theory**

The essence of the theory of farming styles is that:

> … in a farming community there is a set of discrete styles (strategies of farming) of which farmers are acutely aware, and from which they actively choose a specific strategy to guide their own practice. [...] By participating in a style, farmers contribute to the evolution of that style over time. The styles are created, not only through socio-cultural dynamics, but also as a response to structural forces – different styles exist for different market situations of different farmers.

(Vanclay et al. 2006: 62-63)

Different farming styles emerge from the interaction of cultural, social and structural factors in the environment of the producer, the latter representing economic, biophysical and technological relationships in the environment that constrain the variety of behaviours or strategies that can be employed. Farming styles are intended to predict the behaviour of producers including their adoption of agricultural innovations (Beaudeau et al. 1996; Howden and Vanclay 2000; van der Ploeg 2000; Mesiti and Vanclay 2006).

As farming styles are meant to emerge from the praxis of farming they are multi-dimensional and contextual. Hence, the identification of farming styles requires elicitation of data on styles from producers themselves. Given that farming styles are socially constructed by producers of an agricultural commodity in a region then, theoretically, they should be able to identify, describe and exemplify the set of styles that are present in that region for that commodity. Consequently, one approach to identifying farming styles for a commodity in a region is to question producers directly on their perceptions of styles they observe and they themselves exhibit.

The success of efforts to identify farming styles using this approach has been variable. The approach has been confounded by a range of methodological difficulties. For example, descriptions of the styles that were elicited from producers have been heavily laden with producers’ judgements regarding the desirability of the type,
thereby creating a problem of adverse selection (Howden and Vanclay 2000; Vanclay et al. 2006). In other studies, exemplars of all styles could not be identified by change agents or producers, producers that participated in these studies were often unable to identify themselves as exemplifying a particular style, and styles elicited from producers could not be validated by subsequent quantitative analysis (Howden and Vanclay 2000; Mesiti and Vanclay 2006; Vanclay et al. 2006). Hence, the conclusion was reached in these studies that the farming styles that are obtained using this approach are myths or heuristics that describe normative judgements about particular behaviours rather than definitive descriptions of strategically different ways of configuring farming systems (Howden and Vanclay 2000; Vanclay et al. 2006).

Vanclay et al. (2006) conclude that farming styles probably do not exist as discrete, measurable characteristics of individual producers but may exist as ideals which producers strive to emulate. They raise the possibility that farming styles may be better identified in relation to specific management domains within a farming system, or at different levels of a farming system. Different sets of styles would be associated with each domain or level, which they termed ‘points of entry’. The ‘style’ of an individual producer then depends on the ideal they wish to emulate, and the level and domain in the farm system under investigation (Vanclay et al. 2006).

An alternative approach to identifying farming styles is to elicit data on producers’ objectives, social networks, agricultural practices, market positioning and enterprise characteristics and analyse these data, generally using quantitative techniques, to identify farming styles (Rosenberg and Turvey 1991; Fairweather and Keating 1994; Beaudeau et al. 1996; Ondersteijn et al. 2003; Schmitzberger et al. 2005; Brodt et al. 2006; Commandeur 2006; Mesiti and Vanclay 2006). The farming styles that have been identified using this approach have rarely been validated by the identification of exemplars by producers and success in identifying consistent relationships between these styles and the adoption of agricultural practices is variable (Rosenberg and Turvey 1991; Beaudeau et al. 1996; Schmitzberger et al. 2005).

2.4.2 Discussion

Farming styles are socially constructed and are the coherent outcome of social norms concerning the way farming should be organised, the structuring of farm practices in accord with those norms, and linkages with markets, government policy and
technological developments – they are meant to be reproducible and persist through time (Howden and Vanclay 2000; Vanclay et al. 2006).

*The essential feature of the farming styles concept is that among a group of farmers who are geographically and commodity located, there is an ordered and meaningful clustering of the different notions about the most appropriate way to farm.*

(Mesiti and Vanclay 2006: 585)

To be coherent, reproducible and persistent farming styles must be instrumentally, strategically and communicatively rational. For the theory of farming styles to suggest ‘ways of farming’ are ordered and clustered signals that the theory embodies a presumption that there is sufficient scope within the constraint of adaptive convergence for social influences such as values and norms to inject variety into the configuration of farm systems.

In principle, producers exhibiting a particular style will exhibit similar values and goals, and have fashioned their farm systems similarly. Logically, producers possessing similar goals and inhabiting similar environments should exhibit similar behaviour in regard to the adoption of agricultural innovations if they are to be instrumentally and strategically rational. Hence, all the producers that exhibit a particular farming style should be potential adopters of an agricultural innovation if that innovation offers a relevant and compatible technical improvement for that farming style. Therefore, the population of potential adopters of an agricultural innovation could be defined as consisting of those producers that are members of the set of farming styles for which the innovation offers a relative advantage.

The theory of farming styles offers, then, a possible approach to identifying the population of potential adopters of agricultural innovations. However, there are three critical weaknesses with the theory of farming styles as a theory of the adoption of agricultural innovations. First, the theory as proposed by van der Ploeg (1993) did not provide a precise description of relative advantage in terms of the constituents of a farming style. The logic of farming styles predicts that an innovation that demonstrates a technical improvement that is relevant and consistent with that style should be adopted by all producers that operate according to that style. The difficulty is that the theory of farming styles does not describe how an innovation may interact with social norms, the structuring of farm practices, market relationships and
government policy to create a relevant and compatible technical improvement. This makes the prediction of the adoption of agricultural innovations on the basis of farming styles problematic.

Second, the theory did not adequately distinguish between those aspects of farming style that influence the merit of adopting an agricultural innovation and those that influence the timing of the decision to adopt. This is because the original definition of a farming style encompassed factors that influenced the diffusion of an innovation among the population of potential adopters, such as institutional and network relationships, as well as factors that influenced the merit of adopting an innovation such as goals and management practices (van der Ploeg 1993; Beaudeau et al. 1996; Howden and Vanclay 2000; Commandeur 2006).

A farming style encompasses:

Firstly, there are techno-ecological features, such as (pigsty) climate, genetic material and the available options for farming within the constraints of soil type and available physical space. Secondly, there are features like the economic infrastructures, supply and sales markets, transport infrastructure, and investment opportunities. Thirdly, there are institutional infrastructures, such as farmers’ unions and co-operatives, various governmental levels, institutes for research, education, extension, and management support, and animal health care stations.

Commandeur (2006: 113)

The merging of features that influence adoption such as climate and gene base with features that influence diffusion such as contact with research, education and extension institutes may be another reason for the methodological difficulties that have been experienced in the elicitation of styles and in establishing associations between styles and management behaviours. On the one hand, producers are classified into a style on the basis of elements in the farm system such as techno-ecological features that may influence the relative advantage offered by innovations. On the other hand, producers are classified into a style on the basis of characteristics such as contact with educational institutes that may influence the timing of adoption, that is, diffusion. The features and membership of a style will only be durable, and therefore detectable, where the relationship between the elements in the farm system that
influence relative advantage and the characteristics that influence diffusion are stable across producers, and constant across innovations.

Third, the revised version of the theory of farming styles does not contain a sound process for defining farming styles with regard to an agricultural innovation. The revised theory, offered by Vanclay et al (2006), recognised that, to be useful as a description of specific management behaviours, farming styles may need to be defined relative to a particular management level and domain within the farm system. However, they did not provide a conceptual framework for linking a point of entry, such as an agricultural innovation, with management levels and domains within a farm system. In other words, the revised theory still suffers from the weakness of the original in that it lacks a coherent definition of relative advantage.

Furthermore, there are serious problems in relying on group processes to identify farming styles. In principle, for a particular location and commodity, the theory of farming styles predicts producers exhibiting a particular style will share similar values and goals, and have fashioned their farm systems similarly. Conversely, the theory predicts that producers exhibiting different styles for a particular location and commodity will display different values and goals, and have fashioned their farm systems differently. To the degree that differences in producers’ values and goals translate into observable differences in their use of farm practices, differences in farming style will naturally be the subject of normative judgements among producers. This is because differences in style are detected precisely by observing the differential use of desirable and undesirable practices – and the criteria for defining ‘desirable’ in these circumstances is purely subjective.

Hence, processes for eliciting farming styles from producers are likely to extract especially unfavourable descriptions of styles that employ agricultural practices that participants regard as undesirable and indefensible and especially favourable descriptions of styles that employ agricultural practices that participants regard as desirable and defensible (Vanclay et al. 2006). There would seem to be ample potential for the phenomenon of groupthink in these situations (Whyte 1989; Schafer and Crichlow 1996; Park 2000).

The difficulties involved in eliciting impartial descriptions of farming styles is further compounded to the degree that differences in the biophysical contexts of producers
that are not apparent to external observers may also give rise to differences in the use of farm practices that attract normative judgements. Differences in producers’ environments create differences in the suite of practices that are instrumentally and strategically rational. The less observable the differences in environments are, and the less familiar producers are with the environments of other producers, the less informed will be producers’ descriptions of, and normative judgements about, other farming styles.\(^9\) Hence, these are serious problems in relying on group processes to identify farming styles and, consequently, the population of potential adopters of an agricultural innovation based on farming styles.

In conclusion, in the theory of farming styles it is recognised that farming is a context-dependent, socially-constructed process. In principle, the definition of a farming style could be interpreted as a description of the population of potential adopters of an agricultural innovation. However, the theory lacks a meaningful definition of relative advantage and a rigorous method for identifying the same for any particular agricultural innovation.

In principle, the theory of farming styles and diffusion theory are mutually consistent. The theory of farming styles shares with diffusion theory the fundamental proposition that the adoption of agricultural innovations by producers is motivated by the perception that they offer producers a better means of achieving their goals. In other words, both theories recognise that the adoption of agricultural innovations depends on the perception that the innovation offers the producer a relative advantage. Diffusion theory complements the theory of farming styles in distinguishing conceptually between the factors that influence the size of the population of potential adopters of an agricultural innovation and the factors that influence the diffusion of agricultural innovations among that population.

The theory of farming styles, like diffusion theory, does not contain within itself a method for identifying the elements in the context of the producer that determine both the reality, and their perceptions, of the relative advantage offered by an innovation. Such elements can only be identified using a process of discovery external to these theories.

---

2.5 Conclusion

The emergence of the multiple source model of agricultural innovation reinforced and intensified a growing interest in the fields of learning, empowerment and participation among researchers and practitioners in agricultural extension. Common to these fields is a desire to increase the learning, planning and decision-making skills of producers. I have argued here that the theorising in each of these fields is largely consistent with diffusion theory in that they seek to increase the rate of adoption of innovations by improving the knowledge and skills of the producer.

Theories of empowerment, participation and farming styles diverge from classical diffusion theory, as expressed by Rogers (1995), in their greater emphasis on reality as a social construction and the consequences of this for interactions between producers and change agents. Furthermore, these theories present a radically different view of the innovation process compared to the practice of the central source model of innovation which was associated with diffusion theory.

Despite these differences, the theories of empowerment and participation that characterise the multiple source model of agricultural innovation share with diffusion theory the fundamental proposition that the adoption of agricultural innovations by producers is motivated by the perception that they offer producers a better means of achieving their objectives. In other words, the adoption of agricultural innovations depends on the perception that the innovation offers a relevant and compatible technical improvement, that is, relative advantage. And, like diffusion theory, these theories do not contain within themselves a method for identifying the elements in the context of the producer that determine their perceptions of the relative advantage offered by an innovation. Such elements can only be identified using a process of discovery external to these theories. The same can be said for the theory of farming styles.

In the terms of participatory extension, the theory of a socially constructed reality as used in agricultural extension does not appear to provide a mechanism for systematically identifying the processes that structurally couple the producer and their environment and thereby provide the basis for assessing adaptive convergence and defining instrumentally rational actions. Yet, ultimately, participatory approaches to
the development of innovations must deal with the issue of the dissemination of innovations to a wider audience (van de Fliert 2000).

In short, the theories of learning, capacity building, empowerment and participation, and farming styles that have been used in agricultural extension do not contain a sound method for identifying the population of potential adopters of an innovation. As a consequence, these theories do not offer a sound basis for assessing and comparing rates of adoption of agricultural innovations, thereby rendering judgements about the performance of extension problematic, and hampering the efficient allocation of resources to the development and extension of agricultural innovations.

However, the failure of the central source model of agricultural innovation intensified research into methods for identifying productivity constraints in the complex reality of producers’ production environments. The practical purpose of this research was to identify and develop, using participatory approaches, innovative technological and policy solutions to those constraints. Hence, the specific intention of this field of research – farming systems research – was to identify groups of producers that would benefit from the development of an agricultural innovation. In other words, the purpose of farming systems research was to develop agricultural innovations that offered relevant, compatible technical improvements to a specific population of potential adopters (Byerlee et al. 1982; Collinson 2001; Norman 2002; Dorward et al. 2003).

Farming systems theory and farming systems research are considered in detail in the next chapter.
A Theory of the Adoption of Agricultural Innovations

For maximization of production and income a farmer must be able to appreciate the relevance of each practice to his farm situation and the implications of its introduction. [The] farmer must be able to organize a mental image of a cumulative set of practices to be used in planning for future development.

(Crouch 1981: 130)

In a world where information is relatively scarce, and where problems for decision are few and simple, information is almost a positive good. In a world where attention is a major scarce resource, information may be an expensive luxury, for it may turn our attention from what is important to what is unimportant. We cannot afford to attend to information simply because it is there.

(Simon 1978: 13)

3.1 Introduction

I have suggested that the different schools of thought on the adoption of agricultural innovations by primary producers have a common failing. This failing is the absence of a rigorous method for obtaining an intimate understanding of how agricultural innovations contribute to satisfying the needs of primary producers as managers of agricultural enterprises. In this chapter I present a theory explaining how innovations create benefits for producers and thereby contribute to satisfying their needs as managers of agricultural enterprises. As a consequence, this theory provides a framework for predicting the adoption of innovations by primary producers.

The theory draws on thinking from two different disciplines – marketing and farming management. The theory of consumer behaviour, developed within the marketing discipline, is drawn on to create a conceptual framework describing how primary producers make decisions to purchase agricultural innovations. The application of this theory leads to the proposition that the purchase of an agricultural innovation is motivated by the benefits to be had from the innovation, and that these benefits depend on the context of the producer.

Farming systems theory, developed within the farm management discipline, provides a conceptual framework for identifying the factors that influence the benefits to be had from adopting an agricultural innovation. Hence, farming systems theory provides
a means of characterising the context of producers as purchasers of agricultural innovations.

In the next section I describe the theory of consumer purchase behaviour and consider the application of the theory to the purchase of agricultural innovations. I then move to a discussion of farming systems theory and the application of that theory to the adoption of agricultural innovations.

3.2 Consumer purchase behaviour
An extensive literature has developed in the marketing discipline about the decision making and purchasing behaviour of consumers. There are a number of reasons for using the literature on consumer behaviour as the starting point for creating a conceptual framework describing how producers make decisions to adopt agricultural innovations.

First, the decision to adopt an agricultural innovation is a purchase decision. This is an obvious commercial reality for agriculture in developed economies where many technologies can only be acquired through markets. However, the adoption of new technologies and practices is equally, though less overtly, a purchase decision even when these are freely available. The reason is that the acquisition and implementation of an innovation necessarily involves the expenditure of resources that have an opportunity cost. The implementation of even freely available innovations requires the investment of resources in making decisions about the uncertain benefits and costs of reconfiguring the farming system to accommodate the innovation (Dillon and Heady 1958; Norman 1978; Ruthenberg 1980; Crouch 1981; Byerlee et al. 1982; Collinson 2001; Dorward et al. 2003). Hence, the adoption of an agricultural innovation is a purchase decision.

Second, while framing the adoption of agricultural innovations as purchase decisions, primary producers are non-specialist purchasers. Although primary producers undoubtedly specialise in the purchase of agricultural technologies and practices they are generalists in that they make all management decisions, including purchase decisions on inputs. Furthermore, in most instances their scale of operations is too small to allow them to develop product specifications to meet their precise needs and to negotiate the fulfilment of these specifications at particular prices with suppliers.
Hence, primary producers are not specialist purchasers in the sense that organisational buyers are (Assael et al. 1990). Consequently, the literature on organisational buyer behaviour, such as Hill and Hillier (1977) for instance, is largely irrelevant. The literature on decision making by non-specialist purchasers must suffice. This literature is the literature on purchasing by consumers.

Third, the literature on consumer purchasing is founded on social psychology which recognises that decision-making and action involve cognitive and non-cognitive processes, controlled and automatic processes (Krugman 1965; Sherif et al. 1965; Petty et al. 1983; Derbaix and Vanden Abeele 1985; Olson and Zanna 1993; Levy 2005). In distinguishing between these processes, social psychology, and the literature on consumer purchasing, recognise that different decision processes are invoked in different circumstances. This is important as the adoption of a novel agricultural technology or practice is qualitatively different from the routine purchase of familiar, unexceptional agricultural inputs. The former can entail consequences that are orders of magnitude more serious than the latter. This difference suggests that the way producers make a decision to purchase an innovation is likely to be different from the way they make a routine purchase decision. As Derbaix and Vanden Abeele (1985: 163) observe:

> Deliberate, mindful behaviour is effortful and capacity-constrained and will thus be the exception. Behavioural automatisms, motor habits, direct affect referral and cognitive habits (scripts, schemata) rule over much consumer behaviour as they free our conscious cognitive functions for more important tasks and organise his [sic] behaviour efficiently under normal circumstances.

Fourth, and relatedly, in recognising the role of cognitive and non-cognitive processes and controlled and automatic processes in decision making, the literature on consumer behaviour provides criteria for identifying when different types of decision process will be invoked. In other words, the literature provides criteria for predicting the type of decision making a purchaser is likely to employ when contemplating a purchase. As Derbaix and Vanden Abeele (1985: 163) also observe:

Consumers will engage in deliberative thought, in reasoned action primarily when they have no script or schema or when these appear inadequate or cannot be enacted. More specifically, mindful processes are expected… when facing a new, involving situation for which, by definition, there is no available script or schema, e.g., when confronted with a discontinuously innovative product… [or] when experiencing a negative or positive consequence sufficiently discrepant with the consequences of prior enactments, e.g., in case of dissatisfaction with the habitual brand.
In framing the decision to adopt an agricultural innovation as a purchase decision, the literature on consumer behaviour becomes relevant as the source of a framework for predicting the types of decision processes producers are likely to follow when purchasing an agricultural innovation.

In the next section I describe the concept of involvement which is central to explaining and predicting the different types of processes followed by consumers when making purchase decisions.

3.2.1 Involvement

The concept of involvement is central to explaining decision processes used by consumers. Involvement is a construct from social psychology and  

_In the consumer behaviour literature, this [construct] has been closely allied to the information-processing perspective on behaviour and has been considered to be an individual difference variable, identified as a causal or motivating factor with direct consequences upon consumers’ purchase and communication behaviours._

(Gabbott and Hogg 1999: 159)

Involvement is a multi-dimensional construct and refers to the relative strength of the consumer’s cognitive structure related to a focal object, a product (O’Cass 2000). Consumer involvement is intended to predict behaviours such as extensiveness of decision-making, interest in advertising, brand commitment, frequency of product use, shopping enjoyment and social observations of product use and brand use (Mittal and Lee 1989).

Involvement has been described in various ways in the consumer behaviour literature. For instance, Greenwald and Leavitt (1984) described involvement quite simply as the importance or relevance of a product to a consumer. Bloch (1982) went further to describe involvement as the degree of arousal, interest or drive evoked by a particular stimulus or situation. Similarly, Mittal (1989) suggested involvement was the motivational state of a person that is revealed by the level of interest a consumer has in a product or activity. For Zaichkowsky (1985) involvement was the relevance of a product to a consumer’s values, goals and self-concept. O’Cass (2000) defined involvement as the extent to which the consumer views the product as meaningful and engaging in their life, a central part of their life.
There is an underlying theme to these descriptions of involvement. Consumer involvement is a motivational state that results from the consumer’s perceptions that a product or activity can contribute to satisfying their goals, which may be utilitarian, social, or hedonic (Mittal and Lee 1989). In broad terms, this definition suggests there are three fundamental sources of consumer involvement - interest, sign, and hedonic (Laurent and Kapferer 1985; Zaichkowsky 1985; Mittal and Lee 1989; O'Cass 2000). Interest concerns the performance of the product or activity in utilitarian, economic and functional terms. Sign concerns the contribution of the product or activity to self-concept and impression management. Hedonic is the extent to which the product or activity satisfies pleasure or experiential goals.

Consumer involvement may be enduring or situational. Enduring involvement is independent of specific purchase situations. Enduring involvement:

... essentially arises as the result of ongoing interest with the product class, and its association with the individual’s self-concept, values and ego. Such enduring involvement results from the product’s ability to satisfy the consumer’s enduring and self-identity-related needs, rather than from specific purchase or usage goals.

(Dholakia 2001: 1341)

In contrast, situational involvement is only temporary and refers to a raised level of interest in a product resulting from a specific purchase situation. Consequently, situational involvement is often linked with purchase decision involvement in the consumer behaviour literature. Situational involvement is:

...a temporary perception of product importance based on the consumer’s desire to obtain particular extrinsic goals that may derive from the purchase and/or usage of the product.

(Bloch and Richins 1983: 72)

Enduring involvement with a product leads to involvement in the purchase of the product. Situational involvement also leads to involvement in the purchase of the product but in specific situations. Situational involvement arises independently of enduring involvement and is the result of transient factors that are peculiar to the consumer’s current environment (Richins et al. 1992). For example, consumers may experience situational involvement when purchasing gifts as products that are otherwise unimportant to them.
Consumer involvement is also influenced by perceived risk. Perceived risk concerns the potential for undesirable outcomes and has three distinctive dimensions – psychological, social and functional (Dholakia 2001). Psychological risk is the experience of anxiety or psychological discomfort arising from anticipating affective reactions such as worry and regret following the purchase and use of a product. Social risk concerns the potential for adverse consequences that are associated with significant others having unfavourable opinions about one’s purchase and use of a product. Functional risk concerns the risks arising from objective features of a product such as cost, performance, physical harm and the need for the investment of time (Dholakia 2001).  

Clearly, there are parallels between the dimensions of perceived risk and the sources of involvement. As a consequence, some authors view perceived risk as a source of involvement (Laurent and Kapferer 1985), others view perceived risk as a type of involvement (Mittal and Lee 1989), and others view perceived risk as an outcome of involvement (Dholakia 2001). The view is taken here that perceived risk is an outcome of involvement because, for risk to be a concern to the consumer, they must be aware of the potential for the product to prevent the achievement of one or more utilitarian, social or hedonic goals. Consequently, in the absence of at least one of the three fundamental sources of involvement, perceived risk is unlikely to give rise to involvement per se. On the other hand, given that a product is involving then the presence of perceived risk may at least add to the processing effort made by the consumer and possibly heighten interest in the purchase if not the product itself. This view of the relationship between perceived risk and involvement accords with that of Dholakia (2001), Conchar et al. (2004) and O’Cass (2000).

Irrespective of the precise nature of the relationship between involvement and perceived risk, both have been found to influence significantly the extensiveness of

---

10 Note that the way in which perceived risks are framed can affect the rate of adoption of an innovation. For example, Prospect Theory (Kahneman and Tversky 2000) predicts that framing a decision in terms of the potential losses (associated with not adopting the innovation) will tend to induce risk-seeking decision making while framing in terms of the potential gains (from adopting the innovation) will tend to induce more risk-averse decision making. Thus, from the point of view of increasing the rate of adoption, one could argue that it might be more effective to focus on the potential losses that could occur if the innovation were not adopted.
the decision process used by consumers. Involvement has been shown to influence positively the number and types of sources of information consulted about a product prior to purchase, the number of product attributes evaluated, the number of product alternatives considered and trialled, and the time spent on making a purchase (Zaichkowsky 1985; Kapferer and Laurent 1985/1986; Beatty and Smith 1987; Mittal 1989; Mittal and Lee 1989; Richins et al. 1992; Gore et al. 1994; Foxall and Pallister 1998; Dholakia 2001; Hart and Dewsnap 2001; Miquel et al. 2002).

In short, involvement is a motivational state that is proposed to predict the level of effort the consumer will invest in controlled behavioural processes in relation to acquisition of a product. Controlled processes are any combination of cognitive, affective or conative processes of which the consumer is conscious or aware or to which they are attentive (Derbaix and Vanden Abeele 1985; Laros and Steenkamp 2005). High levels of involvement are associated with high effort, extensive decision-making while low levels of involvement are associated with low effort, automatic, preconscious processes (Greenwald and Leavitt 1984; Celsi and Olson 1988; Hawkins and Hoch 1992; Gore et al. 1994; Grunert 1996; Assael 1998).

This thesis is founded on the assumption that the decision to adopt an agricultural innovation is a high involvement purchase decision. To the degree that the adoption of an agricultural innovation is perceived by primary producers as contributing to satisfying their utilitarian, social, or hedonic goals as managers of agricultural enterprises (Gasson 1973; Fairweather and Keating 1994; Frost 2000; Ondersteijn et al. 2003), the decision to adopt will be situationally involving for producers. To the extent that the adoption of an agricultural innovation is perceived by producers to have the potential for undesirable psychological, social and functional outcomes their degree of involvement will be intensified. The higher the involvement and the greater the perceived risks, the greater the effort producers will be prepared to invest in, and the more extensive will be, the adoption decision.

A corollary of the assumption above is that the purchase of any input for an agricultural enterprise will be situationally involving for the producer to the degree that the input is perceived by the producer as contributing to satisfying their utilitarian, social, or hedonic goals as managers of agricultural enterprises. Involvement will be intensified to the extent that the purchase is perceived by the producer to have the potential for undesirable psychological, social and functional
outcomes. The higher the level of involvement and the greater the perceived risks, the greater the effort producers will be prepared to invest in, and the more extensive will be, the purchase decision. Involvement may become enduring for inputs that are highly involving, have high perceived risk and must be purchased repeatedly.\(^{31}\)

### 3.2.2 Complex decision making

High involvement has been shown in the social psychology and consumer behaviour literatures to lead to:

> ...extensive problem solving, which means an active search [for] and use of information, careful processing of information, weighing and evaluating many product attributes before forming beliefs, developing an attitude and moving towards behavioural intention and actual or overt behaviour. Reversibly, low involvement associates with routine, habitual or impulsive behaviour without extensive processing of information.

(Verbeke and Vackier 2004: 159)

In other words, high involvement purchases are characterised by the conscious, effortful search for information about, and extensive consideration of, the attributes of the product and how these relate to the source of involvement. Complex decision making is facilitated when there is adequate time for extensive information search and processing (Beatty and Smith 1987), adequate information is available on product characteristics and the consumer has the ability to process the available information (Greenleaf and Lehmann 1995).

Assael (1998), Klonglan and Coward (1970), Rogers (1995), Parthasarathy et al. (1995), Howard and Sheth (1969), Engel et al (1995) and others have proposed generic, idealised models of varying complexity that describe complex decision making. Complex decision making involves five basic decision stages – problem recognition, search for information, evaluation of alternatives, purchase, and outcomes (Erasmus et al. 2001). The central theme in these models is that the process of making a purchase decision requires the development of benefit, or purchase, criteria which are based on the consumer’s motivation for involvement. These criteria

---

\(^{31}\) The possibility must be recognised, however, that beyond a certain level of perceived risk deliberate consideration of an innovation may become inhibited or even maladaptive. See, for example, the literature on fear appeals (Leventhal 1970; Witte 1992; Janis and Mann 1977).
are used to evaluate the alternative products or brands on offer (Howard and Sheth 1969; Percy and Rossiter 1992; Engel et al. 1995; Assael 1998).

Problem recognition is the awareness of a disparity between the consumer’s current state and some desired state. This disparity creates a motivation to act to resolve the disparity. Problem recognition is a function of the consumer’s past experiences, their characteristics and motives, environmental influences, immediate cues and promotional stimuli (Assael 1998). The nature of the disparity in states and the motivation to act directly influence the specific criteria consumers use to evaluate products and brands.

The search for information in complex decision making is the process of noticing, understanding, interpreting and retaining information in memory about the attributes of products or brands (Assael et al. 1990). Information may be acquired from personal sources such as salespeople, friends and family as well as impersonal sources such as advertising, displays, and media reports. The search for information is more active the higher the level of involvement and the greater the perceived risk. The level of effort devoted to information search is also likely to be greater when the consumer has well-defined purchase criteria (Huffman and Houston 1993) and where the consumer perceives that there are substantial differences between brands (Claxton et al. 1974). The extensiveness of the search for information is increased where the consumer is less familiar with the product (Beatty and Smith 1987; Srinivasan and Ratchford 1991) or if past experience with the product is negative (Bennett and Mandell 1969). Finally, information search increases if consumers are not constrained by time (Beatty and Smith 1987).

The evaluation of alternatives in complex decision making involves the association of desired benefits with different products or brands. Evaluation entails the use of purchase criteria to appraise the perceived characteristics of alternative products or brands to form judgements about them. These judgements are expectations about the degree to which a product or brand will supply the benefits the consumer desires (Assael 1998). The outcome of product or brand evaluation may be one of the following: an intention to purchase; an intention to delay purchase; an intention to seek more information; or a decision not to purchase (Greenleaf and Lehmann 1995).
The benefit or purchase criteria used by the consumer to evaluate products or brands represent the key benefits sought by the consumer and exemplify their usage or consumption situation (Assael 1998). For example, economy, dependability and safety may be key purchase criteria for many consumers with families that are buying motor vehicles to be used daily to transport family members, especially children. Having settled on a set of purchase criteria for deciding between products, the consumer then evaluates the various makes and models against the criteria and makes a decision to purchase.

Consumers can be grouped into market segments, termed benefit segments, on the basis of similarities and differences in the purchase criteria that they use to evaluate a product. Knowledge of the key purchase criteria that will be used by consumers in a segment can be employed to tailor products to meet the specific needs of consumers in that segment and promote products accordingly (Kotler 2003).

The assumption that the decision to adopt an agricultural innovation is a high involvement purchase decision logically leads to the proposition that the adoption of agricultural innovations will be characterised by complex decision making. Complex decision making will be reinforced to the extent that the perceived risk of adopting an agricultural innovation is high and the innovation is discontinuously novel and, so, unfamiliar to producers. Complex decision making is facilitated, in terms of time available for its operation, when contemplating the adoption of an agricultural innovation because such decisions rarely require immediate resolution.

Given that producers do find the adoption of agricultural innovations highly situationally involving and, as a result, they engage in complex decision making, they can be expected to develop purchase criteria for evaluating innovations. Such criteria will represent the key benefits producers are seeking in adopting an innovation. Further, the decision to adopt an innovation will depend on their evaluation of the characteristics of the innovation based on their purchase criteria.

Theoretically, producers’ purchase criteria – the key benefits they seek from an innovation – should reflect their usage or consumption situation. I will argue in the next section that the consumption situation for primary producers is defined by certain salient characteristics of their farming system. These characteristics influence the
benefits to be had from adopting an agricultural innovation and are particular to the innovation. I term these characteristics the *farm context* for the innovation.

### 3.3 The *farm context* for an innovation

Given that the benefits an innovation offers to a producer depend on the producer’s perception of their consumption situation, a conceptual framework is needed which enables the identification of those aspects of the consumption situation that shape the benefits an innovation creates for a producer. I propose that farming systems theory provides such a framework.

#### 3.3.1 *Farming systems theory*

Farming systems theory treats agricultural enterprises as managed systems that consist of hierarchical networks of complicated, interdependent sub-systems that are open to biophysical, economic and social influences (CGIAR 1978; Norman 1978; Norman 1980; Ruthenberg 1980; Byerlee et al. 1982; Norman 2002). For instance:

> A farming system … is a complicated interwoven mesh of soils, plants, animals, implements, workers, other inputs and environmental influences with the strands held and manipulated by a person called the farmer who, given his preferences and aspirations, attempts to produce output from the inputs and technology available to him. It is the farmer’s unique understanding of his immediate environment, both natural and socioeconomic, that results in his farm system.

(CGIA 1978: 8)

Farming systems, like all systems, consist of components and these components are connected to each other by a series of causal relationships (Ackoff 1971; CGIAR 1978; Norman 1980; Haines 1982).

Broadly speaking, the components of a farm system are resources including people, exogenous environmental, social and economic constraints such as access to markets, agricultural technology and management practices, and strategies for managing risks and pursuing objectives. For instance, the components may include biophysical resources such as land, water and livestock; agricultural technologies embodied in plant and machinery such as irrigation systems and pest control systems; enterprise infrastructure such as fencing, watering and drainage layout; and economic resources
such as capital and labour. Components are integrated and linked together to create a coherent whole through agricultural practices such as cultivation practices, breeding and grazing practices, and risk management strategies such as fodder conservation and enterprise diversification. These components and the relationships between them, which may form sub-systems within the farm system, are used by the producer to produce agricultural outputs and realise family and business objectives (CGIAR 1978; Norman 1980).

The presence of causal relationships between components means the components in the system interact, are interdependent, and cannot be modified without causing a related change elsewhere in the system (Haines 1982). In other words, the components of a farming system are, more or less distantly, functionally related in that the state of one component potentially influences the states of other components (Ackoff 1971; Johnny et al. 1981; Byerlee 1987; Gebremedhin and Swinton 2003; Janssen and van Ittersum 2007). The relationships between components in a farm system may extend over space and time, may be direct or indirect, may be reciprocal, and may be non-linear and stochastic (Ruthenberg 1980).

The presence of dynamic, causal relationships between the components of farm systems means that the benefits to be had from introducing an innovation into a farming system will depend on the components of the farm system and the nature of the interrelationships between them. The presence of causal relationships between the components of farm systems restricts the way the components of a farm system can be configured to achieve the objectives of the primary producer. In other words, the interrelationships between components place practical constraints on the ways in which a farm system can be managed within the restrictions created by the resources, technologies and practices that are available, and the strategies required to manage risks (Johnny et al. 1981; Frank 1995a; Frank 1995b; Dorward et al. 2003; Gebremedhin and Swinton 2003). Consequently, the benefits to be had from introducing an innovation into a farm system will depend on precisely how the innovation changes the practical constraints on the way in which a farm system can be managed to achieve the objectives of the producer. Hence, the consumption situation for agricultural innovations is defined by the way in which they change the practical constraints on the way a farm system can be managed to achieve the objectives of the producer.
For example, Haines (1982) described the way in which the introduction of a four year cropping rotation in eighteenth century England overcame the necessity of fallowing land every third year to avoid a long-term decline in soil fertility. Cary et al. (2001) described how the introduction of lucerne into a dryland cropping and livestock enterprises in the riverine plains of the Murray-Darling has been limited by practical difficulties associated with differences in the grazing management of lucerne compared to other perennial pastures, and subsequent impacts on lambing practices. Collinson (2001) described how extension recommendations for tie-ridging, a soil conservation practice for cotton production in Tanzania, required changing because the interaction of this practice with labour requirements for cultivation, planting and weeding actually reduced cotton production despite increasing yields. Cramb (2005) has described how practices and techniques for managing the fertility of acid upland soils in South-East Asia have evolved in response to changes in population densities and market access. Increasing population density reduces the attractiveness of fallowing practices in favour of manuring, composting and the use of legumes. Increasing market access reduces the attractiveness of fallowing practices in favour of purchased fertilisers and trace elements.

Crouch (1981) demonstrated how the correlations between a range of practices for managing pastures, livestock breeding and livestock health in sheep enterprises in New South Wales reflect the logical interrelationships and practical interdependence between these practices. Relatively low correlations were found between practices that generate benefits independently of each other such as spring lambing and inoculation of clover seed. On the other hand, high correlations were found between practices that generate benefits jointly such as fodder conservation, weaner nutrition, mulesing and weaning age – which are all practices that directly contribute to maximising lamb survival. Curruthers (2007) described the interactions between increasing herd sizes and stocking rates, and the management of environmental, quality, occupational health and safety, and social issues on dairy farms in Australia.

These examples illustrate how the benefits to be had from introducing an innovation into a farming system will depend on the manner in which the interrelationships between the components in the system are modified and how these modifications contribute to, or detract from, achievement of the objectives of the primary producer. They indicate how the consumption situation for an agricultural innovation is defined
by the way in which the innovation allows the farm system to be modified and how these modifications contribute to attaining the objectives of the primary producer.

These considerations suggest that a correct description of the consumption situation for agricultural innovation requires the identification of those components and relationships within a farm system that are functionally related to the innovation since they influence the benefits to be had from the innovation. They also suggest that the components and relationships in the farm system that are functionally related to an innovation are the fundamental sources of the purchase criteria used by the producer to evaluate the innovation.

For ease of expression, I will term the consumption situation of primary producers in relation to agricultural innovation the *farm context* for the innovation. Hence, the farm context for an agricultural innovation denotes the components in a farm system, and the relationships between them, that are causally related to the innovation and so shape the benefits to be had from it. In other words, the farm context for an agricultural innovation is defined by elements in the farm system that are functionally related to the innovation (such as resources, constraints, agricultural technology and management practices, and strategies for managing risks) and so influence the achievement of the utilitarian, social and hedonic objectives of the producer.¹²

This definition of farm context provides the basis for identifying the population of potential adopters of an agricultural innovation. The population of potential adopters of an innovation was defined earlier as the set of decision-makers who would perceive an innovation as offering the prospect of better achieving their goals given sufficient knowledge of the consequences of adopting the innovation. Given the definition of farm context, the population of potential adopters of an agricultural innovation can now be defined as the set of producers who would perceive the innovation as offering the prospect of better achieving their goals given sufficient knowledge of their farm context and, therefore, the consequences of adopting the innovation.

Using Rogers’ (1995) terms, the population of potential adopters of an innovation was defined as consisting of the set of decision-makers who would perceive the innovation as offering a relative advantage, given sufficient knowledge of the consequences of adopting the innovation. Given the definition of farm context, the population of

¹² Producer should be taken here to include all relevant stakeholders such as family members.
potential adopters of an agricultural innovation may also be defined as consisting of the set of producers who would perceive the innovation as offering a technical improvement of a type that is relevant to their needs and that is sufficiently compatible with their values, experiences and needs to merit adoption – given sufficient knowledge of their farm context and the consequences of adopting the innovation.

Given that the farm context for an agricultural innovation is defined by elements in the farm system that are functionally related to the innovation, and thereby influence the achievement of the objectives of producers, then the experiences, knowledge and skills of producers may influence the adoption of agricultural innovations in four fundamentally different ways.

First, there may be experiences, knowledge and skills that influence producers’ choices in regard to their utilitarian, social and hedonic objectives. Such experiences, knowledge and skills influence the elements in farm systems that define the farm contexts for an agricultural innovation. Hence, the distribution of experiences, knowledge and skills among producers influences the population of potential adopters of the innovation by influencing perceptions that the innovation offers a technical improvement of a type that is relevant to their objectives.

Second, there may be experiences, knowledge and skills that influence producers’ perceptions of the relevant functional relationships in their farm systems. These will influence their perceptions about the elements in farm systems that define the farm contexts for an agricultural innovation. Hence, these experiences, knowledge and skills will influence producers’ perceptions of the merits of the technical improvement embodied in the innovation. Generally speaking, the distribution of experiences, knowledge and skills among producers influences the rate of adoption of the innovation but not the population of potential adopters since by definition potential adopters have accurate knowledge of the consequences of adoption. However, experiences, knowledge and skills may influence the population of potential adopters of an innovation when they affect producers’ perceptions of the compatibility of an innovation with their values, experiences and needs.

Third, there may be experiences, knowledge and skills that influence producers’ perceptions of the merits of an innovation given their farm context. Such experiences,
knowledge and skills influence producers’ perceptions of the type, relevance and compatibility of the technical improvement offered by an agricultural innovation given their farm context. Hence, the distribution of these experiences, knowledge and skills among producers influences the rate of adoption of the innovation but not the population of potential adopters of the innovation since, by definition, potential adopters have accurate knowledge of the merits of the innovation.

Fourth, there may be experiences, knowledge and skills that producers require for adoption of an innovation to occur but which, in themselves, would not be sufficient to justify adoption of the innovation. The farm context for an innovation is independent of these particular experiences, knowledge and skills in the sense that their acquisition would not be sufficient to justify adoption of the innovation, even though their acquisition may be necessary for adoption to occur. The distribution of such experiences, knowledge and skills among producers influences the rate of adoption but not the population of potential adopters.

For example, awareness of an innovation is a necessary precursor to adoption of the innovation. However, awareness of an agricultural innovation does not justify adoption if the innovation does not contribute to achieving the goals of the producer. Similarly, training may be a prerequisite to the correct implementation and use of an agricultural innovation. However, training does not justify adoption if the innovation does not contribute to achieving the goals of the producer.

Similarly, access to credit may be a prerequisite to the acquisition and implementation of an agricultural innovation. If the innovation would not contribute to achieving the goals of the producer then denial of access to credit is not an element of the farm context for that innovation. On the other hand, if the innovation would contribute to achieving the goals of the producer but access to credit is denied then access to credit is an element of the farm context for that innovation (Sumberg 2005). Whether access to credit emerges as an element defining the population of potential adopters depends on the proportion of the population for whom access to credit is denied, which is an empirical matter.

Hence, the population of potential adopters of an agricultural innovation is defined by the farm contexts for that innovation and is independent of the knowledge and skills that may be needed to evaluate and implement the innovation correctly. This is
because awareness of the innovation and possession of the knowledge and skills to evaluate and implement an innovation correctly are necessary but not sufficient conditions for adoption. Both conditions must be accompanied by the perception that the innovation offers relative advantage for adoption to occur. Consequently, awareness of an innovation and the acquisition of knowledge and skills that enable the innovation to be evaluated and implemented only influence the rate of adoption and the penetration of the innovation.

Given that the population of potential adopters of an agricultural innovation is defined by the farm contexts for that innovation then the population may be classified into ‘benefit segments’. A benefit segment is a subset of the population of potential adopters of an agricultural innovation whose farm contexts for that agricultural innovation are relatively similar but different from the farm contexts of other producers in the population.

The presence of complicated, dynamic, causal relationships between the components of farm systems means that different innovations are likely to be functionally related to different sets of components and relationships in the farm system. To the degree that the introduction of different innovations changes the properties or states of different components or causal relationships in the farm system, the functional relationships that shape the benefits of adopting the innovation will differ from innovation to innovation. Consequently, the components and relationships in the farm system that characterise the consumption situation or farm context for agricultural innovations is likely to vary from innovation to innovation (Byerlee and Hesse de Polanco 1986; Parminter 1994; Frank 1995a; Frank 1995b; Waller et al. 1998; Smale et al. 1999; Chaves and Riley 2001; Douthwaite et al. 2002; McCown 2002; Dorward et al. 2003; Douthwaite et al. 2003; Gebremedhin and Swinton 2003; Cramb 2005).

The presence of dynamic, causal relationships between the components of farm systems also means that the benefits to be had from introducing an innovation into a farm system will depend on the mix of innovations that have already been integrated into the farming system. The causal relationships between the components of farm system will be a product, in part, of the series of innovations that have already been integrated into the farming system. This means the benefits to be had from the adoption of an innovation will depend to some degree on the innovations that have already been adopted by the producer.
The more closely an innovation is functionally related to another then the more likely the benefits of adopting the innovation will depend on the prior or concurrent successful adoption of the other innovation. When a group of two or more innovations is functionally related then that group may be described as a ‘technology cluster’ (Rogers 1995: 235). Technology clusters occur when the successful adoption of one innovation depends on the prior adoption of other innovations or the concurrent adoption of complementary innovations (Rogers 1983; Frank 1995a; Frank 1995b; Douthwaite et al. 2002; Douthwaite et al. 2003). Hence, the introduction of an innovation into a farm system will influence to some degree the potential to use subsequent innovations to favourably reconfigure the farming system (Byerlee and Hesse de Polanco 1986; Leathers and Smale 1991).

This means the interrelatedness among components in a farm system can influence the sequencing of the adoption of innovations in the process of farm development. Crouch (1981) argued that the process of farm development can be characterised as the ordered adoption of a succession of innovative practices, techniques and technologies. In the early stages of farm development innovations can be adopted relatively independently of each other. However, as development proceeds, the adoption of more recent innovations comes to depend increasingly on the prior adoption of earlier innovations. A stage in farm development is reached where, in a practical sense, the random selection of innovations cannot continue (Crouch 1981; Frank 1995a). Further development requires integrating new practices and techniques with the complex mix of technologies and practices adopted earlier. Crouch (1981) was able to support this argument using data on the adoption of management practices spanning a range of farm operations in wool production (see also Cramb (2005); Frank (1995a) and Frank (1995b)).

Explicit in the process of farm development described by Crouch (1981) is the idea that, as development proceeds, the functional relationships between innovations will generally tend to grow in strength and complexity. As new ideas and innovations are generated and adopted, new functional relationships may be created between previously unrelated practices. At the same time, well-established functional

---

13 The idea that the interrelatedness between components in a farming system gives rise to properties such as functional relationships, technology clusters and ordered paths of farm development has parallels in the organisational management literature on product innovation (Abernathy and Clark 1985; Gatignon et al 2002; Henderson and Clark 1990; Smith 2000; Tushman and Anderson 1986).
relationships may be strengthened, weakened or even eliminated. At a practical level this means there will be less and less scope for farmers to adopt innovations independent of consideration of the farm system as development progresses.

Consequently, the detailed impact of the history of innovation on a farm is argued to create a more or less idiosyncratic set of farming practices which contribute to the farm context independently from the complex of physical resource endowments. This can confound attempts to infer farm context, and benefit segments, from such endowments.

In summary, the consumption situation for an agricultural innovation – the farm context - will depend in part on the previous adoption of other, functionally-related innovations. Furthermore, the greater the degree of interdependency between innovations the less random and haphazard and the more ordered and structured the sequencing of the adoption of innovations becomes.

Thus, in the early stages of property development some practices can be adopted independently of each other. However, if development is to occur the adoption of succeeding practices is dependent on the prior adoption of others. A stage in farm development is reached when random selection cannot continue, and it is then that the relative managerial capacities of each farmer become important. At this stage the selection of practices is neither random nor haphazard.

(Crouch 1981: 123)

The presence of dynamic, causal relationships between the components of farm systems also means that, to the degree that there is variety in farm systems, there will be variety in the consumption situations for an innovation and variety in the benefits to be had from the innovation.

Variety in the types of farm systems stems from a number of sources. To begin with variety arises from the sheer volume and diversity of components and their properties, and the linkages that are present between them (Byerlee et al. 1982; Haines 1982; Byerlee 1987). For example,

The complexity of small farms has its roots in the number of separate and composite activities undertaken; the number of effective constraints impinging on these activities; the crucial temporal interdependencies among activities; the poor formal records and information base for decision-making; the number of attributes that contribute to the farm family’s utility; and last, but by no means least,
the inevitable lack of certainty in nearly all facets of production, marketing, and life.

(Anderson and Hardaker 1979: 11)

Variety can also arise because farm systems can be configured in different ways to achieve the same or different objectives (Katz and Kahn 1978; Byerlee et al. 1982; Hardaker et al. 1984; Byerlee 1987; Mawapanga and Debertin 1996; Cramb 2005; Demont et al. 2007).

The potential for variety in farm systems is amplified by the functional dependence between components. Functional dependence between components in a farm system means that changes in the state of one component will cause changes in the state of other components (Ackoff 1971; Byerlee 1987). Presumably, differences in the state of components that lie at the centre of a network of linkages will create differences in the state of functionally-dependent components. These differences may, in turn, generate a cascade of changes in the state of components, and the linkages between them, across the system. Hence, differences in the state of key components may translate into substantively different types of farm systems. In short, differences in the components of farm systems such as resources, constraints, technologies and practices together with differences in the strategies and objectives of producers create different types of farm systems (Haines 1982; Byerlee and Hesse de Polanco 1986; Byerlee 1987; Traxler and Byerlee 1993; Frank 1997; Dorward et al. 2003; Demont et al. 2007).

Logically, the benefits of adopting any particular innovation will vary from one type of farm system to another and innovations will require adaptation to different farm systems (Byerlee 1987; Pannell 1999b; Collinson 2001; Norman 2002; Sumberg 2002; Douthwaite et al. 2003). This means that the consumption situation (farm context) for an agricultural innovation will differ from one type of farm system to another. Consequently, the identification of the population of potential adopters of an agricultural innovation requires identifying the farm context for each of the relevant types of farm systems. In effect, different farm contexts define different benefit segments for an innovation (Reece et al. 2004; Sumberg and Reece 2004).

The application of farming systems theory here leads to the conclusion that the task of identifying the population of potential adopters of an agricultural innovation requires identifying the various farm contexts for an innovation. Hence, the task of identifying
the potential market for an agricultural innovation entails acquiring a detailed understanding of the relevant functional dependencies within each of the different types of farm systems for which the innovation may create benefits. This entails obtaining an intimate understanding of producers as managers and of their farm systems. Obtaining such an understanding has been a key theme in farming systems research.

3.3.2 Farming systems research

Farming systems research was developed in response to the failure of traditional scientific reductionism to develop technologies suitable for small scale, resource-poor farmers in less favourable, heterogeneous production environments (Norman 1980; Norman 2002). Hence, the primary focus of much farming systems research has been the task of designing and developing innovations for farm systems (Byerlee et al. 1982; Hardaker et al. 1984; Norman 2002).

Farming systems research, and the participative approaches to research and extension that evolved from it, was based on the proposition that researchers had to begin with understanding the problems of farmers from the perspectives of farmers, and that innovative solutions to those problems had to be based on a proper understanding of farmers’ objectives and their biophysical and socioeconomic environments (Collinson 2001; Norman 2002). This meant the knowledge of farmers was essential in the innovation development and evaluation process. Hence, consistent with systems thinking (Cooksey 2001), farming systems research has tried to meet the challenge of understanding farm systems by conducting research that draws on the unique knowledge of the manager of the farm system and the multiple perspectives of researchers from different disciplines (Byerlee et al. 1982; Collinson 2001). Consequently, key features of farming systems research were a whole systems approach to the analysis of agricultural enterprises, collaborative research involving scientists from a range of biophysical and social disciplines and partnerships between farmers and scientists (Hardaker et al. 1984; Collinson 2001; Norman 2002).

14 This is not to downplay the importance of farming systems research that has focused on the identification and removal of exogenous constraints on the performance of farming systems such as provision of fertilisers, credit and infrastructure. This research is of limited relevance here as it concerns innovations to components of farm systems that lie beyond the managerial influence of the producer and so cannot legitimately be considered to be innovations that may be adopted at the discretion of the producer (Sumberg 2002, 2005).
Farming systems research explicitly recognises that the adoption of agricultural innovations is driven by the self-interest of producers as expressed by their objectives (Lindner 1987; Cary 1992; Collinson 2001; Norman 2002). In addition, farming systems research also recognises that producers: have a thorough knowledge of their local environment including spatial and temporal variability; have an intimate understanding of their farm systems, problems and priorities; have criteria for evaluation of options; and actively engage in experimentation as part of their farming routine (Norman 2002; Sumberg et al. 2003). For example

… farmers are intentionally rational in the way they manage their farming operations, including their choice of technology [...]. That is, they choose farming technologies in order to further their goals, subject to the constraints imposed by resource availability (land, labour, and capital) and environmental conditions (biophysical and socioeconomic). This underlying rationality is reflected in the evolution of farming systems as circumstances change.

(Cramb 2005: 71)

Farming systems research is founded on this being the case. This is consistent with the assumption that the decision to adopt an agricultural innovation is a high involvement purchase decision and the proposition that the adoption of agricultural innovations will be characterised by complex decision making.

In meeting the challenge of designing an innovation that will produce predictable benefits for the manager of the farm system the emphasis in farming systems research has been on classifying agricultural enterprises such that all the enterprises within a class have a similar type of farm system, and therefore are subject to common constraints (Norman 1978; Norman 1980; Byerlee et al. 1982; Collinson 2001; Norman 2002; Dorward et al. 2003). Typically, farms are classified into systems or categories using a mix of biophysical, financial and physical criteria (Norman 1978; Bernhardt et al. 1996; Gibon et al. 1999; Kobrich et al. 2003). As the farms in a category are in similar circumstances then the same solution should apply to all farms in that category, more or less (Byerlee et al. 1982; Byerlee 1987). Innovations are then formulated, designed and developed to increase the productivity of those systems by relaxing one or more of the common constraints.

The products of farming systems research were expected to diffuse among agricultural enterprises within a class, termed a ‘recommendation domain’, because
the innovations were designed to integrate precisely with their type of farm system (Byerlee et al. 1982; Byerlee 1987; Dorward et al. 2003; Kobrich et al. 2003). In short, the potential adopters of an innovation were generally presumed to be those agricultural enterprises with farming systems consistent with the recommendation domain, although this presumption has been increasingly questioned in the light of experience (Douthwaite et al. 2003; Reece et al. 2004; Sumberg and Reece 2004).

The emphasis in farming systems research on the creation of technical solutions to constraints on agricultural productivity has meant that this research has had a practical focus on the design of innovations that fit with a particular type of farm system (Byerlee et al. 1982; Hildebrand 1982; Hardaker et al. 1984; Colin and Crawford 2000). This has had a number of consequences.

First, there has been a concentration in farming systems research on identifying innovations that create the least disruption to a farming system by designing innovations that fit into farm systems as easily and advantageously as possible (CGIAR 1978; Byerlee et al. 1982; Hildebrand 1982; Hardaker et al. 1984; Collinson 2001; Dorward et al. 2003). As a result, the incorporation of innovations designed for one type of farming system into another type appears to have received limited attention in farming systems research. Relatedly, the incorporation of more disruptive innovations that do not fit as easily and advantageously into farming systems also appears to have received limited attention in farming systems research.

Second, there has been an emphasis on identifying prototypes of innovations that can be adapted to different farm systems (Norman 1978; Norman 1980; Collinson 2001; Douthwaite et al. 2002; Douthwaite et al. 2003). This emphasis has been driven by the consideration of the regional heterogeneity in farm systems and the limited resources available to invest in the design, development and adaptation of innovations. The heterogeneity in farm systems means that any particular design for an innovation is unlikely to suit all types of farm systems equally and that innovations will require adaptation to local conditions (Norman 1980; Byerlee 1987; Sumberg et al. 2003; Reece et al. 2004). This has resulted in a focus on relatively few biophysical, economic and social constraints in the selection of criteria for the classification of farming systems and delineation of recommendation domains (Norman 1980; Byerlee et al. 1982; Kobrich et al. 2003; Reece et al. 2004; Sumberg and Reece 2004).
The identification of recommendation domains has necessarily entailed the aggregation of information across producers on critical characteristics of their farming systems. There is a risk in this process that there may be a proportion of producers for whom the innovation is unsuitable but whose farm systems have, nevertheless been judged to fit within the recommendation domain (Dorward et al. 2003; Reece et al. 2004). For example, the aggregation process may combine characteristics or scores that are incommensurable, treat relationships between characteristics as linear when they are non-linear, or exclude characteristics that are critical but present among a relatively small proportion of farm systems (Taplin 1997; Riley and Fielding 2001). As a consequence, the resulting innovation may technically suit the farm systems of some producers as defined by the recommendation domain but not fit with their particular farm context. In short, an innovation may not suit the entire suite of farm contexts within a recommendation domain identified by farming systems research.

Furthermore, the difference between recommendation domains in farming systems research and the set of farm systems for which an innovation creates benefits will be enhanced to the degree that the innovation may generate benefits for farm systems that lie outside the recommendation domain. Concern has been expressed that the farming systems approach has been limited by the difficulty of coping with diversity in farming contexts (Collinson 2001; Norman 2002; Kobrich et al. 2003).

Third, there has been a concentration on identifying methods for eliciting information from producers about the farm context for innovations ex ante and processes for involving producers in the design and development and adaptation of flexible technologies (Byerlee et al. 1982; Byerlee 1987; Dorward et al. 1997; Collinson 2001; Riley and Fielding 2001; Dorward et al. 2003; Douthwaite et al. 2003; Sumberg et al. 2003; Reece et al. 2004; Joshi et al. 2007). The task of developing innovative solutions to practical problems in farm systems requires obtaining an intimate understanding of producers and their farm systems. Given the contextually-dependent and complicated nature of farm systems, such an understanding can only be obtained from careful and considered questioning of, and interaction with, producers. Hence, processes for identifying key surmountable constraints and exploitable opportunities (Hardaker et al. 1984), and for reliably interacting with producers in the identification, development, and evaluation of possible innovative solutions, are strategically critical to the success of farming systems research (Sumberg et al. 2003). As a result,
methods for eliciting information from producers about the farm context for innovations following their development appears to have received limited attention in farming systems research.

In conclusion, the task of developing an innovation for a farm system entails acquiring a detailed understanding of the relevant functional dependencies within that farm system, preferably prior to the development of the innovation. The formulation of methods to perform this task has been the focus of farming systems research. In contrast, the task of identifying the population of potential adopters of an agricultural innovation, once the innovation has been developed, entails acquiring a detailed understanding of the relevant functional dependencies within each of the different types of farm systems for which the innovation may create benefits. The formulation of a method to perform this task is the focus of this research.

3.3.3 Hyper-rationality, adoption and the rate of adoption

I have proposed that the adoption of agricultural innovations is a highly involving activity for producers and that, as a consequence, producers invest time and effort in identifying elements in their farm systems that would be functionally related to innovations, actively searching for information on the characteristics of innovations, and establishing in some form causal descriptions of the potential consequences that might flow from adopting innovations. This is consistent with the assessment in farming systems research that producers are intentionally rational in the way they manage their farming operations, including their choice of technology (Cramb 2005). At the same time, this characterisation is also consistent with the views that producers are not, and need not be, hyper-rational agents engaged in optimising behaviour when contemplating the adoption of agricultural innovations (Wright 1986; Murray-Prior 1994; Campbell 1995). As Crouch (1981) observed, the decision to adopt an innovation is often a matter of practical sense as the scope to adopt innovations is restricted by the mix of technologies and practices adopted previously, resource constraints, and management strategies of the producer. This suggests that, in many instances, agricultural innovations will fail to pass the screening associated with producers’ strategic image (Beach and Connolly 2005). Consequently, the choice is
usually stark: the decision not to adopt an innovation is often a simple matter of elimination rather than a question of optimisation based on finely balanced criteria.

Furthermore, the complex interrelationships between technologies, practices, resources and strategies in farming systems means producers must be confident that the benefits an innovation appears to offer will be realised to justify the necessary investment in adjustments to their farm systems as well as investment in the innovation itself. Hence, innovations that appear to offer only a marginal relative advantage are unlikely to be considered as deserving candidates for adoption.

In addition, the complexity of farming systems, together with the inherent unpredictability of elements that are critical to performance, such as commodity prices and seasonal conditions, means that there is a perceived risk associated with the adoption of any agricultural innovation. Consequently, agricultural innovations that only offer a marginal benefit in terms of technical advantage must be perceived as virtually risk free to merit consideration for adoption. This is most likely to be the case with incremental innovations which, by definition, are likely to be highly compatible with the farming system (Henderson and Clark 1990). Hence, the decision to adopt incremental innovations that offer a marginal relative advantage is more likely to depend on simple calculation than on complicated, finely balanced optimisation.

A systems perspective on the adoption of agricultural innovations supports the conclusion that producers need not be hyper-rational in this regard. From this perspective the adoption of agricultural innovations is largely a matter of system improvement rather than system design (van Gigch 1974). Consequently, the adoption and integration of agricultural innovations into a farm system is a process of identifying and realising infra-marginal gains rather than optimisation of marginal benefits through refinement of system design.

In the preceding chapter I argued that models of the adoption decision process are alike in proposing that the adoption of an innovation is a function of the decision-maker’s perception of the degree to which the innovation contributes to the achievement of their goals – be they utilitarian, social or hedonic. I also argued that these models were similar in that, while they recognise that the elements in the context of the decision-maker that influence the contribution of an innovation to the
goals of a decision-maker vary from innovation to innovation, they do not contain mechanisms for identifying precisely which elements in a decision maker’s context are influential for a particular innovation. Consequently, in the absence of a process for systematically identifying the elements in the context of the decision-maker that influence the contribution of an innovation to the goals of a decision-maker, efforts to explain the observed adoption of agricultural innovations have met with limited success (Abadi Ghadim and Pannell 1999; Pannell et al. 2006).

Furthermore, given that observed adoption is the outcome of the diffusion of an innovation through the population of potential adopters – which cannot be properly specified - then such efforts will suffer to the degree that variables describing farm context which influence membership of the population of potential adopters, are conflated with demographic variables such as age and education and personality traits such as innovativeness and self-efficacy which influence the rate of diffusion of the innovation through the population of potential adopters.

I propose that, given adoption decisions primarily concern infra-marginal gains, by assuming the adoption of agricultural innovations is highly involving for producers and by hypothesising that the benefits to be had from adopting an agricultural innovation are influenced by particular elements in a farming system, these difficulties may be overcome.

The assumption that the adoption of agricultural innovations is a highly involving for, and triggers complex decision making by, producers means they will invest time and effort in identifying a set of purchase criteria for evaluating prospective innovations. Such criteria will represent the key benefits producers are seeking in adopting an innovation. I have hypothesised that these criteria, which are employed by the producer to assess whether an innovation offers a relative advantage, are the elements in the farm system that influence the benefits to be had from an innovation and thereby contribute to, or detract from, the achievement of the utilitarian, social and hedonic objectives of the producer.

The population of potential adopters is defined as those producers for whom an innovation would offer a relative advantage given sufficient knowledge of the consequences of adopting the innovation. Hence, the population of potential adopters of an agricultural innovation may be specified by identifying the set of farm contexts.
for which an innovation creates benefits. This means that the variables that decide whether a producer is a member of the population of potential adopters of an innovation are limited the components and relationships in the farm system that are functionally related to an innovation, together with those objectives of the producer that are pertinent to his or her role as the manager of an agricultural business. This also means that those variables that determine the population of potential adopters of an agricultural innovation can be properly distinguished from those variables that influence the diffusion of that innovation through that population.

The exposition of a method to identify the elements in farm systems that influence the benefits to be had from an agricultural innovation is the subject of the next chapter.

### 3.4 Conclusion

In this chapter I have drawn on social psychology to characterise the adoption of agricultural innovations by producers as high involvement purchases. I have argued the purchase of any input for an agricultural enterprise will be situationally involving for the producer to the degree that the input is perceived by the producer as contributing to satisfying their utilitarian, social, or hedonic goals as managers of agricultural enterprises. Involvement will be intensified to the extent that, within limits, the purchase is perceived by the producer to have the potential for undesirable psychological, social and functional outcomes.

The higher the level of involvement and the greater the perceived risks, the greater the effort producers will be prepared to invest in, and the more extensive will be, the purchase decision. Hence, high involvement purchases normally invoke complex decision making in the purchaser in that the purchaser deliberately formulates criteria to assess alternative courses of action based on the benefits they are seeking. These benefits should epitomise the usage or consumption situation for the purchase.

In the case of agricultural innovations I have argued on the basis of farming systems theory that the consumption situation is defined by those elements in the farm system of a producer that are functionally related to an innovation – the set of which I have termed the farm context for an innovation. Hence, the population of potential adopters of an agricultural innovation may be specified by identifying the set of farm contexts for which an innovation creates benefits. The formulation of a method to perform this task is the subject of the next chapter.
We should increase our understanding of the motivations for adopting an innovation. Strangely, such “why” questions about adopting an innovation have only seldom been probed by diffusion researchers; undoubtedly, motivations for adoption are a difficult issue to investigate.  

(Rogers 1995: 109)

4.1 Introduction

In the preceding chapter I described a theory predicting the adoption of innovations by primary producers. This theory embodies an assertion that a producer will only consider adopting an agricultural innovation when the producer believes the innovation will create benefits for them in the conduct of their agricultural enterprise and that the benefit an innovation creates will depend on a subset of elements of the farm system. These elements consist of the strategies, resources, technologies and practices on hand that shape the benefits to be had from a particular innovation. I have termed these elements the farm context for an innovation. Hence, knowledge of the farm context for an agricultural innovation provides a foundation for identifying the population of potential adopters of the innovation.

In this chapter I describe an approach to quantifying the population of potential adopters of an agricultural innovation. Broadly speaking, the approach involves two stages. The first stage is to identify the elements in farm systems that shape the benefits to be had from adopting a particular innovation and which thereby form the farm contexts for the innovation. The second stage is to quantify the proportion of producers in the population possessing the farm contexts for the innovation. This proportion is an estimate of the population of potential adopters of the innovation.
In the next section the ontological and epistemological foundations of an approach to quantifying the population of potential adopters are discussed. Following this discussion methods for accomplishing the two stages in the approach are proposed. First, a method for identifying the set of farm contexts for an agricultural innovation is proposed. The issues to be considered in judging the reliability and validity of the method are then considered in some detail.

Second, methods for quantifying the population of potential adopters of an innovation, and methods for statistically testing the association between adoption of the innovation and farm context, are proposed. The issues to be considered in judging the reliability and validity of these methods are then discussed. In this discussion the use of methodological triangulation to establish the external validity of the first stage of the approach is considered.

The chapter is completed with the presentation of a plan for testing the extent to which farm context as a predictor of the adoption of agricultural innovations can be generalised.

Finally, four different ways of testing the external validity of farm context as a predictor of the adoption of agricultural innovations are proposed. These are combined to create a plan for using case studies to establish the extent to which farm context may be generalised as a theory of the adoption of agricultural innovations.

4.2 Knowledge of farm contexts

Four propositions are central to the methodology used in this thesis. The first proposition is that the benefits to be had from adopting agricultural innovations depend on farm context. This means that knowledge of a producer’s farm context is the basis for predicting whether a producer is a potential adopter of an innovation and why. Hence, the purpose of the research is to explain and predict.

The second proposition central to this thesis is that the farm context can consist of elements – such as resources, technologies and practices - that are external to the decision-maker. Hence, the concept of a farm context presupposes the existence of a real world external to the decision-maker.
The third proposition, argued on the basis of high involvement in the previous chapter and considered further below, is producers’ reasons for adopting innovation will mirror their farm context. It follows from this proposition that producers with similar farm contexts will advance similar reasons for adopting an innovation. It also follows that producers from different farm contexts that adopt an innovation will offer different reasons for their behaviour. This proposition requires the assumption that producers’ perceptions of their farm systems, the characteristics of innovations and interactions between the two, are grounded in an external reality to such a degree that producers with similar farm contexts will offer similar reasons for adopting an innovation. This assumption is necessary if the behaviour of one producer is to be predicted from the reasoning and behaviour of another.

The fourth proposition relates to sources of knowledge about farm contexts. In the theory that I have proposed, the benefits to be had from an innovation depend on those elements of the farm system that are functionally related to the innovation. These elements constitute the farm context for the innovation and are peculiar to the innovation. The theory does not predict what those elements may be for any particular innovation; what precisely they may be is a matter for investigation with each innovation.

The fourth proposition, then, is that producers are the most authoritative source of knowledge about their farm contexts. This proposition means that, among all observers, producers have the richest understanding of their farm systems and the likely consequences of changing that system. Hence, producers will be the best source of information about the likely consequences of introducing an innovation into their farm systems and the factors that shape those consequences.

The validity of this proposition rests on the idea that farm systems are fundamentally complex and varied. A consequence of complexity is that knowledge of the dynamic properties that characterise a particular farm system comes from the accumulated experience of intervening in the system to influence its behaviour. The experience of intervening in the farm system creates opportunities for gathering information about the structure, causal relationships, feedback loops and emergent properties of the system. This experiential information provides the foundation for anticipating how an innovation could change the farm system and which elements in the system will influence those changes.
A consequence of variety in farm systems is that knowledge of the properties that characterise one farm system does not necessarily translate into knowledge of the properties of other farm systems. In other words, experience with one farm system does not provide reliable insights into other farm systems. This means that experience with one farm system cannot be relied upon to provide reliable predictions about the benefits an innovation creates for other farm systems. Therefore, the experiences of producers across a range of farm systems must be obtained in order to anticipate how an innovation could interact with different farm systems so that the set of farm contexts for the innovation can be identified.

These four propositions anchor the paradigm for this research. The purpose of the research is to explain and predict. Hence the study is positivist in intent. The logic of the theory presupposes the existence of a real world external to the producer. Hence, the ontological position of the study is realist. The source of knowledge about farm systems and farm contexts is producers’ accumulated experiences of farming. Hence, the epistemological foundation of the study is modified dualist. Taken together these propositions are consistent with a study based within the post-positivist paradigm (Clark 1998; Lincoln and Guba 2000).

These four propositions also define the methodological steps for the identification of the population of potential adopters of an innovation. First, given that producers are the richest sources of knowledge about their farm systems, and that their reasons for adopting an innovation will mirror their farm context, then the elements in farm systems that influence the benefits to be had from an innovation, and so define the farm contexts for an innovation, must be elicited from producers themselves.

Second, once the farm contexts for an innovation have been elicited, in principle, an estimate of the population of potential adopters and the incidence of each context can be ascertained by the statistical analysis of a survey of a representative sample of producers.

The surveying of a representative sample of producers also offers the possibility of using data and methodological triangulation (Denzin 1997) to establish confidence in the rigour of the elicitation procedure. This may be achieved by statistically verifying the relationships elicited from producers between farm contexts and the adoption of the innovation. Data triangulation involves the use of a variety of data sources in a
study (Janesick 2000). In this case, data triangulation entails using interviews and surveys to provide different sources of data on farm context and the adoption of innovations. Methodological triangulation involves the use of multiple methods to analyse a problem (Janesick 2000). In this case, methodological triangulation entails using laddering and convergence techniques in interviews, and statistical techniques with surveys, as different methods for investigating the relationship between farm context and adoption of agricultural innovations.

4.3 Methods for identifying farm contexts
Given that producers are the richest sources of knowledge about their farm systems, and that their reasons for adopting an innovation will mirror their farm context, the elements in the farm system that define the farm context for an innovation must be elicited from producers themselves. In selecting an elicitation process there are two issues that are critical to the rigour of the process.

The first critical issue concerns the reliability of information supplied by producers during the elicitation process. In characterising the adoption of an agricultural innovation as a form of high involvement purchase, I have proposed that complex decision making summarises the process primary producers follow in reaching a decision as to whether they will adopt the innovation.

Complex decision making entails deliberate and systematic evaluation of the merits of the innovation prior to adoption. The merits, or otherwise, of the innovation derive from the degree to which the innovation is perceived by the producer to create benefits when implemented in their farm context. The process of identifying benefits requires producers to invest effort in learning about the attributes of the innovation. The process of identifying benefits also requires producers to invest effort in developing an understanding of the elements in their farm system that are functionally related to the innovation, and in developing an appreciation of the likely consequences of implementing the innovation.

These considerations suggest that producers are likely to have formed comprehensive mental models of their farm systems and to draw on these when seriously contemplating adopting an innovation. Hence, the use of complex decision making in high involvement purchase decisions such as the adoption of an agricultural
innovation implies that the producer develops explicit chains of reasoning to guide their decision making. This is consistent with general psychological theories of the fundamental logic of decision-making such as image theory (Beach and Mitchell 1987; Beach and Potter 1992; Beach and Connolly 2005) and theories of specific decision-making processes in particular circumstances such as explanation-based decision theory, where the focus is on “reasoning about the evidence and how it links together” (Pennington and Hastie 1989).

Image theory treats decisions as social acts and recognises that decision-makers come to a decision with a store of knowledge which influences their decisions and guides their behaviour (Beach and Potter 1992; Nelson 2004). This knowledge can be metaphorically classified into three categories or images. These are the value image which consists of knowledge about what truly matters and is based on beliefs and values (of the producer in this case), the trajectory image which consists of knowledge about what constitutes a desirable future and is based on goals, and the strategic image which consists of knowledge about how to go about securing that future and is based on plans (Beach and Mitchell 1987; Beach and Strom 1989; Beach and Potter 1992; Beach and Connolly 2005). Plans in the strategic image have two aspects: tactics and forecasts. Tactics are concrete behaviours while forecasts focus on the outcomes of those behaviours. The various plans in the strategic image must be coordinated so that they do not interfere with each other and the decision-maker can pursue their goals in an orderly fashion (Beach and Connolly 2005). The relevant constituents of these images (principles, goals and plans) are employed to frame a situation; that is, to interpret a situation and imbue a decision with meaning.

There are two kinds of decisions in image theory: progress decisions and adoption decisions. Progress decisions are decisions about whether a plan is making progress towards achievement of its goal (Beach and Connolly 2005). These decisions rely on forecasts as to whether the anticipated outcome plausibly includes achievement of the goal or not. If the forecast does include goal achievement the plan is retained. If not, the plan is abandoned and a new or amended plan must be adopted (Beach and Connolly 2005).

Adoption decisions augment knowledge and concern adding new principles to the value image, new goals to the trajectory image or new plans to the strategic image.
The criterion for adding a new goal or plan is whether it is compatible with existing principles and consistent with existing goals or plans of the decision-maker. If a goal or plan is sufficiently incompatible with existing principles or interferes with existing goals or plans then it is rejected. Importantly, adoption decisions are accomplished by screening options in the light of relevant principles, goals and plans (Beach and Mitchell 1987; Beach and Strom 1989; Beach and Potter 1992). Note that compatibility criteria are non-compensatory (Beach and Strom 1989). This limits the need for making a choice between options to those situations where two or more options survive screening. When two or more options pass screening the decision-maker may call on one or more of a repertoire of decision strategies to make a choice depending on the circumstances of the choice. These circumstances include characteristics such as unfamiliarity with, and complexity of, the choice, significance and irreversibility of the outcomes, and the decision-maker’s motivation (Beach and Connolly 2005).

In terms of image theory, the adoption of an agricultural innovation is an adoption decision in the image theory sense because it involves the incorporation of a new tactic, in the form of the innovation and associated changes to the farm system, into relevant plans in the producer’s strategic image. The innovation is screened by considering the compatibility of the amended plans with the value image and the consistency of the amended plans with the trajectory image. If the amended plans fail the screening test then the change in tactics is rejected as is the agricultural innovation. If the amended plans pass the screening test then the change in tactics is implemented and the innovation is adopted.

Arguably, the constituents of the value, trajectory and strategic images that are relevant to producers’ screening of agricultural innovations are what have previously been defined as the purchase criteria that are employed in complex decision making to evaluate an agricultural innovation. In other words, the elements in the farm system that influence the intensity of the technical improvement an agricultural innovation offers, the relevance of the improvement to producers’ objectives, and the compatibility of the improvement with their values, experiences and needs ultimately

---

15 The addition of a new principle to the value image is rare for adult decision-makers except in the case of cultural, revolutionary or other deep, longer term change. In this case, a dire or extreme threat to the survival of an organisation (e.g. farm) may be sufficient to generate modifications in the value image of the producer.
translate into the constituents of the strategic, trajectory and value images respectively of producers.

In addition to being broadly consistent with image theory, which presents a general model of the fundamental logic of decision-making, complex or extensive decision making is also broadly consistent with explanation-based decision theory (Pennington and Hastie 1989). Explanation-based decision theory provides a description of the specific mechanisms that are employed to make important, non-routine decisions in everyday life in circumstances where a large base of implication-rich, conditionally-dependent pieces of evidence must be evaluated as a preliminary to choosing a course of action and, as well, important dimensions of the decision may be unknown (Hastie and Pennington 2000).

In essence this theory proposes that the construction by the decision-maker of causal models or explanations linking evidence and consequences is central to the decision process in these circumstances and that the primary focus for the decision-maker is on reasoning about the evidence and how it links together (Cooksey 1996). Confidence in the explanation, and the subsequent decision, depends on the narrative comprehensiveness of the explanation which is the capacity of the explanation to completely, consistently and plausibly link evidence together, and the uniqueness of the explanation which to the potential for other equally plausible explanations (Hastie and Pennington 2000).

In short, the idea is that producers gather evidence on the attributes of the technological alternatives available to them. This evidence is processed into a coherent causal model, an explanation, which is used to evaluate the extent to which the alternatives will meet their farming needs and upon which a decision is finally made (Cooksey 1996).

If the purchase criteria that producers use to evaluate innovations are defined by their farm contexts, and if producers do base their evaluations of innovations on explicit chains of reasoning, there should be shared and complementary patterns of reasoning among producers who adopt an innovation. In other words, producers with similar farm contexts will offer similar explanations for their decision making, and these explanations will differ from those of producers whose farm contexts are dissimilar. Furthermore, differences in the reasoning of producers from different contexts should
follow logically from differences in their farm contexts. Moreover, the decisions of producers who have seriously considered, but chosen not to adopt, an innovation should follow logically from the absence of a farm context suitable for the innovation.

These considerations suggest that an essential test of the reliability of information supplied by producers during the elicitation process is the degree to which the chains of reasoning underpinning the decisions of producers logically reflect similarities and differences in farm contexts. Hence, a critical feature of the elicitation process is a procedure that emphasises comparing and explaining similarities and differences in the information supplied by producers. This suggests that a dialectical approach to elicitation is required to ensure that the theory of action elicited from producers is a theory-in-use rather than an espoused theory (Argyris 1995; Dick 1999; Kahle et al. 2000).

Dialectical approaches to elicitation combine structured process and unstructured content. As a consequence, they allow the progressive refining of data analysis and interpretation (Dick 1999). The emphasis in a dialectical approach to elicitation is on testing agreement, and explaining disagreement, between participants. Where there is agreement between participants, this can be tested by questioning to establish the conditions that would lead to disagreement. Where there is disagreement on a topic, participants are questioned to establish an explanation for the disagreement (Dick 1999).

The second issue that is critical to the rigour of the elicitation process concerns variety in farm contexts. For any particular innovation, there may be a range of elements in the farm system that can combine in different ways to define the various farm contexts for the innovation. This means there may be a variety of farm contexts for an innovation and they are unlikely to be identifiable *a priori*. The unknown variety in farm contexts has three important implications for the elicitation process.

First, while there may be a variety of farm contexts, there is an expectation that producers with similar farm contexts will advance similar reasons for adopting an innovation while producers from different farm contexts will offer different reasons for adopting an innovation. I have argued that an essential test of the reliability of information supplied by producers during the elicitation process is the degree to which the chains of reasoning underpinning the decisions of producers logically
reflect similarities and differences in farm contexts. Hence, a critical feature of the elicitation process is that the process should not confound this test by providing producers with an opportunity to share observations on their farm contexts. Consequently, dialectical elicitation processes that rely on the sharing of information among participants such as Delphi techniques (Critcher and Gladstone 1998; Powell 2003) and focus groups (Kitzinger 1994; Krueger 1994; Morgan 1997) are not suitable for identifying farm contexts.

Second, given that there is variety in farm contexts, an individual producer is unlikely to be aware of all the farm contexts that are relevant to a particular agricultural innovation. Hence, a number of producers spanning the range of farm contexts must be involved in the elicitation process if the variety in farm contexts is to be described adequately. Yet the range of contexts, and the elements in the farm system that provide the dimensions to that range, can only be identified through the elicitation process. This means a sample of producers that is representative of the various farm contexts associated with an innovation cannot be identified \textit{a priori}. Consequently, dialectical elicitation processes that rely on group methods such as those mentioned above are also not suited to identifying farm contexts since the proper composition of such groups cannot be determined \textit{a priori}.

Third, given that the elements in a farm system that constitute the farm context for an innovation are to be discovered through the elicitation process, the process cannot be structured \textit{a priori} in terms of content or sample design. Consequently, a process is required that allows the elements that constitute farm context to emerge through disclosure, testing and confirmation. The process should also allow the sampling strategy to be refined as the elements that constitute farm context emerge.

These considerations suggest that, among the dialectical approaches to elicitation, convergent interviewing (Dick 1999) would be the most appropriate technique for identifying farm contexts. Convergent interviewing essentially involves a sequence of interviews with the information in each interview analysed and interpreted for consistency with previous interviews.

\textbf{4.3.1 Convergent interviewing}

The first step in the process is the selection of an opening sample of producers to interview. Generally, the opening sample is obtained from interviews with researchers
and extension personnel that are extensively involved in the development or promotion of the innovation of interest. In practice, the identification of the sample involves obtaining contact details for producers who have adopted the innovation of interest, producers who have not, and producers who have tried and abandoned the innovation, if they exist. As well, contact details may be obtained for producers with different demographic characteristics and for producers who differ in the scale and location of their agricultural enterprises. These producers may, or may not, have adopted the innovation. Subsequently, producers are contacted, usually by telephone, and an interview arranged. Most interviews occur in the homes of the interviewees or elsewhere on their property.

Each interview is undertaken using a process similar to laddering (Grunert and Grunert 1995; Bourne and Jenkins 2005). This first involves the establishment of rapport with the interviewee. Questioning about the subject of interest commences with inquiries that are virtually content free. Through a combination of active listening and inquiry that becomes increasingly precise in response to the detail provided by the interviewee, the content of the questioning becomes increasingly specific to the subject of interest. Interviewers test their understanding of the reasoning and decision making of the interviewee by asking clarification questions.

Usually, participants are informed that the purpose of the interview is to understand their management of a farm activity (relevant to the innovation of interest such as irrigation) but are not informed that the specific purpose of the interview is to understand their adoption of a particular innovation (such as micro-irrigation). The opening question introduces the general agricultural activity that is relevant to the innovation of interest and invites the producer to share their knowledge. This question is preceded by an explanation that we are interested in learning about producers’ experiences. For example, an interviewer may ask at the commencement of an interview about the adoption of integrated pest management techniques:

‘We are interested in learning about the different experiences farmers have with pest management. Can you tell us about how you manage pests like codling moth?’

As the producer describes their management actions and decisions interviewers test their understanding of the reasoning of producers by asking clarification questions. The intention is that the interviewers are able to trace the causal reasoning of the
producer in forming an opinion as to the benefits or otherwise, based on the specific characteristics of their farm system, of an innovation. Where the interviewer is unable to detect, or is unsure of, the causal logic of the producer, a series of clarification questions is asked seeking further, more detailed explanation from the producer. For example, an interviewer may ask during an interview about the adoption of soil moisture monitoring techniques:

'Just before you were saying that, even though you use micro-irrigation, monitoring soil moisture with tensiometers would not be much use because you are on a channel delivery system. Can you tell me how channel delivery effects monitoring with tensiometers?'

As the interview progresses the process of active listening and clarification questioning should allow interviewers to develop confidence in their understanding of the components of the farm system that constitute the farm context for the producer. As this occurs the opportunity arises for interviewers to identify and seek explanations for differences in the reasoning and decisions of producers. This stage in the interview can reveal subtle differences in producers’ farm contexts that have a critical influence on the benefits to be had from an innovation. For example, during an interview about the adoption of soil moisture monitoring techniques an interviewer may ask:

'Can you tell me how come you’re able to use tensiometers even though your irrigation water is delivered through the channel system? Some growers have told us that, because they are on a channel delivery system, they can’t take advantage of tensiometers.'

The interviewee may have responded:

'Because I’m at the head of the channel water is always going past so I am able get water whenever I need it - they were probably further down the system or on a spur.'

Towards the close of an interview, the interviewers summarise for the producer their interpretation of his or her reasoning and decision making. This summary provides an opportunity for a final check on the accuracy with which the interviewers interpret and reproduce the reasoning of the producer.

The laddering process is quite cognitively demanding in that the interviewer is required to constantly evaluate what the producer is saying. As the interview progresses the interviewer needs to identify:
• statements that suggest the interviewer has an incomplete understanding of the reasoning of the producer and formulate questions to obtain additional information that will improve the interviewer’s understanding,

• statements that suggest a gap or inconsistency in the reasoning of the producer and formulate questions to fill the gap or resolve the inconsistency,

• statements that are inconsistent with the explanations of producers from previous interviews and formulate questions to clarify and understand the apparent inconsistency,

• statements that complement the explanations of producers from previous interviews and formulate questions to test the interviewer’s understanding of the complementarity.

Given the cognitive effort involved, interviews are best conducted by pairs of interviewers. This allows one interviewer to take the role of maintaining a discussion with the producer while exploring a line of questioning. The other interviewer takes the role of observing and evaluating the statements made by the producer. The other interviewer also records key statements made by the producer. Interviewers may swap roles during the interview as they each identify different issues that require further explanation from the producer.16

Following the interview, the interviewers compare their understandings of the producer’s reasoning about the benefits offered by the innovation and the elements in their farm system that influenced those benefits. Any further points of agreement with the reasoning of producers who were interviewed previously are identified and questions designed to test the extent of agreement are formulated for use in subsequent interviews. Any additional areas of disagreement with the reasoning of producers who were interviewed previously are identified and questions exploring the basis for such disagreement are formulated for use in subsequent interviews.

Following an interview, interviewers may also seek the opinion of research and extension personnel to check their understanding of the technical aspects of the introduction of the innovation into farm systems. Such checks create an opportunity

16 Interviews may also be recorded using tape or digital media.
for researchers and extension personnel to identify and suggest alternative explanations and interpretations that can be explored in subsequent interviews.

The process of testing agreement and seeking explanations for areas of disagreement creates opportunities for identifying previously unidentified elements in the farm system that constitute the farm context for an innovation. The process also creates opportunities for testing and confirming the influence of those elements on the benefits to be had from the innovation. In doing so, the process allows the sample design to be progressively refined as data from successive interviews are analysed and interpreted (Dick 1999).

The convergent interviewing process continues until repeated interviews do not provide any new information and interviewers are satisfied that they have logically consistent explanations for the different patterns of reasoning they have elicited from producers.

4.3.2 Sampling strategy

Assuming that there is a limited set of different farm contexts for an agricultural innovation, in principle the set can be identified by interviewing producers from each context. That the set has been identified can be known by the fact that the same patterns of reasoning keep recurring in interviews. All that is required is to undertake interviews sufficient to span the set of contexts.17

As the set of relevant contexts cannot be known in advance a ‘snowball’ sampling technique must be employed (Cooper and Emory 1995). The elements that define different farm contexts for an innovation should progressively emerge as different chains of reasoning are observed as interviews proceed. Confirmation of the relevance of those elements, and the manner in which they influence the adoption of the innovation, is obtained by identifying and interviewing producers who differ on those elements as they are isolated. This is conceptually-driven sequential sampling (Miles and Huberman 1994).

To maximise the likelihood that the full set of farm contexts is identified a number of sampling strategies may be pursued in seeking new cases to interview. These include maximising the variation in the sample by deliberately seeking disconfirming cases,

17There is the possibility that the set of farm contexts for an innovation may be too large to be feasibly spanned by a practical number of interviews. This would be signalled by a failure to identify recurring patterns of reasoning: that is, failure to reach convergence.
opportunistic sampling based on the emergence of new information and critical case sampling where the characteristics of the case permit logical generalisation and maximum application of information to other cases (Miles and Huberman 1994). In this regard the explanations of producers who have considered, but chosen not to adopt, an innovation, and producers who have tried and abandoned the innovation, are especially important.

These strategies can be augmented through the use of case selection on reputation (Goetz and LeCompte 1984) and on dimensional sampling (Johnson 1990). Case selection on reputation creates opportunities for relevant experts, such as extension and research staff, to nominate cases they believe are of particular interest. Dimensional sampling involves selecting cases representative of variability along dimensions that are of interest. A dimension may be an element of the farm system that is emerging from interviews as an important component of the farm context. A dimension may also be a key indicator of a competing explanation for differences in producers’ behaviour (such as scale of enterprise).

### 4.4 Validating farm context as a qualitative construct

In describing a method for identifying farm contexts in the preceding section, the soundness or reliability of the elicitation process is a major concern. Similar concerns apply in regard to the use of participatory methods in agricultural research and extension and the approach that has been suggested to ensuring the trustworthiness of those methods is similar to that employed here (Pretty 1995).

There are two fundamental dimensions to soundness or rigour: reliability and validity (LeCompte and Goetz 1982; Miles and Huberman 1994). Reliability largely concerns the ease with which findings can be replicated. Validity largely concerns the extent to which findings can be regarded as accurate, credible, transferable and useful.

Reliability can be distinguished into two categories: external and internal. External reliability concerns the replicating of the study by others by providing sufficient information for others to follow the same process of inquiry. Miles and Huberman (1994) provide a comprehensive list of issues to be evaluated in assessing external reliability. These include checking that:
... methods and procedures [are] described explicitly and in detail...conclusions [are] explicitly linked with exhibits of condensed data...the researcher has been explicit and self-aware as possible about personal assumptions, values and biases, affective states ...competing hypotheses or rival conclusions [are] really considered ...

(Miles and Huberman 1994: 278)

Concern for external reliability motivated the attention paid in the preceding section to describing laddering and convergent interviewing as the technique for eliciting farm contexts. Similarly, attention has been paid to justifying and describing the sampling techniques that underpin the elicitation process.

The extract from Miles and Huberman (1994) highlights the potential to improve the external reliability of the elicitation process by presenting empirical evidence to support chains of reasoning, inferences and conclusions. An example is the use of verbatim quotes from interviews to support the identification of the benefits of an innovation and how these benefits relate to specific elements in a farm system.

The interpretation comparison phase of the convergent interviewing process also contributes to the external reliability of the elicitation process. This phase creates an opportunity for the interviewers, through their interaction, to reflect on and discuss how they arrive at their interpretations of the statements of producers and to identify what assumptions, values and biases may be influencing their interpretations.

The interpretation comparison phase of the convergent interviewing process also contributes to the external reliability of the elicitation process by providing an opportunity for competing hypotheses and rival explanations to be considered. This is especially important when combined with the use of sampling strategies such as maximising variation, opportunistic sampling and critical case sampling. These sampling strategies provide opportunities for evidence to emerge that challenges preconceptions and prejudices while allowing established patterns of thinking to emerge.

Internal reliability concerns the replicating of findings by others by providing sufficient information for others to establish the consistency and stability of the process of inquiry over time and across researchers. Whereas external reliability is concerned with ensuring the methods and processes used in a study can be faithfully
reproduced by others, internal reliability is concerned with ensuring that, if a study were faithfully repeated by others, similar results would be obtained.

Internal reliability is promoted by demonstrating that

...basic paradigms and analytic constructs clearly specified ...data [were] collected across the full range of appropriate settings, times, respondents and so on suggested by the research question ...
...comparable data collection protocols ...multiple observers’ accounts converge ...

(Miles and Huberman 1994: 278)

Internal reliability concerns quality control and this extract highlights the potential to improve the internal reliability of the elicitation process by ensuring that fundamental concepts, and the relationships between them, are unambiguously defined. Hence, the attention paid in the preceding chapters to defining and distinguishing concepts such as innovation, adoption, diffusion, technical improvement, relative advantage and so on. Similarly, attention has been paid in preceding chapters to proposing relationships between these concepts and the theoretical grounds for proposing them.

Selecting and describing a sampling strategy that is conceptually consistent with the data elicitation process is also a critical factor in promoting internal reliability. Sampling strategies such as snowball sampling, maximising variation, opportunistic sampling and critical case sampling were selected to maximise the chances that producers were interviewed from across the full range of appropriate settings. These strategies were augmented through the use of case selection on reputation and dimensional sampling to identify disconfirming cases or cases that are of interest because they could offer competing explanations.

Internal reliability is also promoted by ensuring interviews are conducted in similar or at least transparent ways. This means, specifically, that the laddering process is employed to elicit information in each interview. The use of two experienced interviewers in each interview is helpful in this regard.

As a final point in regard to internal reliability, the use of two interviewers also creates opportunities for interviews to be conducted with different pairings of interviewers. This creates possibilities for independent observers, such as extension and research staff, to participate in interviews and evaluate the convergent interviewing process itself, as well as the information obtained through the process.
Validity is the second fundamental dimension to evaluating the soundness or rigour of an inquiry (LeCompte and Goetz 1982; Miles and Huberman 1994). Validity largely concerns the extent to which findings can be regarded as accurate, credible, transferable and useful. Validity can be distinguished into two categories: internal and external. Internal validity is concerned with judging the sensibility, authenticity and credibility of findings.

Miles and Huberman (1994) provide a comprehensive list of issues to be evaluated in assessing internal validity. These include checking that

\[
\text{... triangulation among complementary methods and data sources} \\
\text{[produced] generally converging conclusions ... the findings [were]} \\
\text{internally coherent ... rules for confirmation of propositions,} \\
\text{hypotheses, and so on [are] explicit ... rival explanations [were]} \\
\text{actively considered ... conclusions [were] considered accurate by} \\
\text{original informants}
\]

(Miles and Huberman 1994: 279)

These issues reinforce the importance of the sampling strategy and the convergent interviewing process in establishing the rigour with which farm contexts are identified. The theory underpinning the identification of farm context predicts that interviews across a sufficient range of cases will generate converging findings and these findings should be internally coherent in the sense that there should be systematic and complementary patterns of reasoning across cases. The dialectical process of convergence is intended to identify complementary and coherent patterns in reasoning across interviews by seeking explanations for differences in chains of reasoning.

As a structured process convergent interviewing contains explicit rules regarding the confirmation of propositions regarding the nature and number of farm contexts there may be for an agricultural innovation. These rules are reinforced by the choice of sampling strategy. For example, the use of dimensional sampling provides opportunities to systematically investigate the influence on producers’ reasoning of variation in a variable of particular interest. This variable could be an element of the farm system that is emerging as an important component of the farm context. Alternatively, the variable could be a critical indicator proposed by a rival explanation.
In focusing on identifying and explaining differences in chains of reasoning the convergent interviewing process creates opportunities for rival explanations to be considered. As different chains of reasoning are elicited, alternative explanations for these differences will be progressively formulated and tested in the search for convergence. The use of strategies such as maximum variation sampling and dimensional sampling is essential to ensuring there is the best possible chance of identifying cases that will provoke active consideration of rival explanations.

The internal validity of the findings obtained through the elicitation process may also be evaluated by seeking responses on the findings from participants in the process. For example, towards the close of an interview, the interviewers may supply a verbal statement summarising their interpretation of the participant’s reasoning and decision making. The making of this statement creates an opportunity for participants to comment on the accuracy of interviewers’ interpretations of participants’ reasoning – a process called participant verification (Lincoln and Guba 2000).

In addition, interview outcomes may be discussed with researchers, extension and advisory staff to test the interviewers’ interpretations against their particular perspectives. This may increase the validity of findings by reducing the likelihood of misunderstandings over technical matters and by creating opportunities for alternative interpretations to be introduced into the elicitation process.

External validity is concerned with judging the transferability of findings. In this instance the interest is, first, in how well the findings from the sample of producers in regard to a particular innovation generalise to the population of producers and, second, in how well the method for identifying the population of potential adopters generalises across innovations. The first issue is considered here, the second issue is considered in detail in section 4.6.

Miles and Huberman (1994) provide a comprehensive list of issues to be evaluated in assessing external validity. These include checking that

...[the] sampling [is] theoretically diverse enough to encourage broader applicability ...a range of readers report the findings to be consistent with their own experience ...a cross-case theory using the [narrative] sequences [has been developed] ...the findings [have] been replicated in other studies to assess their robustness ...

(Miles and Huberman 1994: 279)
These issues highlight once again the importance of the sampling strategy and the convergent interviewing process in establishing the rigour of the inquiry. The process of seeking convergence in combination with strategies such as maximum variation sampling is essential to securing a theoretically diverse sample.

Testing the consistency of the findings with the experiences of extension and research personnel may reinforce the external validity of the findings in regard to the identification of farm contexts. Ideally, the findings would resonate with research and extension personnel that have extensive knowledge of the experience that producers have had with an innovation. Consequently, seeking feedback from research and extension personnel is one means of testing the external validity of the set of farm contexts identified for an innovation.

The theory underpinning the identification of farm context predicts that such contexts can best be identified by cross-case comparisons. Hence, the identification of the elements that comprise the set of farm contexts for an innovation constitutes the development of a cross-case theory using narrative sequences elicited from producers. In this regard the process of seeking convergence is essential to ensuring the circumstances in each case contribute to, and are explained by, the set of farm contexts that are identified. Hence, the convergent interviewing technique also contributes to establishing the external validity of findings by supporting the development of a general cross-case theory using the narrative sequences elicited from producers.

As indicated in the excerpt from Miles and Huberman (1994) the robustness of findings may also be tested by replication. Theoretically, the findings from the elicitation procedure should generalise from the sample of producers who are interviewed to the population of producers. Consequently, an obvious and decisive evaluation of the robustness of the elicitation process is to test whether similar findings can be obtained from a sample of producers that is representative of the population of producers. One way in which this may be done is to conduct a large-scale survey of a random sample of producers and test for statistically significant relationships between farm contexts and the adoption of the innovation of interest.

The validation of the findings from a qualitative research method, such as convergent interviewing, through the application of quantitative methods is an example of
methodological triangulation (Denzin 1997). Triangulation strategies, because they rely on consistency between two or more methods, have been argued to provide much stronger evidence for the soundness of interpretations of the real world than can possibly be achieved with single methods (Denzin 1997). However, the usefulness of a triangulation strategy depends on the validity of the expectation that the findings from alternative methods should corroborate each other and on the independence of the methods (Miles and Huberman 1994).

In this instance there is an expectation, justified by theory, that the elicitation process will generate findings from a sample of producers that should apply to the population of producers. Consequently, the statistical analysis of appropriate data drawn from a random sample of producers should provide quantitative corroboration of the qualitative findings obtained from the elicitation process. Hence, the use of methodological triangulation to establish external validity is worthwhile in this instance.

Although the two methods are characterised by different data collection methods and modes of analysis, they may not be completely independent. Complete independence is difficult to achieve because the findings from the convergent interviewing process must, logically, inform the design of the instrument for collecting quantitative data.

Consider, for example, designing a questionnaire that is to be mailed to a random sample of producers. Logically, the items in the questionnaire seeking information on the elements in the farm system that constitute the farm context for an innovation must be constructed using the findings from the convergent interviewing process. This means the results from the survey may be biased for two reasons. One is that producers whose contexts differ from those identified in the elicitation process and included in the questionnaire may not complete and return the questionnaire. This introduces a self-selection bias (Zikmund 1997) towards mistakenly concluding that the statistical findings corroborate the findings from the convergent interviewing process.

The second source of bias is that, given a necessarily limited range of responses to choose among, producers whose contexts differ from those identified in the elicitation process may construct responses that are not truly representative of their circumstances (Peterson 2005). This acquiescence bias (Zikmund 1997) may also lead
to mistakenly concluding that the statistical findings corroborate the findings from the convergent interviewing process.

These sources of potential bias may be reduced in two ways. First, bias may be reduced by incorporating items representing rival explanations in the questionnaire. Second, bias may be reduced by piloting the questionnaire with producers who did not participate in the convergent interviewing process. Piloting with producers and relevant experts is critical to crafting a well-designed questionnaire (Converse and Presser 1986) containing items that are reliable and valid (Carmines and Zeller 1979). Hence, piloting also reduces the possibility of mistakenly concluding that the statistical findings do not corroborate the findings from the convergent interviewing process.

The design of questionnaires to elicit quantitative information on farm contexts and the adoption of agricultural innovations from a random sample of producers is considered in detail in the next section.

4.5 Methods for quantifying farm contexts

Through the elicitation process various elements of the farm system that are thought to form the set of farm contexts for an innovation are identified. The benefits the innovation is thought to generate in each farm context are also identified. Hence, the elicitation process yields a set of hypothesised associations between the various elements that constitute the set of farm contexts for an innovation, the adoption of the innovation and the benefits of the innovation. In principle then, these hypothesised associations may be tested statistically by gathering quantitative data on the elements that form the farm contexts and data on the adoption of the innovation. Such data could be gathered, for instance, by distributing a mail questionnaire to a random sample of producers.

Theoretically, the elicitation process should provide sufficient information to design a survey instrument containing questions that are meaningful to producers. This requires that the questions bear on producers’ own experiences and behaviour, the subject matter is important to producers and the questions are designed to provide a common frame of reference to the target population (Converse and Presser 1986). The elicitation process should also support the use of closed questioning in the survey
instrument, as the findings from the process would allow appropriate response categories to be developed. The use of closed questions is encouraged when suitable response categories can be formulated as this promotes specificity and a common frame of reference (Converse and Presser 1986).

Ideally, once the elicitation process has been completed the findings could be used to develop a series of structured questions seeking quantitative data on the presence or absence of the various elements of the farm system that are hypothesised to form the set of farm contexts for an innovation. The findings could also be used to develop a series of structured questions seeking quantitative data on the presence or absence of the innovation and the benefits the innovation is hypothesised to generate in each context. Subject to appropriate design and piloting as described by, for example, Converse and Presser (1986) and Frazer and Lawley (2000), a mail survey containing such questions could be distributed to an appropriate size random sample of producers. Statistical tests of hypotheses concerning the association between farm contexts and the adoption and benefits of the innovation could then be undertaken using the responses.

In principle, five types of quantitative analyses could be undertaken using quantitative data on farm contexts and the adoption and benefits of an innovation. First, producers could be classified into segments representing the set of farm contexts for an innovation. This type of analysis would involve using data on the presence or absence of the elements in the farm system that are hypothesised to constitute the set of farm contexts for the innovation to classify producers into segments representing each farm context. Such a classification could be obtained using a quantitative clustering procedure designed for application to binary data such as monothetic divisive clustering (Aldenderfer and Blashfield 1984).

The application of quantitative clustering procedures can, however, become problematic when there are incommensurable differences in the relative importance of the attributes used to calculate the similarity coefficients between producers. In such cases a classification could be obtained by systematically assigning producers to segments using a procedure that reflects the hierarchical logic of the farm context such as elimination-by-aspects (Tversky 1972).
Second, having classified producers into a set of farm contexts, the association between the presence or absence of the farm contexts for an innovation and the frequency of adoption of the innovation could be tested statistically. Typically, as the data involved are likely to be categorical this would involve relatively simple statistical tests such as cross-tabulations (Liebetrau 1983). Relatedly, the association between the elements of the farm context and the adoption of the innovation could be tested statistically. These types of analyses constitute validation of the findings from the qualitative elicitation process through methodological triangulation. Again, this would usually involve relatively simple statistical tests such as cross-tabulations or analysis of variance depending on whether the data on the elements in the farm context were categorical or continuous in nature (Tabachnick and Fidell 1989).

Since different farm contexts consist of different combinations of elements in the farm system, the relationship between adoption of an innovation and any particular element in the farm system cannot be assumed to be stable across farm contexts. Consequently, linear regression procedures, including procedures such as Probit or Logit analysis (Judge et al. 1982), are inappropriate and unlikely to perform satisfactorily. Theoretically, procedures such as classification of producers into contexts and subsequent estimation of regression trees could be applied to estimate the relative influence of elements within a farm context on the adoption of an innovation. In this way the functional dependence between the innovation and the elements that constitute the farm context for that segment could be tested statistically.

Third, having classified producers into a set of farm contexts, the relationship between farm context and the benefits to be had from an innovation could be tested statistically. This type of analysis would require data on the benefits producers believe an innovation offers as well as data on farm context itself. This type of analysis would usually involve relatively simple statistical tests such as cross-tabulations or analysis of variance depending on the nature of the data (Tabachnick and Fidell 1989).

Fourth, the association between adoption and other variables of interest could also be tested statistically given that appropriate data have been collected. For example, data could be collected on characteristics of producers such as their age and education, or traits such as innovativeness. Data could also be collected on business characteristics such as size, equity and off-farm income. Associations between the adoption of the
innovation and such characteristics, or between farm context and such characteristics, could be tested to identify spurious relations or rival explanations for behaviour.

Fifth, having classified producers into a set of farm contexts, estimates could be made of the proportion of potential adopters in each segment and the potential population of adopters of the innovation as whole, given the sample of producers is statistically representative of the population of producers. Kalton (1983), for example, provides formulae based on random sampling for calculating the size of the sample required for key parameters of a population, such as the proportion of the population falling within a group or segment, to be estimated with a given level of confidence.

In describing a method for quantifying farm context a number of issues have a bearing on the soundness of the method. The first is the extent to which the elements that comprise the farm context are measurable in practice. The farm context for an innovation may include climatic variables, biophysical variables such as soil, topography and property layout, technologies and management practices, and producers’ strategies for accommodating relevant uncertainty in the business environment. Occasionally, measuring some of these variables or the relationships between them may be problematic.

Such measurement problems raise two issues regarding the quantification of farm context. First, while producers may indicate certain conditions are present in their farm system, the elements in the farm system that give rise to those conditions cannot always be measured. This means that, at best, certain farm context variables may only be measurable at an ordinal level. This places a practical limit on the precise detail with which the association between the elements that constitute the farm context and the adoption of an innovation can be investigated using statistical techniques.18

Second, while producers may indicate that an innovation provides certain benefits, the presence of these benefits cannot always be confirmed using measurements of the

18 For example, in a study by Kaine and Bewsell (2000a; 2004a) dairy farmers indicated an important element in the farm context for the adoption of automatic irrigation was the time and effort involved in irrigating their property. Calculating the time and effort involved in irrigating a property was complicated as it depended on a number of factors including the layout of paddocks, the number of points where irrigation water was delivered into the property, and the rate of water movement through those points. The problem of comparing the time and effort irrigation involved across farms was further complicated by differences in the availability of labour to undertake irrigation and other farm activities. Hence, while farmers may have stated that poor irrigation layout was influential in their decision to adopt automatic irrigation, measuring precisely the way in which elements in the farm system contributed to ‘poor layout’ by analysing responses to a self-administered mail survey was impractical.
elements in farm systems that give rise to them. This is a more serious issue as this type of measurement problem means that associations between farm context and the benefits created by an innovation cannot be statistically tested at all. As a consequence, the possibility that information supplied by producers may be biased due to response construction cannot be ruled out as the association between farm context and the benefits created by an innovation cannot be tested (Peterson 2005).\textsuperscript{19}

Where the association between farm context and the benefits created by an innovation cannot be statistically tested the association between the benefits created by the innovation and the frequency of adoption of the innovation may be tested. Producers may be classified into segments on the basis of benefits and the relationship between segment membership and the frequency of adoption of the innovation may then be tested statistically. The reliability of such a test would be influenced, of course, by the extent to which the innovation had diffused among the population of potential adopters. Estimates may still be made of the proportion of the population of potential adopters in each benefit segment and the potential population of adopters of the innovation as whole, given that the sample of producers is statistically representative of the population of producers.

The second critical issue in the quantifying of farm contexts concerns the representativeness of the sample of producers who complete and return the survey. The sample may not be representative of the population of producers for two broad reasons. First, the sample may be too small to be regarded as statistically representative of the population. The only solution to this is to increase the size of the sample by issuing or re-issuing reminders or by distributing more surveys, or by changing the method of surveying (Zikmund 1997). Each method has its disadvantages.

\textsuperscript{19} See, for example, the case study in chapter five on the adoption of micro-irrigation and soil moisture monitoring by fruit growers. Fruit growers indicated an important benefit of adopting micro-irrigation was the reduced time and effort involved in irrigating their orchards. The time and effort involved in irrigating an orchard depended on a number of factors including the size and layout of the orchard and the type of irrigation system. Whether reducing the time and effort devoted to irrigation would create a benefit also depended on the availability of labour and the timing of irrigation activities relative to other activities in the orchard such as spraying and harvesting. Hence, while growers stated that saving ‘time and effort’ was influential in their decision to adopt micro-irrigation, measuring precisely the way in which elements in the farm system contributed to creating this benefit was impractical using a self-administered mail survey.
The second reason the sample may not be representative is because of self-selection bias, a form of non-response bias (Zikmund 1997). Here, because a particular group of producers did not complete and return the questionnaire, the sample is unrepresentative of variation in the population of producers. Usually, non-response bias is detected by comparing the variability in the sample with the variability of the population of producers on characteristics that are traditionally considered descriptive of the industry (Zikmund 1997). Typically, these characteristics include the distribution of enterprises by location, area and volume of production, and the age and formal education status of producers. The presence of non-response bias on these traditional characteristics obviously limits the extent to which the findings can be generalised to the population of producers. For example, some of the elements that constitute the farm context for an innovation may be correlated with location. If the spatial distribution of the sample of producers is statistically significantly different from the spatial distribution of the population of producers then the distribution of farm contexts in the sample will be biased relative to the distribution in the population.

Non-response bias may still be present, however, even though a sample appears representative on the characteristics that are traditionally considered descriptive of the industry. This can occur when the non-response bias occurs on a characteristic that is uncorrelated with the traditional characteristics. The elements that constitute the farm context for an innovation may, for example, be uncorrelated with characteristics such as location and size of enterprise. Consequently, the distribution of farm contexts in the sample may, theoretically, be biased even though the spatial and scale distribution of the sample of producers may not be. This may occur, for instance, if non-response rates are higher among producers whose farm systems are unsuited to an innovation. As a result, errors may occur in estimates of the population of potential adopters and in estimates of the proportion of producers in each farm context.

Practical tactics for overcoming or assessing the extent of non-response bias on non-traditional characteristics such as farm context are limited. Ideally, data on the farm contexts of non-respondents would need to be collected to establish the impact of non-response bias on sample estimates. Other data gathering methods, such as personal interviews or phone interviews may be used to obtain such data from a sample of non-respondents, where they can be identified (Zikmund 1997).
In principle, the soundness of the procedures used to assess farm context may be judged by conducting formal tests of the reliability and validity of their results. The reliability of a measuring procedure is the consistency in the results that are obtained when the same phenomenon is repeatedly measured using the procedure. Measurement validity concerns the extent to which a measuring procedure actually measures the concept that it is intended to measure. There are three primary forms of validity – criterion-related or predictive validity, content validity and construct validity.

Carmines and Zeller (1979) describe and discuss four methods for directly testing the reliability of a measure and recommend two, the alternative-form and internal consistency methods. The other two methods, the test-retest and split-halves methods, are generally regarded as untrustworthy because the former method is subject to intervening event, and memory carry-over, effects and the latter is an inferior form of the internal consistency method (Carmines and Zeller 1979). However, the alternative-form method is impractical to apply to measures of farm context because parallel measures of farm context usually cannot be constructed. The internal consistency method may be applied in those situations where one or more elements in the farm context are measurable using a multiple-item scale. Using this method, the degree of reliability of a multiple-item scale as a measure of some aspect of farm context is given by the average correlation between the items in the scale (Carmines and Zeller 1979). The higher the correlation between the items the more reliable is the scale.

Where farm context is not measurable using multiple-item scales, some limited inferences could be made about the reliability of measures of farm context from tests of the predictive validity of these measures. For example, predictive validity is likely to be low in the absence of a reasonably high degree of reliability. Hence, high predictive validity is indirect evidence for a high degree of reliability. Unfortunately, since low predictive validity may result from poor validity or low reliability, this indirect test is not symmetrical.

Predictive validity or criterion-related validity is the degree to which a measurement procedure predicts behaviour that is external to the measurement procedure (Nunnally 1978). Here, the purpose of developing measures of farm context is to predict the adoption of an innovation, behaviour that is external to the measurement of farm
context. Hence, the association between measures of farm context for an innovation and a measure of the adoption of the innovation is, potentially, a test of predictive validity.

The reliability of such predictive tests will depend on the stage in the diffusion process that has been reached. Predictive tests may be less reliable early in the diffusion process as there is the possibility that, where the population of potential adopters is small relative to the population of producers, the proportion of the population of potential adopters that has adopted the innovation may be too small for statistically significant differences in the frequency of adoption between members and non-members of the population of potential adopters to be detected.  

Content validity is the extent to which a measurement procedure fully spans the relevant domain of content (Carmines and Zeller 1979). Hence, the content validity of measures of farm context is an assessment of the extent to which they span the complete set of elements in the farm system that shape the benefits to be had from an innovation. Content validity cannot be directly tested. The confidence that could be placed in the content validity of measures of farm context can only be inferred from the confidence that may be placed in the reliability and validity of the elicitation process and the predictive validity of the measures themselves.

Construct validity is the extent to which ‘a particular measure relates to other measures consistent with theoretically derived hypotheses concerning the concepts that are being measured’ (Carmines and Zeller 1979: 23). Hence, the magnitude of the association between measures of farm context for an innovation and measures of the benefits to be had from the innovation is a test of construct validity as the former are hypothesised to create the latter. Construct validity is particularly useful when a measurable criterion for testing the predictive validity of farm context cannot be formulated.  

---

20 Assuming the sample of producers comprises both potential adopters and non-adopters. If a sample of producers consists entirely of potential adopters then observed adoption will simply be a function of factors that influence the diffusion of the innovation.

21 There is another, less well-known method for establishing validity termed ‘known groups validity’ (Hattie and Cooksey 1984). This method could be potentially useful in the future given a sufficiently large number of statistical studies into farm context and the adoption of innovations, and access to a panel with appropriate expertise.
As a final point, a simple test of the soundness of the methods used to identify and quantify farm contexts may be conducted, in principle, by interviewing a sample of the producers who participated in the survey. Given that a sample of producers has been classified into farm context or benefit segments using their responses to a survey questionnaire, there is the possibility of interviewing these producers to establish the accuracy of the classification procedure. This would involve using laddering techniques to elicit producers’ reasoning and decision making in regard to the innovation of interest and checking the concordance between the producers’ explanations of their decisions and the explanations predicted by their membership of a farm context segment.

Methodological triangulation of this form would encourage confidence in the predictive power of the approach I have proposed to identifying farm contexts for an agricultural innovation and estimating the population of potential adopters of the innovation.

Table 4.1 contains a summary of the major components of the approach that has been proposed in this chapter to identifying farm contexts for an agricultural innovation and quantifying the population of potential adopters of the innovation.

4.6 Validating farm context as a predictor of adoption

I proposed in chapter three that the adoption of an agricultural innovation was highly involving for primary producers and contingent on the benefits the innovation creates for them as managers of farm businesses. I argued that the benefits an innovation creates for producers are a function of certain elements in their farm systems that define the farm context for an innovation. Hence, the adoption of an agricultural innovation depends on the presence in the farm system of the elements that define the farm context for the innovation. Four propositions follow from this argument that provides a basis for three different ways of testing the external validity of using farm context as a means of identifying of the population of potential adopters of an agricultural innovation.
Table 4.1 Components of method for identifying and quantifying farm context

<table>
<thead>
<tr>
<th>Identification of farm context:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elicitation of components of farm context</td>
</tr>
<tr>
<td>Elicitation of benefits</td>
</tr>
<tr>
<td>Checking interpretation of farm context with experienced experts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Quantification of farm context:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classify segments</td>
</tr>
<tr>
<td>Estimate segment size and population of potential adopters</td>
</tr>
<tr>
<td>Test for association between farm context segments and benefits</td>
</tr>
<tr>
<td>Test for association between farm context segments and adoption</td>
</tr>
<tr>
<td>Test for association between benefit segments and adoption</td>
</tr>
<tr>
<td>Test for association between other variables and adoption</td>
</tr>
<tr>
<td>Validation interviews</td>
</tr>
</tbody>
</table>
First, the incidence of adoption of an innovation should be higher among producers with farm systems where the elements of the farm context for that particular innovation are present compared to producers with farm systems where those elements are absent. This proposition is expected to hold across agricultural industries. Consequently, the external validity of farm context as a predictor of adoption could be tested by conducting case studies spanning industries that are theoretically diverse; for example, intensive and extensive agricultural industries, perennial and annual cropping industries, livestock industries, and irrigated and dry land industries (Miles and Huberman 1994).

Second, the proposition that incidence of adoption of an innovation should be higher among producers with farm systems where the elements of the farm context for that particular innovation are present compared to producers with farm systems where those elements are absent is also expected to hold for different types of agricultural innovations. Consequently, the external validity of farm context as a predictor of adoption can be tested by conducting case studies spanning innovations that are theoretically diverse. For example, innovations that vary across one or more of the characteristics that influence the rate of diffusion of innovations such as trialability, compatibility, complexity and observability of innovations (Rogers 1995).

Third, sampling to ensure variety in the nature of agricultural innovations will tend to yield farm contexts that consist of different elements for different innovations. These elements may include climatic variables, biophysical variables such as soil, topography and aspect, existing technologies and management practices, and producers’ strategies for accommodating relevant uncertainty in the business environment. This proposition provides a justification for testing the external validity of farm context as a predictor of adoption by conducting case studies that span these different elements.

Fourth, given the complexity of farm systems, there may be a number of farm contexts that suit a particular innovation. Since the benefit an innovation creates for producers depends on the nature of their farm context, the type of benefit an innovation offers may differ across farm contexts. Hence, the population of potential adopters of an innovation may be partitioned into different benefit segments based on differences in their farm contexts. This proposition provides a justification for testing the external validity of farm context as a predictor of adoption by conducting case
studies that demonstrate that adoption of an agricultural innovation can be motivated by different benefits and that the differences in benefits are associated with different farm contexts.

Relatedly, given the complexity of farm systems, different innovations may be integrated into different farm systems to create similar benefit, at least in principle. In other words, producers with different farm systems but seeking the same benefit may adopt different innovations to obtain that benefit. Hence, in theory, the external validity of farm context as a predictor of adoption could also be tested by conducting case studies that demonstrate that adoption of different agricultural innovations may be motivated by the same benefits and that the differences in the innovation adopted are associated with different farm contexts.

Taken together, these four ways of testing the external validity of farm context provide a basis, using a suitable series of case studies, to test the degree to which the concept of farm context as a definition of the population of potential adopters of an agricultural innovation, and the method proposed in this chapter for identifying farm context, can be used to predict the adoption of agricultural innovations.

In table 4.2 the four different ways of testing external validity are combined and summarised. The rows in the table represent each of the four ways of testing external validity that have been proposed. The attributes of each way of testing external validity are reported in the second column. In short, the table provides a set of criteria for using a series of case studies to assess the extent to which farm context may explain the adoption of agricultural innovations.

Over the last decade a series of studies has been undertaken into farm context and the adoption of agricultural innovations. In the next chapter I select case studies from this series using the criteria contained in table 4.2. The case studies will be used to assess the extent to which farm context may be used to predict the population of potential adopters of agricultural innovations and, thereby, contribute to explaining the adoption of agricultural innovations.
Table 4.2 Criteria for testing external validity of farm context as a theory of adoption

<table>
<thead>
<tr>
<th>Dimension of variation</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Livestock Perennial crop Annual crop Intensive Extensive Irrigated Dry land</td>
</tr>
<tr>
<td>Innovation</td>
<td>Trialable Observable Compatibility Complexity</td>
</tr>
<tr>
<td>Farm context</td>
<td>Strategic Technological Biophysical Climatic</td>
</tr>
<tr>
<td>Benefit</td>
<td>Different benefits from the same innovation</td>
</tr>
<tr>
<td></td>
<td>Different innovations create similar benefits</td>
</tr>
</tbody>
</table>
The series of studies was not originally part of a systematic program of research designed to investigate the contribution of farm context to explaining the adoption of agricultural innovations. Rather, it is a diverse collection reflecting the eclectic and largely pragmatic concerns of investors interested in promoting the adoption of innovations that were of particular interest to them. Importantly, the collection spans a useful range of industries and innovations.

The studies were not all equally comprehensive in their objectives. The original objectives in some studies were to identify the elements in farm systems that comprise the farm contexts for an agricultural innovation, statistically test relationships between farm context and adoption, as well as to estimate the population of potential adopters of the innovation. The original objective in others, though, was limited to only identifying the elements in farm systems that comprise the farm contexts for an agricultural innovation. The second quantification stage of estimating the population of potential adopters, and statistically testing relationships between farm context and adoption, did not occur in these case studies. Consequently, these latter studies cannot be treated as cases contributing to establishing the external validity of farm context with the same confidence as the more comprehensive studies.

Earlier, in table 4.1, the major components of the approach to identifying farm contexts for an agricultural innovation and estimating the population of potential adopters of the innovation were summarised. This summary provides a basis for distinguishing the confidence that may be placed in the contribution each particular study may make toward establishing the external validity of farm context.

Consequently, the components contained in table 4.1, in conjunction with the criteria contained in table 4.2, provide a framework for choosing a set of case studies from among the series of studies that have been conducted which can be used to assess the extent to which farm context explains the adoption of agricultural innovations.

4.7 Conclusion

In this chapter I have described an approach to quantifying the population of potential adopters of an agricultural innovation. Broadly speaking, the approach involves two stages. In the first stage the elements in farm systems that shape the benefits to be had
from an innovation, and thereby form the farm contexts for the innovation, are identified. A dialectical method for eliciting the set of farm contexts for an agricultural innovation from primary producers was proposed. Issues to be considered in judging the reliability and validity, both internal and external, of the method were considered in some detail.

In the second stage of the approach the proportion of producers with farm systems that are consistent with the farm context for the innovation is quantified. This proportion is an estimate of the population of potential adopters of the innovation. Methods for quantifying the population of potential adopters of an innovation were proposed and the issues to be considered in judging the reliability and validity of these methods were discussed. The use of statistical tests of association between adoption of an innovation and farm context as a form of methodological triangulation to establish the external validity of the first stage of the approach was highlighted.

The chapter was completed with a presentation of a schema for testing the extent to which farm context, as a definition of the population of potential adopters of an agricultural innovation, can be generalised across innovations and industries and contributes to predicting the adoption of agricultural innovations.
Case Studies of the Population of Potential Adopters

*It seems that in the empirical literature every measurable characteristic of farms and farmers has been found to be statistically related to some measure of adoption of some innovation.*

(Pannell et al. 2006: 1411)

5.1 Introduction

In the preceding chapter a method was described to quantify the population of potential adopters of an agricultural innovation. This was based on the assumption that the adoption of agricultural innovations is a highly involving decision for primary producers and the hypothesis that the benefits to be had from adopting an agricultural innovation are primarily influenced by the farm context. I also presented criteria for evaluating the extent to which this hypothesis may be tested. In this chapter I report the results of using a selection of case studies to empirically test the hypothesis about the adoption of agricultural innovations against these criteria.

In the next section I describe the selection of the case studies using the criteria developed in the previous chapter. I then describe each case study in detail. The chapter is concluded with a discussion of the case studies with respect to the criteria used for testing the hypothesis.

5.2 Case study selection

The method for identifying the population of potential adopters of agricultural innovations that I described in the previous chapter has been used by me and other researchers in more than thirty studies. I was the primary author in most of these studies (see Table 5.1). The method has been used with respect to the adoption of
agricultural innovations such as irrigation systems in the horticultural, viticultural, vegetable and dairy industries in Australia, breeding practices and animal health practices in sheep and cattle in Australia and New Zealand, and pest and disease management practices in horticulture and viticulture in Australia and New Zealand among others (see Table 5.1). The method has also been employed to investigate producers’ responses to policy initiatives such as industry deregulation, regulation of dairy effluent management and automation of public irrigation infrastructure, and to formulate priorities for agricultural research (see Table 5.1).

These studies were not part of a systematic program of research designed to test my hypothesis regarding the adoption of agricultural innovations. Rather, they comprise a diverse collection reflecting the eclectic and largely pragmatic concerns of investors interested in promoting the adoption of agricultural innovations that were of particular interest to them. Importantly, the collection spans a useful range of industries and innovations.

Also, these studies were not all equally comprehensive in their objectives. The objectives in some were to identify the elements in farming systems that comprise the farm contexts for an agricultural innovation and to estimate the population of potential adopters of the innovation. The objective in others was limited to identifying the elements in farming systems that comprise the farm contexts for an agricultural innovation. The second quantification stage did not occur in these more limited studies. Consequently, these studies cannot be treated as contributing to establishing the external validity of farm context with the same confidence as the more comprehensive studies. The characteristics of all the studies in terms of the method described in the previous chapter for predicting the population of potential adopters of an agricultural innovation are reported in Table 5.2.

In most of the studies at least some of the purchase criteria that were identified as constituting the farm context relevant to a particular innovation were concrete biophysical elements of the farm environment that are often used to classify enterprises into farming systems: topography, soil type, climate, type of enterprise, and scarcity of natural resources such as water.
<table>
<thead>
<tr>
<th>Designation</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Differences in the estimated slopes of supply response curves identified for dairy enterprises with different farm system characteristics&lt;br&gt;   (Kaine et al. 1994a)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Analysis of the adoption of compact calving among beef enterprises in Victoria&lt;br&gt; (Kaine and Lees 1994; Kaine and Lees 1996)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Analysis of the adoption of enterprise planning aids among mixed crop and livestock enterprises&lt;br&gt; (Kaine et al. 1994b; Kaine et al. 1998)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Analysis of the adoption of grazing management practices to maintain pasture composition among livestock enterprises in the temperate high rainfall zone&lt;br&gt; (Kaine 1995; Reeve et al. 2000)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Analysis of the adoption of sub-surface drainage in dryland dairying&lt;br&gt; (Kaine and Niall 1999; Kaine and Niall 2001a)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Analysis of the adoption of irrigation technologies and soil moisture monitoring among horticultural enterprises&lt;br&gt; (Kaine and Bewsell 1999; Kaine and Bewsell 2002a; Kaine and Bewsell 2002b; Boland et al. 2005; Kaine et al 2005; Kaine and Bewsell 2005a)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Analysis of the adoption of irrigation technologies among dairy enterprises in northern Victoria&lt;br&gt; (Kaine and Bewsell 2000a; Kaine and Bewsell 2004a )</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Analysis of the adoption of breeding technologies among wool enterprises in Victoria&lt;br&gt; (Kaine and Niall 2001b; Kaine et al. 2002)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Analysis of the adoption of irrigation technologies and fertiliser practices among dairy enterprises in Gippsland, Victoria&lt;br&gt; (Kaine and Bewsell 2001a; Kaine and Bewsell 2001b; Kaine and Bewsell 2002c )</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Analysis of the adoption of irrigation technologies among viticultural enterprises in south-eastern Australia&lt;br&gt; (Kaine and Bewsell 2000b; Kaine and Bewsell 2002d ; Kaine and Bewsell 2002e; Burrows et al 2003)</td>
<td></td>
</tr>
</tbody>
</table>

Note: The designations in the left-hand column are based on the approximate chronological order in which the studies were conducted.
Table 5.1 Listing of studies (continued)

<table>
<thead>
<tr>
<th>Designation</th>
<th>Description</th>
</tr>
</thead>
</table>
| 11          | Analysis of the adoption of planning aids among mixed cropping and livestock enterprises in south-eastern Australia  
(Kaine et al. 2001; Kaine et al. 2003a; Kaine et al. 2003b; Kaine et al. 2004a ) |
| 12          | Analysis of the adoption of irrigation technologies and soil monitoring among vegetable enterprises in south-eastern Australia  
(Bewsell and Kaine 2001; Bewsell and Kaine 2002 ) |
| 13          | Analysis of the use of animal health technologies among sheep and cattle enterprises in New Zealand  
(Kaine et al. 2003c) |
| 14          | Analysis of the adoption of irrigation technologies, soil moisture monitoring, pest and disease management techniques and participation in quality assurance programs among horticultural enterprises  
(Kaine and Bewsell 2003; Bewsell and Kaine 2004; Kaine and Bewsell 2004b; Kaine and Bewsell 2005b) |
| 15          | Analysis of the adoption of irrigation technologies, pest and disease management techniques and participation in quality assurance programs among viticultural enterprises in New Zealand  
(Bewsell and Kaine 2003) |
| 16          | Analysis of the adoption of Environmental Management Systems among viticultural enterprises in Australia  
(Tee et al. 2007) |
| 17          | Analysis of control over farm performance among livestock enterprises in New Zealand to inform research priorities  
(Kaine et al. 2004b) |
| 18          | Analysis of the adoption of riparian fencing and other practices among dairy enterprises in New Zealand  
(Bewsell and Kaine 2005; Bewsell et al 2005; Bewsell and Kaine 2006) |
| 19          | Analysis of the reactions of irrigators to channel automation in northern Victoria  
(Cowan et al. 2005; Cowan et al. 2006) |
| 20          | Analysis of the adoption of Partial Rootzone Drying among wine enterprises in Sunraysia, Victoria  
(Linehan et al. 2005) |

Note: The designations in the left-hand column are based on the approximate chronological order in which the studies were conducted
Table 5.1 Listing of studies (continued)

<table>
<thead>
<tr>
<th>Designation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Analysis of the adoption of once-a-day milking among dairy enterprises in New Zealand (Bewsell 2005; Bewsell et al. 2008)</td>
</tr>
<tr>
<td>22</td>
<td>Analysis of the adoption of centre pivot irrigation technology among dairy enterprises in northern Victoria (Hill et al. 2004)</td>
</tr>
<tr>
<td>23</td>
<td>Analysis of the adoption of sheep breeding techniques among wool enterprises in Australia (Kaine et al. 2006)</td>
</tr>
<tr>
<td>24</td>
<td>Analysis of the adoption of alternative forage crops among dairy enterprises in northern Victoria (Ambrosio and Linehan 2006)</td>
</tr>
<tr>
<td>25</td>
<td>Analysis of the adoption of sustainable deficit irrigation among viticultural enterprises in Sunraysia, Victoria (Ambrosio et al. 2006a)</td>
</tr>
<tr>
<td>26</td>
<td>Analysis of the adoption of feed management techniques among sheep and beef enterprises in New Zealand (Bewsell and Brown 2006; Brown and Bewsell 2007)</td>
</tr>
<tr>
<td>27</td>
<td>Analysis of the participation in water markets among dairy enterprises in North Central and Goulburn Broken regions of Victoria (Morse-McNabb et al 2007)</td>
</tr>
<tr>
<td>28</td>
<td>Analysis of the adoption of land class fencing and perennial pastures among livestock enterprises in western Victoria (Cowan and Linehan 2007)</td>
</tr>
<tr>
<td>29</td>
<td>Analysis of the landholder responses to biosecurity measures in Victoria (Murdoch et al. 2006; Murdoch et al. 2007)</td>
</tr>
<tr>
<td>30</td>
<td>Analysis of the adoption of intensive pear technology among horticultural enterprises in Victoria (Mansfield and Grills 2006)</td>
</tr>
</tbody>
</table>

Note: The designations in the left-hand column are based on the approximate chronological order in which the studies were conducted.
<table>
<thead>
<tr>
<th>Designation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>Analysis of compliance in the management of effluent systems among dairy enterprises in Victoria and New Zealand (Davies et al. 2007)</td>
</tr>
<tr>
<td>32</td>
<td>Analysis of the adoption of precision agriculture technologies among grain enterprises in northern Victoria (Ambrosio and Linehan 2004; Ambrosio et al. 2006b; Ambrosio and Linehan 2007)</td>
</tr>
<tr>
<td>33</td>
<td>Analysis of the adoption of the use of nutrition inputs among viticultural enterprises in Victoria and South Australia (Hill et al. 2007)</td>
</tr>
<tr>
<td>34</td>
<td>Analysis of the adoption of soil and petiole testing among viticultural enterprises in Victoria and South Australia (Hill et al. 2008)</td>
</tr>
</tbody>
</table>

Note: The designations in the left-hand column are based on the approximate chronological order in which the studies were conducted.
Table 5.2 The composition of studies with respect to identifying and quantifying farm context

<table>
<thead>
<tr>
<th>Identification of farm context:</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of components of farm context</td>
<td>All</td>
</tr>
<tr>
<td>Elicitation of benefits</td>
<td>All except 1, 3, 4, 11, 17</td>
</tr>
</tbody>
</table>

Quantification of farm context:

<table>
<thead>
<tr>
<th>Study type</th>
<th>Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classify contexts</td>
<td>1-11, 14, 17, 23, 27</td>
</tr>
<tr>
<td>Estimate context size and population of potential adopters</td>
<td>2, 3, 5-11, 14, 17, 23, 27</td>
</tr>
<tr>
<td>Test for association between farm contexts and benefits</td>
<td>5, 8, 14, 23, 27</td>
</tr>
<tr>
<td>Test for association between farm contexts and adoption</td>
<td>2, 3, 5, 8, 14, 23, 27</td>
</tr>
<tr>
<td>Test for association between benefit segments and adoption</td>
<td>6, 7, 9, 14, 27</td>
</tr>
<tr>
<td>Test for association between other variables and adoption</td>
<td>2, 14</td>
</tr>
<tr>
<td>Validation interviews</td>
<td>5, 6, 8, 23, 27</td>
</tr>
</tbody>
</table>

Notes: The numbers in the right-hand column correspond to the designation of studies in Table 5.1
However, in most studies some of the purchase criteria were more socio-economic in nature though often no less concrete than biophysical criteria.

Such criteria included the length of time needed to irrigate a property, the period of time taken to spray an orchard, the availability of labour, and the layout of channels on a property. Often there were relatively subtle interactions between an innovation and these criteria. For example, property layout can have a critical impact on the benefits of automatic irrigation (Kaine and Bewsell 2000a) or the choice of spray irrigation technology (Kaine and Bewsell 2002c). Property layout, as well as topography, also influences the effectiveness of pheromone mating disruption in controlling orchard pests (Kaine and Bewsell 2003).

In some studies perceptions of risk and the strategies used to ameliorate risk were key purchase criteria. For example, perceptions of risk in regard to the performance of rams in different environments, and the strategies for avoiding this risk, were the key factors influencing the way wool producers chose studs from which to purchase rams and use performance data to select rams (Kaine and Niall 2001b; Kaine et al. 2006). Producers’ perceptions of price and business risk, and the business strategy they used to mitigate these risks, appeared to influence producers’ propensities to adopt financial management aids (Kaine et al. 1994b; Kaine et al. 1998). Perceptions of risk in regard to predictions of pest infestations relative to the capability of fruit growers to respond quickly to an infestation are a key factor influencing the adoption of integrated pest management techniques (Kaine and Bewsell 2003).

Fifteen of the studies reported in Table 5.1 included both the quantitative and the qualitative stages of the approach to quantifying the population of potential adopters of an agricultural innovation and so qualified as potential case studies. Four of these were selected as case studies because they spanned the criteria developed in the previous chapter for testing the extent to which (a) farm context, as the key to definition of the population of potential adopters of an agricultural innovation, can be generalised across innovations and industries and (b) contributes to predicting the adoption of agricultural innovations. The characteristics of these selected case studies in terms of those criteria are reported in Table 5.3.

The four case studies were:

---

22 I was the primary researcher in all case studies.
1. The adoption of sub-surface drainage and feed pad technologies among dryland dairy enterprises in southern Victoria

This case study was selected as the elements that constituted the farm context were purely biophysical and the innovation was simple, relatively easy to trial, the benefits were clear and the innovation was compatible with producer’s experiences. In addition, this study also included validation interviews and provides an example where producers sought similar benefits from different innovations (Kaine and Niall 1999; Kaine and Niall 2001a).

2. The adoption of technologies for objectively monitoring soil moisture among irrigated horticultural enterprises in northern Victoria and southern New South Wales

This case study was selected as the elements that constituted the farm context for these practices were a mixture of biophysical and socio-economic. The innovation was relatively simple and easy to trial but the benefits of the innovation were not always obvious. The innovation was not always entirely compatible with producer’s experiences (Kaine and Bewsell 1999; Kaine and Bewsell 2002a; Kaine and Bewsell 2002b).

3. The adoption of breeding practices among wool enterprises in Victoria

This case study was selected as the elements that constituted the farm context for these practices were largely perceptual. The innovation was relatively complex and difficult to trial and the benefits of the innovation were not always obvious. The innovation was not always compatible with producers’ experiences. This case study included validation interviews and the original study was repeated and extended in a later, national study (Kaine and Niall 2001b; Kaine et al. 2006).

4. The adoption of planning aids among mixed cropping and livestock enterprises in south eastern Australia

This case study was selected as the elements that constituted the farm context for these practices were largely perceptual. This study was also chosen because the elements that constituted the farm context were identified using theoretical arguments rather than elicited directly from producers using
Table 5.3 The composition of case studies with respect to testing criteria

<table>
<thead>
<tr>
<th>Industry representativeness:</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensive</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irrigated</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry land</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Perennial crop</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Annual crop</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Innovation representativeness:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trialable:</td>
</tr>
<tr>
<td>practicality</td>
</tr>
<tr>
<td>consequences</td>
</tr>
<tr>
<td>reversibility</td>
</tr>
<tr>
<td>Observable</td>
</tr>
</tbody>
</table>

| Compatible:                 |
| experience                  | high  | low   | variable | variable |
| values                      | high  | high  | high     | variable |
| Complexity                  | low   | low   | high     | high    |

<table>
<thead>
<tr>
<th>Dimension of farm context:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic</td>
</tr>
<tr>
<td>Labour and lifestyle</td>
</tr>
<tr>
<td>Technology and practice</td>
</tr>
<tr>
<td>Biophysical</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benefit and context:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different contexts mean the same innovation offers different benefits</td>
</tr>
<tr>
<td>Different contexts mean different innovations offer similar benefits</td>
</tr>
</tbody>
</table>
convergent interviewing. The innovations tended to be complex and difficult to trial, and the benefits of the innovations were not always obvious. The innovations were not always compatible with producers’ experiences and values. The original study was also replicated some years later (Kaine et al. 1994a; Kaine et al. 1998; Kaine et al. 2001; Kaine et al. 2003a; Kaine et al. 2003b; Kaine et al. 2004a).

Inspection of Table 5.3 reveals that these four case studies span a variety of intensive and extensive agricultural industries and include livestock and cropping enterprises. The case studies differ qualitatively across the four characteristics of innovations that influence their rate of diffusion as well as the four different dimensions of farm context. The case studies also include an instance where differences in farm contexts mean different innovations offer similar benefits. The four case studies span such a variety in the characteristics of industries, types of innovations and dimensions of farm contexts that, taken together, they provide a basis for confidence in the generalisability of the results of the case studies.

Each of the case studies will be described in detail to demonstrate that different elements of farm systems influence the benefits and costs of adopting different innovations and that the purchase criteria used to evaluate innovations will change accordingly. These studies will be argued to confirm that purchase criteria are frequently innovation specific and often cannot easily be generalised across innovations. Hence, attempts to seek general relationships across innovations are problematic.

5.3 Case studies

Generally, each of the case studies will be described in four parts. First the objectives and conduct of the case study will be presented in the background to the case study. Second, the application of the qualitative stage of the method is described and the results of that stage presented. Third, the application of the quantitative stage of the method is described and the results of that stage presented. Finally, the description of the case study is completed by a discussion of the findings and the implications for agricultural extension.
5.3.1 Adoption of sub-surface drainage technologies

Selection criteria
This case study is an example of the adoption of an agricultural innovation by intensive dryland livestock enterprises. The case study was selected as the elements of the farm system that constituted the farm context for the adoption of sub-surface drainage and feed pads were purely biophysical. Sub-surface drainage in the form of mole drains or tile pipes is relatively easily installed and can be trialled on an area of the farm that is especially prone to waterlogging before full-scale adoption. Feed pads involve completely removing cattle from pasture for a number of days or weeks while pastures are waterlogged and susceptible to pugging damage. Since cattle are not grazing their nutritional requirements must be met by using relatively expensive supplements. Feed pads vary in sophistication of design and expense. Again, the benefits, in terms of reduced soil erosion and improved pasture production are easily observed. There was nothing to suggest that sub-surface drainage or feed pads were incompatible in any way with producer’s experiences and values.

Background
Waterlogging occurs on dryland dairy farms across southern Victoria and Tasmania during the winter months. The grazing of waterlogged pastures causes pugging which is the penetration into soil surface and pasture sward by the hooves of grazing animals in wet conditions (Nie et al. 2001). Pugging causes direct damage to pasture and soil structure which leads to reduced pasture growth and pasture utilisation, resulting in reduced milk production and reduced farm income.

There are a number of options for managing waterlogged pastures such as installing surface or sub-surface drainage, or using management techniques such as on-off grazing or standing-off cattle (Mickan 1993; Mickan 1996; MacEwan 1998). Sub-

---

This section is a summary of, and contains material reproduced from, Kaine and Niall (1999). This case study was financially supported by the Victorian Department of Natural Resources and Environment.
Surface drainage involves installing plastic pipes (tile drains), mole drains or various combinations of both beneath the soil surface, usually on or within the subsoil. The installation of pipes is particularly expensive, prohibitively so in soils with poor water flow. Mole drains are channels created in the sub-soil by pulling a metal plug through the soil. The channels overlay a system of plastic collector pipes. This type of drainage is much less expensive than pipe drainage. Moles can be installed in soils that have poor water flow, but do not work well in soils that lose their structure when waterlogged such as dispersive clays and sedimentary silts. Moles installed in such soils collapse when the soil becomes saturated.

Surface drainage involves installing ditches, levees, banking, humping and hollowing, and various combinations of these techniques. These methods are generally used to intercept surface water flows. Deep ditches may be used to intercept sub-surface water flows or as collector drains for sub-surface drainage. Their use depends on topography. Humping and hollowing has been used to create well drained areas in paddocks where sub-surface drainage is not feasible.

On-off grazing involves grazing cattle for limited periods each day when pastures are waterlogged and susceptible to pugging damage. Cattle may be temporarily housed in laneways, yards, on high ground or ridges, on a loafing pad or feed pad. Cattle are put out to pasture to graze for three to four hours then removed from the pasture. Pugging damage is avoided by limiting the time cattle spend grazing while maximising pasture utilisation. This approach may require additional supplementary feeding and labour. Information on criteria for assessing when on-off grazing should be implemented is limited. This approach requires soils that can sustain grazing for limited periods without damage when waterlogged.

Finally, standing-off cattle involves completely removing cattle from pasture for a number of days or weeks while pastures are waterlogged and susceptible to pugging damage. Cattle may be kept in laneways, yards, on high ground or ridges, on a loafing pad or feed pad. Cattle may also be kept in a ‘sacrifice’ paddock which is renovated following the end of the wet period. Dry cattle may also be agisted. The period cattle may need to be kept off pasture depends on the length of time pastures are waterlogged. In some cases this period may extend to a number of weeks. Since cattle are not grazing their nutritional requirements must be met by using relatively expensive supplements (hay, silage, grain, etc).
There was concern among organisations responsible for natural resource management that the rate of adoption of sub-surface drainage, in particular, was too slow resulting in soil and water degradation and reduced farm incomes. As a consequence an extension program was under consideration to promote sub-surface drainage to dairy farmers. The objective in this case study was to identify the population of potential adopters of methods for managing waterlogging of pastures including, in particular, sub-surface drainage.

**Qualitative stage**

Following the approach described in the preceding chapter, convergent interviewing was used in the first stage of the case study to identify the elements in the farming systems of dairy enterprises that defined the farm context for adopting sub-surface drainage and on-off grazing in conjunction with stand-off areas such as feed pads. In-depth personal interviews were conducted with approximately fifty dairy farmers to identify the elements in their farming systems that influenced the benefits to be had from sub-surface drainage and on-off grazing. Interviews were conducted as described in the preceding chapter with two interviewers present at each interview.

Initially, unstructured interviews were conducted until the point was reached where farmers could be allocated among a set of proposed market segments that were internally consistent with respect to key differences in farm contexts. The dairy farmers who took part in the round of unstructured interviews were nominated by extension staff of the then Victorian Department of Natural Resources and Environment. These farmers were selected for interviewing because they used different methods for managing waterlogging and represented a variety of locations.

A series of structured interviews was conducted to validate the findings from the unstructured interviews and to develop a survey questionnaire. The dairy farmers who took part in the subsequent round of structured interviews were selected using purposive sampling from lists provided by extension staff, milk company representatives and other farmers. The dairy farmers who took part in these interviews were selected to reflect a variety of locations and farms of different scales, and included dairy farmers of different ages and educational backgrounds.
The interviews revealed waterlogging to be a highly involving issue for most dairy farmers as it had a dramatic impact on farm income and lifestyle, even when it only occurred occasionally and for short periods. The various management alternatives could be extremely expensive and most entailed some degree of uncertainty. This meant, first, that farmers were likely to have a reasonably accurate picture of the income losses they were experiencing and second, that they were likely to have devoted quite considerable time and effort to formulating strategies for managing waterlogged soils on their farms.

The evidence from the interviews suggested that two critical issues were driving the choice between the different management solutions. These were the severity and timing of waterlogging, and whether or not soils were suited to some form of sub-surface drainage. Farmers indicated in the interviews that the severity of waterlogging was related to the area, frequency and duration of waterlogging and was best measured by the impact of waterlogging on grazing management and pasture utilisation.

The evidence from the interviews indicated that waterlogging posed a severe threat to the viability of a dairy enterprise when it frequently prevented pastures from being fully utilised during spring. Such instances were signalled by lower-than-average stocking rates, calving earlier or later than the norm, or shorter-than-average lactation periods. The fundamental problem was that pasture could not be grazed for even short periods when waterlogged without experiencing pugging damage in the paddock, which then required either renovation, or resowing. The issue next in importance in these circumstances was whether or not soils were suited to some form of sub-surface drainage. This was largely determined by soil type, though topography and farm layout also played a role.

Where pasture could be grazed without damage for short periods when wet, the impact of waterlogging on production appeared less severe. Here, the choice was among a range of techniques for managing grazing. The issue of importance in these circumstances was the frequency of waterlogging. Where waterlogging was frequent and prolonged, on-off grazing and investing in feed pads may have been warranted. Where waterlogging was unusual or especially brief then standing cattle off in yards, sheds, sacrifice paddocks or shifting to block or paddock grazing may have been appropriate.
**Quantitative stage**

A mail survey based on the findings from these interviews was developed, piloted and then distributed to dryland dairy farmers across Gippsland and South Western Victoria. The purpose of the survey was to obtain accurate estimates of the population of potential adopters of sub-surface drainage and to quantify the relative importance and distribution of the elements in dairy farming systems that influenced the adoption of the various methods for managing waterlogging within the dairy farming population in those regions.

Approximately 3000 questionnaires were delivered using a random sampling stratified by district since the number of farms in each district was different and the incidence of waterlogging across districts was not uniform. Questionnaires were mailed in mid-January 1999 with a reminder posted in early February 1999. The case study and survey were publicised through local print media and industry newsletters. A total of 985 questionnaires had been returned by the time the data analysis commenced, some ten weeks after the initial mailing, representing an effective response rate of 35 per cent.

Dairy farmers who did not experience problems with waterlogging were asked to return uncompleted questionnaires in a supplied reply paid envelope. Approximately 33 per cent of the questionnaires returned were from respondents who indicated that waterlogging was not a problem on their farm. This percentage was consistent throughout the ten weeks during which questionnaires were returned. This result suggests that waterlogging posed some sort of a problem for, at most, 67 per cent of dairy farmers in the areas surveyed.

In the questionnaire dairy farmers were asked to supply details on the characteristics of their properties, on the severity and timing of waterlogging, and their use of the various options for managing waterlogging. Respondents who had installed sub-surface drainage were asked to supply details on the severity and timing of waterlogging on their properties before and after the installation of sub-surface drainage. The average area, milking area, herd size and stocking rate for the farms in the sample were not significantly different from the averages for all farms in the areas surveyed (Victorian Dairy Industry Authority, 1999).
The sample of respondents was classified into different farm contexts based on their responses to questions regarding the timing and severity of waterlogging and the suitability of their soil for sub-surface drainage (see Table 5.4). Respondents who had installed sub-surface drainage were excluded from the classification procedure. These respondents were excluded to allow testing of the hypothesis that the frequency of adoption of sub-surface drainage would differ across the different farm contexts. This was tested using the following three-step procedure.

First, farm contexts for management of waterlogging were identified using responses from respondents that had not installed sub-surface drainage. Second, respondents that had installed sub-surface drainage were then allocated to one of these farm contexts based on their responses to questions regarding the timing and severity of waterlogging and the suitability of their soil for sub-surface drainage prior to the installation of sub-surface drainage. Third, the hypothesis that the frequency of adoption of sub-surface drainage would differ across the different farm contexts was tested by testing for significant differences in the percentage of respondents in each segment that had installed sub-surface drainage.

A solution of six clusters was chosen and the formation of these is illustrated in the classification tree in Figure 5.1. Each branch in the tree indicates whether an element is present or not in a farm system. The resulting clusters represent six different farm contexts for management of waterlogging. The profiles of each farm context, in terms of the variables used to form the context, are presented in Table 5.5.

Waterlogging should be a serious problem for respondents in contexts one (severe spring and winter waterlogging), two (serious spring and winter waterlogging) and three (moderate spring and winter waterlogging) because they are unable to take full advantage of high rates of pasture growth in spring. Note that waterlogging prevented these respondents from fully utilising their pastures in winter as well as spring. This meant that milk production from the farms in these contexts was substantially affected.

---

24 The classification was conducted using a monothetic divisive clustering algorithm available in CLUSTAN (Wishart 1987) which is specifically designed for use with dichotomous data. The similarity coefficient used was squared Euclidean distance. The algorithm operates by placing all respondents in one segment and then dividing respondents into successively smaller and smaller segments depending on the distribution of their characteristics.
Table 5.4 Classification questions for waterlogging of pastures

Questions

1. Does waterlogging stop you from fully grazing (utilising) the pastures in spring?

2. Does waterlogging limit your pasture growth in spring?

3. Please pick the statement below that best describes your situation:

   a) You cannot graze waterlogged paddocks even for a couple of hours without experiencing too much pugging damage.

   b) Initially, you can graze waterlogged paddocks for a few hours without too much damage but on the next rotation you cannot graze wet paddocks even for a few hours without experiencing too much pugging damage.

   c) Most of the time you can graze waterlogged paddocks for a few hours without too much damage but stock cannot be left on all day.

   d) You can graze pretty well all day without any pugging damage unless conditions are really severe.

4. Are the soils on your property suited to sub-surface drainage (e.g. mole or tile drains)?

Note: The answers to the questions on spring pasture growth and utilisation are dichotomous (1 = yes, 0 = no). The responses to the grazing management question were disaggregated to create four separate dichotomous variables (1 = yes, 0 = no), one variable for each alternative. The responses to the question on the suitability of soil for sub-surface drainage were recoded to create a dichotomous variable (1 = yes, 0 = no or don’t know).

Source: Kaine and Niall (1999: 38)
Figure 5.1 Classification of farm contexts for waterlogging of pastures
Adapted from Kaine and Niall (1999: 41)
<table>
<thead>
<tr>
<th>Contexts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of respondents</td>
<td>7</td>
<td>17</td>
<td>16</td>
<td>14</td>
<td>12</td>
<td>33</td>
</tr>
<tr>
<td><strong>Does waterlogging:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limit growth of spring pasture</td>
<td>88</td>
<td>96</td>
<td>79</td>
<td>34</td>
<td>26</td>
<td>39</td>
</tr>
<tr>
<td>Limit grazing of spring pasture</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Grazing:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cannot graze waterlogged paddocks at all</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>26</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Can graze waterlogged paddocks for one rotation</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>74</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Can graze waterlogged paddocks for a few hours</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Can graze waterlogged paddocks all day</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Soil is suited to sub-surface drainage</td>
<td>16</td>
<td>22</td>
<td>25</td>
<td>19</td>
<td>21</td>
<td>18</td>
</tr>
</tbody>
</table>

**Notes:** Numbers are percentage of respondents in each context (excludes respondents that had installed sub-surface drainage)

Contexts: 1 – Severe spring and winter waterlogging; 2 – Serious spring and winter waterlogging; 3 – Moderate spring and winter waterlogging; 4 – Serious winter waterlogging; 5 – Moderate winter waterlogging; 6 – Light winter waterlogging

Source: Kaine and Niall (1999: 42)
by waterlogging and suggested that, where feasible, investment in sub-surface drainage may have been worthwhile for most of the respondents in these contexts.

Since respondents in context three could graze waterlogged pastures for a few hours each day, on-off grazing over extended periods may be a viable alternative to sub-surface drainage for some in this context.

Waterlogging should be less of a problem for respondents in contexts four (serious winter waterlogging), five (moderate winter waterlogging) and six (light winter waterlogging). Although waterlogging prevented these respondents from fully utilising pastures in winter, they were able to take advantage of high rates of pasture growth in spring. This means that, although farm output is affected by waterlogging, investment in sub-surface drainage is less likely to be worthwhile for these respondents. These respondents may counter waterlogging by following appropriate grazing management strategies such as on-off grazing.

In Table 5.6 the profiles of respondents in each context are reported in terms of timing and severity of waterlogging. The profiles confirm that waterlogging on farms unable to utilise spring pasture (contexts one, two and three) was much more severe than on farms that could (contexts four, five and six). The majority of respondents in these contexts experienced waterlogging during most of spring as well as winter, many on more than half the area of their farms. These respondents were likely to experience waterlogging in most years or every year, and waterlogging tended to occur continuously for a month or more.

Respondents in these contexts were also significantly more likely than respondents in contexts four, five and six to experience problems with pasture growth and utilisation in winter because of waterlogging. They were also significantly more likely to report that waterlogging had an unfavourable impact on pasture composition.

In contrast, the majority of respondents in contexts four, five and six tended to experience waterlogging on less than half the area of their farms. Also, these respondents were more likely to only experience waterlogging in winter. Waterlogging on these farms generally lasted for less than a month and was unlikely to occur every year.
Table 5.6 Farm context profiles for severity of waterlogging of pastures

<table>
<thead>
<tr>
<th>Contexts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>Area prone to waterlogging</em>:</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than one quarter of farm</td>
<td>40</td>
<td>19</td>
<td>27</td>
<td>41</td>
<td>48</td>
<td>66</td>
</tr>
<tr>
<td>Between one quarter and half the farm</td>
<td>13</td>
<td>35</td>
<td>38</td>
<td>23</td>
<td>42</td>
<td>20</td>
</tr>
<tr>
<td>Between half and three quarters of the farm</td>
<td>20</td>
<td>29</td>
<td>26</td>
<td>26</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>More than three quarters of the farm</td>
<td>27</td>
<td>17</td>
<td>8</td>
<td>10</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><em><em>Waterlogging usually happens</em>:</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every second or third year</td>
<td>10</td>
<td>30</td>
<td>25</td>
<td>31</td>
<td>44</td>
<td>43</td>
</tr>
<tr>
<td>Most years</td>
<td>58</td>
<td>61</td>
<td>59</td>
<td>53</td>
<td>43</td>
<td>31</td>
</tr>
<tr>
<td>Every year</td>
<td>23</td>
<td>5</td>
<td>10</td>
<td>3</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td><strong>Does waterlogging:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limit grazing of winter pasture*</td>
<td>97</td>
<td>96</td>
<td>95</td>
<td>92</td>
<td>86</td>
<td>22</td>
</tr>
<tr>
<td>Limit grazing of winter pasture*</td>
<td>91</td>
<td>89</td>
<td>90</td>
<td>79</td>
<td>60</td>
<td>47</td>
</tr>
<tr>
<td>Unfavourably affect pasture composition*</td>
<td>94</td>
<td>93</td>
<td>89</td>
<td>66</td>
<td>58</td>
<td>51</td>
</tr>
</tbody>
</table>

Notes: Numbers are percentage of respondents in each context (excludes respondents that had installed sub-surface drainage).
An asterisk denotes statistically significant differences at 0.05 using Pearson’s chi-square test.
Contexts: 1 – Severe spring and winter waterlogging; 2 – Serious spring and winter waterlogging; 3 – Moderate spring and winter waterlogging; 4 – Serious winter waterlogging; 5 – Moderate winter waterlogging; 6 – Light winter waterlogging.

Source: Kaine and Niall (1999: 105-106)
### Table 5.6 Farm context profiles for severity of waterlogging of pastures (continued)

<table>
<thead>
<tr>
<th>Waterlogging usually lasts*</th>
<th>Contexts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only a day or so at a time</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>A week or two at a time</td>
<td></td>
<td>16</td>
<td>13</td>
<td>18</td>
<td>27</td>
<td>46</td>
<td>35</td>
</tr>
<tr>
<td>Continuously for a month</td>
<td></td>
<td>28</td>
<td>40</td>
<td>31</td>
<td>40</td>
<td>34</td>
<td>31</td>
</tr>
<tr>
<td>Continuously for two or more months</td>
<td></td>
<td>56</td>
<td>47</td>
<td>48</td>
<td>31</td>
<td>11</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Waterlogging usually occurs in:</th>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td></td>
<td>19</td>
<td>8</td>
<td>10</td>
<td>10</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>July</td>
<td></td>
<td>48</td>
<td>66</td>
<td>52</td>
<td>53</td>
<td>49</td>
<td>43</td>
</tr>
<tr>
<td>August</td>
<td></td>
<td>94</td>
<td>94</td>
<td>96</td>
<td>95</td>
<td>91</td>
<td>88</td>
</tr>
<tr>
<td>September*</td>
<td></td>
<td>84</td>
<td>93</td>
<td>86</td>
<td>76</td>
<td>63</td>
<td>71</td>
</tr>
<tr>
<td>October*</td>
<td></td>
<td>52</td>
<td>41</td>
<td>37</td>
<td>15</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>November*</td>
<td></td>
<td>13</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

Notes: Numbers are percentage of respondents in each context (excludes respondents that had installed sub-surface drainage)
An asterisk denotes statistically significant differences at 0.05 using Pearson’s chi-square test
Contexts: 1 – Severe spring and winter waterlogging; 2 – Serious spring and winter waterlogging; 3 – Moderate spring and winter waterlogging; 4 – Serious winter waterlogging; 5 – Moderate winter waterlogging; 6 – Light winter waterlogging
Source: Kaine and Niall (1999: 105-106)
**Grazing management**

In Table 5.7 the profiles of respondents in each context are reported in terms of impacts on grazing management. For most grazing practices, the percentage of respondents in each context using the practices was not statistically significantly different. However, the percentage of respondents in each context grazing paddocks prone to waterlogging early in winter before wet weather was likely to arrive, on-off grazing, stopping strip grazing or slowing their rotation was statistically significantly different across the contexts (see Table 5.7).

Respondents in contexts one (severe spring and winter waterlogging) and six (light winter waterlogging) were less likely than respondents in other contexts to graze paddocks prone to waterlogging early in winter. The smaller percentage in context one may be explained by the fact that the respondents in this context were more likely than respondents in other contexts to experience waterlogging across the whole farm. The smaller percentage for respondents in context six may be explained by the fact that respondents in this context were less likely than respondents in other contexts to experience waterlogging.

Respondents in contexts three (moderate spring and winter waterlogging) and five (moderate winter waterlogging) were more likely to use on-off grazing than respondents in other contexts. This reflected the fact that the respondents in these two contexts were able to graze waterlogged paddocks for a few hours without too much damage but could not leave stock on waterlogged paddocks all day.

Respondents in other contexts could either graze all day (context six), could only graze waterlogged paddocks for one rotation (contexts two and four), or could not graze waterlogged paddocks at all (context one).

The reason why significant differences were found in the percentage of respondents in each context who stopped strip grazing was unclear. If respondents stop strip grazing, they reduced the stocking rate on the area being grazed by increasing the area available for grazing at any point in time. This strategy may be adopted where a reasonably large area of the property is subject to waterlogging and waterlogged pastures can be grazed for a few hours for one rotation (but cannot be grazed on subsequent rotations).
### Table 5.7 Farm context profiles for impact of waterlogging on grazing management

<table>
<thead>
<tr>
<th>Management practice</th>
<th>Contexts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain rotation and feed more hay or grain</td>
<td></td>
<td>31</td>
<td>47</td>
<td>40</td>
<td>58</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>Speed up rotation</td>
<td></td>
<td>6</td>
<td>16</td>
<td>19</td>
<td>10</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Slow down rotation*</td>
<td></td>
<td>13</td>
<td>17</td>
<td>21</td>
<td>7</td>
<td>23</td>
<td>9</td>
</tr>
<tr>
<td>Graze driest paddocks first</td>
<td></td>
<td>78</td>
<td>72</td>
<td>67</td>
<td>65</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>Graze drained paddocks first</td>
<td></td>
<td>31</td>
<td>32</td>
<td>34</td>
<td>37</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>Graze paddocks prone to waterlogging early*</td>
<td></td>
<td>50</td>
<td>59</td>
<td>63</td>
<td>55</td>
<td>56</td>
<td>39</td>
</tr>
<tr>
<td>Graze specially selected paddocks</td>
<td></td>
<td>28</td>
<td>36</td>
<td>45</td>
<td>34</td>
<td>37</td>
<td>26</td>
</tr>
</tbody>
</table>

Note: Numbers are percentage of respondents in each context (excludes respondents that had installed sub-surface drainage)
An asterisk denotes statistically significant differences at 0.05 using Pearson’s chi-square test

Source: Kaine and Niall (1999: 107-109)
### Table 5.7 Farm context profiles for impact of waterlogging on grazing management (continued)

<table>
<thead>
<tr>
<th>Management practice</th>
<th>Contexts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start strip grazing</td>
<td></td>
<td>9</td>
<td>4</td>
<td>10</td>
<td>11</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Stop strip grazing*</td>
<td></td>
<td>22</td>
<td>34</td>
<td>23</td>
<td>34</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>Start back fencing*</td>
<td></td>
<td>9</td>
<td>9</td>
<td>11</td>
<td>5</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>On-off grazing during the day*</td>
<td></td>
<td>23</td>
<td>31</td>
<td>41</td>
<td>27</td>
<td>42</td>
<td>11</td>
</tr>
<tr>
<td>On-off grazing during the night</td>
<td></td>
<td>10</td>
<td>14</td>
<td>3</td>
<td>7</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Leave paddock gate open</td>
<td></td>
<td>41</td>
<td>48</td>
<td>54</td>
<td>46</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Stand cows overnight in yards or laneways*</td>
<td></td>
<td>3</td>
<td>13</td>
<td>10</td>
<td>5</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Leave cows in a winter sacrifice paddock</td>
<td></td>
<td>29</td>
<td>18</td>
<td>13</td>
<td>10</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>Graze dry cows in a sacrifice paddock*</td>
<td></td>
<td>41</td>
<td>38</td>
<td>40</td>
<td>29</td>
<td>26</td>
<td>18</td>
</tr>
</tbody>
</table>

**Notes:** Numbers are percentage of respondents in each context (excludes respondents that had installed sub-surface drainage)
An asterisk denotes statistically significant differences at 0.05 using Pearson’s chi-square test
Contexts: 1 – Severe spring and winter waterlogging; 2 – Serious spring and winter waterlogging; 3 – Moderate spring and winter waterlogging; 4 – Serious winter waterlogging; 5 – Moderate winter waterlogging; 6 – Light winter waterlogging

Source: Kaine and Niall (1999: 107-109)
Strategies such as grazing areas prone to waterlogging early in winter are unlikely to be completely effective where the area prone to waterlogging is relatively large. If waterlogged pastures can be grazed for a few hours each day for one rotation then waterlogging might be managed initially by on-off grazing and strip grazing. If pastures continue to remain waterlogged for more than one rotation then strip grazing may have to be abandoned and stock spread over larger areas in order to avoid concentrated pugging damage.

We found that a significantly higher percentage of respondents, on properties where between 50 and 75 per cent of the farm was subject to waterlogging, stopped strip grazing when paddocks got waterlogged. Hence, the reason a significantly higher percentage of respondents in contexts two and four had stopped strip grazing when paddocks got waterlogged may have been because a high percentage of the farms in these contexts were properties where between 50 and 75 per cent of the farm was subject to waterlogging and the respondents in these contexts were, thus, only able to graze waterlogged pastures for a few hours each day for one rotation.

Significant differences were also found in the percentage of respondents in each context who slowed their rotation (see Table 5.7). If respondents slowed their rotation they could increase the bank of feed available to their herd and reduce pugging damage. Respondents who were able to graze waterlogged paddocks for a few hours each day (contexts three and five, in particular) may have had the opportunity to slow their rotation by reducing the area grazed each day and feeding additional hay and silage to compensate.

**Surface and sub-surface drainage**

Respondents who had installed sub-surface drainage were included in this part of the analysis. These respondents were allocated to one of the six farm contexts based on their responses to questions regarding the timing and severity of waterlogging and the suitability of their soil for sub-surface drainage prior to the installation of sub-surface drainage.

In Table 5.8 the profiles of respondents in each context are reported in terms of investment in surface and sub-surface drainage. Approximately 79 per cent of respondents believed the soils on their property were suited to surface drainage of
Table 5.8 Farm context profiles for surface and sub-surface drainage

<table>
<thead>
<tr>
<th>Contexts</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of total sample</td>
<td>8.2</td>
<td>18.5</td>
<td>16.8</td>
<td>14.0</td>
<td>11.8</td>
<td>30.7</td>
</tr>
<tr>
<td>Installed humps and hollows*</td>
<td>19</td>
<td>29</td>
<td>29</td>
<td>41</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>Installed sub-surface drainage*</td>
<td>26</td>
<td>20</td>
<td>17</td>
<td>13</td>
<td>11</td>
<td>6</td>
</tr>
</tbody>
</table>

Notes: Numbers are percentage of respondents in each context (includes respondents that had installed sub-surface drainage) An asterisk denotes statistically significant differences at 0.05 using Pearson’s chi-square test
Contexts: 1 – Severe spring and winter waterlogging; 2 – Serious spring and winter waterlogging; 3 – Moderate spring and winter waterlogging; 4 – Serious winter waterlogging; 5 – Moderate winter waterlogging; 6 – Light winter waterlogging

some kind (humps and hollows or spoon drains for example). Of these respondents, approximately 95 per cent had some type of surface drainage working successfully on their farms. There was no significant difference across the contexts in the percentage of respondents who believed their soils were suited to surface drainage or the percentage of respondents who had surface drainage.

The most common forms of surface drainage are V drains, spoon drains or spinner cuts and humps and hollows (ploughed in lands). The percentage of respondents with humps and hollows varied significantly across the contexts and may be explained as follows (see Table 5.8). The installation of humps and hollows is a relatively expensive and time-consuming exercise. This type of drainage would be most likely to be contemplated in two situations. The first situation is where waterlogging has had a severe impact on spring pasture utilisation but soils are not suited to sub-surface drainage, a possibility for some respondents in contexts one, two and three (each without spring access).

The second situation is where waterlogging has had only a limited impact on pasture utilisation in spring but a severe impact on pasture utilisation in winter such as in context four (serious winter waterlogging). It may be worthwhile installing humping and hollowing in these circumstances to alleviate problems with waterlogging in winter. This may explain the higher frequency of humps and hollows in context four.

Approximately 29 per cent of respondents believed the soils on their property were suited to sub-surface drainage and approximately 16 per cent of respondents in total had installed sub-surface drainage such as mole or tile drains. The percentage of respondents in each farm context that had installed sub-surface drainage was statistically significantly different, ranging from a high of 26 per cent in context one to a low of 6 per cent in context six (see Table 5.8).

Respondents indicated that installing sub-surface drainage had allowed them to increase their stocking rate (35%), to increase milk production per cow (36%), to cut silage earlier (28%) and to feed less grain (15%).

These results confirm the findings from the qualitative stage of the analysis. They support the proposition that the population of potential adopters of sub-surface drainage consists primarily of respondents in contexts one, two and three with soils that are suited to sub-surface drainage. This suggests that the population of potential
adopters of sub-surface drainage was approximately 12 per cent of dryland dairy farmers in the two regions that experienced problems with waterlogging.\textsuperscript{25}

The results also suggest that the penetration of sub-surface drainage among respondents in the population of potential adopters was extremely high, at almost 90 per cent, among respondents in context one (severe spring and winter waterlogging), and approaching 70 per cent among the estimated population of potential adopters as a whole.\textsuperscript{26}

\textit{Extension}

The results indicated that respondents in the different farm contexts had different information needs but there were some unifying themes from an extension perspective. First, information about drainage options would be most relevant to respondents in contexts one, two and three. Second, information about grazing management strategies, especially on-off grazing, feed pad design and supplementary feeding, would be especially relevant to respondents in contexts three, four and five.

Extension strategies and priorities were formulated by combining, using a program logic approach (Mayeske 1994), the results of the case study with the knowledge and experience of the Department staff involved in dairy extension in the two regions. Program logic is an approach to planning where program investments are linked to program results by a sequence of events and activities that are planned on the basis of systematic relationships between inputs, outputs and outcomes that reflect the underlying rationale for the program.

\textsuperscript{25} Approximately 44 per cent of respondents in the sample were classified into contexts one, two and three. Only 29 per cent of respondents in the sample, approximately, had soils suited to sub-surface drainage, and this percentage was not statistically significantly different across the contexts. Consequently, extrapolating from the sample, the population of potential adopters was 12 per cent of the population of relevant dairy farmers.

\textsuperscript{26} Approximately 29 per cent of the producers in contexts one, two and three were assumed to be members of the population of potential adopters of sub-surface drainage. Penetration is the percentage of the population of potential adopters that have adopted. Hence the penetration of sub-surface drainage was 90 per cent (26 per cent of a possible 29 per cent) for context one and 69 per cent (20 per cent of a possible 29 per cent) for contexts one, two and three in aggregate.
Briefly, the strategies and priorities that emerged were that:

- Information needs and skills in relation to sub-surface and surface drainage would be the highest priority for respondents in contexts one and two, and a high priority for respondents in context three.

- Information needs and skills in relation to feed pad (and related structures) design and management and on-off grazing would be the highest priority for respondents in contexts four and five, and a high priority for many respondents in context three.

- Respondents in contexts three and four would be interested in more permanent structures suitable for feeding or housing stock for longer periods (weeks or months).

- Respondents in context five would be interested in more temporary structures suited to feeding or standing cows for short periods (days).

- Respondents in all farm contexts may have had information needs in relation to basic grazing management strategies (such as the economics of ‘sacrifice’ paddocks) but these would be a low priority.

These context-specific priorities were validated by conducting a final round of unstructured interviews with five dairy farmers from each context. The dairy farmers were identified from the contact details they supplied when completing the survey questionnaire. These interviews were also used to verify the classification of the farmers into farm contexts for sub-surface drainage.

The validation interviews confirmed and reinforced the earlier findings of the case study and the context specific priorities for extension. Respondents in contexts one and two, and to a lesser extent context three, were aware of the benefits of installing sub-surface drainage, and were interested in workshops on topics such as soil testing and integrating drainage installation into a farm development plan. Some respondents in context three were interested in comparative studies of the economics of sub-surface drainage and using feed pads in conjunction with on-off grazing. Respondents in contexts four and five believed that, in their circumstances, sub-surface drainage was not economically justifiable. They were interested, together with respondents in
context three, in workshops on topics such as feed pad and loafing pad design, on-off grazing and managing animal health in feed pad systems.

**Conclusion**

The results indicated that waterlogging was sufficiently severe for respondents in contexts one, two and three to justify investing in sub-surface drainage when soils, topography, farm infrastructure and debt allowed. Although respondents in contexts four, five and six also experienced problems with waterlogging, it seems these respondents were generally able to manage waterlogging through a combination of surface drainage and grazing strategies.

These results support the view that the population of potential adopters of sub-surface drainage depends on the farm context as defined by the timing and severity of waterlogging, and the suitability of soils for sub-surface drainage. The results from the quantitative stage confirmed the findings from the qualitative stage of the approach.

The results indicated that, in contrast to the belief that motivated the case study, a relatively high percentage of the potential population of adopters had adopted sub-surface drainage. This was consistent with the expectation that waterlogging of pastures in winter and spring would be highly involving for affected respondents and, as a consequence, they would be likely to have a reasonably accurate picture of the production and income losses they were experiencing and to have devoted considerable time and effort to formulating and implementing strategies for managing waterlogged soils, including the adoption of sub-surface drainage.

As a consequence of the case study the original emphasis of the extension program on promoting sub-surface drainage was reduced and an increased emphasis was placed on promoting the adoption of on-off grazing and providing information on feed pad designs.
5.3.2 Adoption of soil moisture monitoring technologies

Selection criteria

This case study is an example of the adoption of an agricultural innovation by intensive, irrigated enterprises producing a perennial tree crop. The study was selected as the elements of the farm system that constituted the farm context for the adoption of techniques for measuring soil moisture were a mixture of biophysical and socio-economic. Soil moisture monitoring is relatively easily installed and can be trialled at little expense on a block in an orchard before full-scale adoption. The benefits of using soil moisture monitoring were not always immediately obvious and there was evidence to suggest that monitoring might produce results that could be incompatible with producers’ experiences with irrigation management.

Background

In recent years techniques for objectively monitoring soil moisture such as neutron probes and tensiometers have been developed for use in scheduling the irrigation of perennial and annual crops. At the time this case study was conducted best management practices were being identified for horticultural irrigation. These practices included irrigation scheduling, nutrient management, salinity control and vigour management and the use of objective monitoring of soil moisture was seen to be critical to the successful adoption of these best management practices (Boland et al. 1998; Meissner 1998).

The major motivation driving the development of these techniques and best practices was the concern of organisations responsible for natural resource management to increase the efficiency of water use in irrigation industries. While the technology to objectively monitor soil moisture has been available for some years only a minority of fruit growers were using the technology (Boland et al. 1998). Most growers continued to rely on subjective assessments of soil moisture and their experience to schedule irrigations.

27 This section is a summary of, and contains material reproduced from, Kaine and Bewsell (1999); Kaine and Bewsell (2002a) and Kaine and Bewsell (2002b). This case study was financially supported by the Victorian Department of Natural Resources and Environment.
The objective in this case study was to identify the population of potential adopters of techniques for objectively monitoring soil moisture. This knowledge was to be used to develop extension strategies promoting more widespread adoption of these techniques and the associated best management practices among fruit growers in northern Victoria and southern New South Wales.

Qualitative stage
Following the approach described in the preceding chapter, convergent interviewing was used in the first stage of the case study to identify the elements in the farming systems of fruit growing enterprises that defined the farm context for adopting soil moisture monitoring techniques such as tensiometers and neutron probes. In-depth, unstructured personal interviews were conducted with approximately thirty fruit growers and were conducted as described in the preceding chapter with two interviewers present at each interview.

The fruit growers who took part in the interviews were nominated by research and extension staff of the then Department of Natural Resources and Environment and New South Wales Agriculture in each region. These farmers were selected for interviewing because they used different irrigation systems, they used different methods for scheduling irrigations, and they represented a variety of locations and enterprises of different scales.

The interviews revealed that irrigation management was a highly involving issue for fruit growers. The management of irrigation was a critical determinant of farm production and income, and could also influence growers’ lifestyles. From the interviews it became apparent that the benefits of using new irrigation scheduling methods depended on:

- The need to conserve irrigation water
- The type of irrigation system used by the fruit grower and the land and labour resources available to the orchard enterprise
- The planting techniques used by the grower.
Conservation of water
The supply of irrigation water had not restricted the production of fruit growers interviewed in the Shepparton, Cobram and Swan Hill districts in northern Victoria. These growers regularly received water allocations in excess of their requirements. These growers did not mention the price of irrigation water as a reason for conserving water. This meant that growers in these districts would only need to conserve irrigation water if they were experiencing:

- Production problems due to high water tables, soil salinity or water salinity which could be influenced by irrigation management
- Problems with the delivery of irrigation water to the property because of the design of the district irrigation infrastructure.

On the other hand, the availability of water did restrict the production of some growers around Tumut and Batlow in southern NSW. The growers in these districts used privately constructed dams on their properties to collect run-off from rainfall which was used for supplementary irrigation. These growers did attempt to conserve irrigation water to maximise their fruit production.

Irrigation systems, labour and land
The type of irrigation system used by the fruit grower directly influences the ability of the grower to vary the timing and length of irrigations. Growers must simultaneously manage a number of key farm enterprise activities including spraying, picking, grading, and marketing in conjunction with irrigation. This places a premium on the growers’ time. Typically, fruit blocks take between six and ten hours to flood irrigate. Consequently, growers with flood irrigation will endeavour to concurrently irrigate as many fruit blocks as possible to reduce the amount of time spent irrigating. Blocks must also be given two or three days to dry out after irrigating before spraying or picking can commence. The result is that, on orchards with flood irrigation, operations such as spraying and picking are undertaken during the week and irrigation carried out on weekends with all blocks on the farm being irrigated. This means that growers with flood irrigation have little opportunity to vary their irrigation routine, especially once picking has commenced.
Growers with impact sprinkler irrigation (under-tree knocker sprinklers) have more flexibility to vary their irrigation routine than growers with flood irrigation. Impact systems are pressurised, relatively high volume, controlled-flow systems. Because impact sprinklers are controlled-flow systems there is no need to continuously monitor each block while irrigating and the water delivered to each block can be controlled by varying the irrigation period. Consequently, growers with impact sprinkler irrigation had the potential to irrigate blocks sequentially and to customise the irrigation of each block. This means irrigation on one block need not interfere with activities such as spraying and picking on another block. However, growers with impact sprinkler irrigation must water the entire block. Consequently, blocks must be left to dry out after being irrigated before activities such as spraying and picking can be undertaken.

The extent to which the potential benefits of impact sprinkler irrigation can be realised depends on the supply reliability of the irrigation distribution system. Growers serviced by spur channels, for example, may experience difficulties obtaining continuous supplies of moderate volumes of water over a sustained period. In these circumstances growers with impact sprinkler irrigation may be forced to operate in a fashion similar to growers with flood irrigation, ordering large volumes and irrigating blocks concurrently to complete irrigation as rapidly as possible.

Fruit growers with impact sprinkler irrigation systems do have the potential to schedule irrigation using objective monitoring of soil moisture as these systems can provide some flexibility to irrigate without severely constraining other farm activities and to customise the irrigation of a fruit block.

Growers with micro-irrigation that were interviewed indicated that they had the most flexibility to vary their irrigation scheduling. Micro-irrigation systems are pressurised, relatively low volume, controlled flow systems. As a result, there is no need to continuously monitor each block while irrigating and the water delivered to each block can be controlled by varying the irrigation period. This means that growers with micro-irrigation have the flexibility to irrigate blocks sequentially and to customise the irrigation of each block.

Irrigation water is delivered directly to the base of the fruit tree by micro-irrigation systems. This means less water is required to irrigate a block of trees. It also means
that, as blocks are not flooded, other activities such as spraying and picking can be undertaken concurrently with irrigation. Micro-irrigation is often the only form of irrigation suitable for orchards on hilly or sandy country.

**Planting techniques**

The capacity to customise irrigation means that growers can use micro-irrigation to overcome watering problems in blocks composed of a range of soil types. Also, as water is delivered directly to the base of the fruit tree by micro-irrigation systems, these systems may be more effective than flood or impact systems on blocks using high density planting techniques. High density planting techniques such as the Tatura Trellis involve hilling the soil under trees which prevents flood irrigation, and arranging trees in a trellis formation which prevents irrigation using impact sprinklers. Trees planted using these techniques must be irrigated using micro-irrigation. Micro-irrigation systems are also more effective than flood or impact systems on blocks planted to dwarf rootstocks.

In short, micro-irrigation offers four potential benefits:

- Reduced use of water
- Reduced use of labour
- Greater control over the volume of irrigation water applied
- Direct application of irrigation water to fruit trees thereby avoiding wetting of the orchard floor.

Since micro-irrigation offers the flexibility to irrigate without constraining other farm activities and to customise the irrigation of a fruit block, fruit growers with this type of irrigation system did have the potential to schedule irrigation using objective monitoring of soil moisture. However, growers indicated that the installation of pressure irrigation systems was expensive and changing irrigation systems often entailed the investment of substantial time and effort in planning and implementing the change, and adjusting management practices accordingly.

In conclusion, the interviews with fruit growers indicated that the elements in the farm system that were critical to the adoption of irrigation scheduling using techniques for
objectively monitoring soil moisture were the use of micro-irrigation, and to a lesser extent the use of impact sprinkler irrigation.

Where the supply of irrigation water was not constraining production, growers were most likely to use micro-irrigation to reduce water use when they needed to manage a water table or salinity problem, or were experiencing difficulties with the supply of irrigation water. Otherwise, growers used micro-irrigation to reduce the demands irrigation imposed on labour and to overcome the constraints flood irrigation imposed on the conduct of other activities such as spraying and picking. Growers also used micro-irrigation when adopting high density planting techniques.

Irrigation scheduling and soil moisture monitoring
Monitoring using techniques such as tensiometers and neutron probes is used to tailor the timing and length of irrigations to more closely match the water requirements of fruit trees. In the interviews, fruit growers who had micro-irrigation and some experience of soil moisture monitoring indicated that they did not believe that scheduling irrigation on the basis of soil moisture monitoring would substantially improve fruit quality or quantity. In other words, they believed fruit trees were not sufficiently sensitive to the timing of irrigations for the differences between scheduling using traditional techniques and scheduling using objective monitoring to be noticeable.

The number of soil moisture monitors that needed to be installed in a fruit block, and their arrangement across the block, depended on the variation in soil types within the block. If the soil profile was fairly uniform then soil moisture across the block can be predicted using only a small number of monitors. Consequently, monitors would be relatively inexpensive to install and taking soil moisture readings would be a simple task.

On the other hand, where the soil profile was quite diverse a large number of monitors would be needed to predict soil moisture in different parts of the block. Consequently, monitors would be relatively expensive to install and taking soil moisture readings would be a time consuming task. Where a block was being redeveloped sub-main design and tap positioning may also influence the siting of monitors.
Interviews with growers revealed that, in general, the installation of pressurised irrigation systems was a prerequisite for the adoption of soil moisture monitoring techniques. However, growers indicated that the installation of objective monitoring was unlikely to be considered, even where it was practical, unless the installation of micro-irrigation had failed to contain a water table or salinity problem, or additional labour savings were sought through automatic irrigation. If scheduling using monitoring was not expected to generate an improvement in the quantity or quality of fruit produced then the only potential benefits objective monitoring was considered to offer were reduced water use or reduced labour use.

Objective monitoring of soil moisture can be used to manage Regulated Deficit Irrigation (RDI). RDI involves reducing the water applied during irrigation to manage vegetative growth. RDI can be undertaken without using objective soil moisture monitoring, especially if impact sprinkler or micro-irrigation has been installed, though not, perhaps, with the same degree of precision. Hence, growers suggested they were unlikely to install soil moisture monitors simply to institute RDI.

In principle, objective monitors may be employed as part of an automatic irrigation system. Automatic systems are used to save labour. These systems may also be programmed using a timing system. Monitors were likely to be used where soils were relatively uniform and irrigation water was continuously available.

In conclusion, growers who had installed spray or micro-irrigation were unlikely to use objective monitoring of soil moisture to schedule irrigation unless:

- Objective monitoring of soil moisture had been shown to be more reliable, easier to use and quicker than traditional techniques
- There was a continuing need to conserve water to maximise production
- There was a continuing need to conserve water to manage a water table or salinity problem.
- There was a continuing need to reduce labour.

**Quantitative stage**

A mail survey based on the findings from the interviews was developed, piloted and then distributed to fruit growers in northern Victoria and southern New South Wales.
The purpose of the survey was to obtain accurate estimates of the population of potential adopters of objective techniques for monitoring soil moisture in those regions.

On the basis of the findings from the qualitative stage the questionnaire was designed in three parts. The first part sought information on some basic orchard characteristics such as orchard size, tree types, and the length of irrigation season and so on. Given that the installation of pressurised irrigation systems was a prerequisite for the adoption of soil moisture monitoring techniques, the second part of the questionnaire was designed to elicit information on the irrigation systems used in the orchard. These spanned aspects such as type of irrigation system, area of orchard irrigated using each system, method of ordering irrigation water, and so on. Information was also sought in this section on respondents’ reasons for installing micro-irrigation systems. Respondents were asked to indicate which of the key factors that influence the adoption of micro-irrigation best described their reasons for installing micro-irrigation. In the third part of the survey information was sought on the use of soil moisture monitoring systems. Respondents were asked to indicate which of the key factors that influenced the adoption of monitoring best described their reasons for trying or using soil moisture monitoring. The questionnaire was printed in the form of a 12 page booklet and mailed with a cover letter explaining the project and providing contact details.

Questionnaires were sent to all fruit growers in the Shepparton, Cobram and Swan Hill districts of Victoria and the Tumut and Batlow districts of New South Wales. The population of growers in these districts was approximately 780\textsuperscript{28}. The questionnaires were mailed in May 2000 with a reminder posted four weeks later. The case study and survey were also publicised through the local print media and industry newsletters. Forty-four questionnaires were returned with incorrect addresses or from people who were not fruit growers. This gave an effective mail out of 736 questionnaires. A total of 251 questionnaires had been returned some ten weeks after the initial mailing. This represented a response rate of 34 per cent.

The general characteristics of the sample are reported in Table 5.9.

\textsuperscript{28} Approximately 650 fruit growers in Victoria and 130 fruit growers in New South Wales.
Table 5.9 Orchard characteristics by district

<table>
<thead>
<tr>
<th></th>
<th>Shepparton¹</th>
<th>Cobram²</th>
<th>Swan Hill³</th>
<th>Tumut and Batlow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average orchard area (ha)</td>
<td>32.5 (1.2 - 260.0)</td>
<td>34.3 (2.0 - 405.0)</td>
<td>14.2 (0.8 - 120.0)</td>
<td>56.3 (3.2 - 800.00)</td>
</tr>
<tr>
<td>Average percentage of orchard area under:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood irrigation*</td>
<td>27.4</td>
<td>8.7</td>
<td>34.3</td>
<td>0</td>
</tr>
<tr>
<td>Under-tree sprinkler irrigation*</td>
<td>6.7</td>
<td>39.6</td>
<td>1.2</td>
<td>0</td>
</tr>
<tr>
<td>Micro-jet irrigation*</td>
<td>37.1</td>
<td>14.8</td>
<td>3.0</td>
<td>25.6</td>
</tr>
<tr>
<td>Mini-sprinkler irrigation*</td>
<td>18.5</td>
<td>33.1</td>
<td>1.8</td>
<td>6.7</td>
</tr>
<tr>
<td>Drip irrigation*</td>
<td>6.1</td>
<td>0</td>
<td>55.3</td>
<td>67.5</td>
</tr>
</tbody>
</table>

Notes: An asterisk denotes statistically significant differences at 0.05 using analysis of variance F-test. The numbers in parentheses are ranges.
1. Includes East Shepparton, Ardmona, Tatura and Kyabram
2. Includes Invergordon
3. Includes Tresco, Woorinen and Nyah
Source: Kaine and Bewsell (2002a: 6)
Table 5.9 Orchard characteristics by district (continued)

<table>
<thead>
<tr>
<th>Percentage of orchards growing:</th>
<th>Shepparton¹</th>
<th>Cobram²</th>
<th>Swan Hill³</th>
<th>Tumut and Batlow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples*</td>
<td>92</td>
<td>40</td>
<td>2</td>
<td>91</td>
</tr>
<tr>
<td>Pears*</td>
<td>93</td>
<td>60</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Cherries*</td>
<td>6</td>
<td>10</td>
<td>0</td>
<td>26</td>
</tr>
<tr>
<td>Peaches*</td>
<td>50</td>
<td>93</td>
<td>71</td>
<td>46</td>
</tr>
<tr>
<td>Nectarines*</td>
<td>21</td>
<td>60</td>
<td>86</td>
<td>60</td>
</tr>
<tr>
<td>Apricots*</td>
<td>51</td>
<td>45</td>
<td>69</td>
<td>3</td>
</tr>
<tr>
<td>Plums*</td>
<td>55</td>
<td>53</td>
<td>78</td>
<td>20</td>
</tr>
</tbody>
</table>

Irrigation season (months)**  
5.5  5.8  7.1  5.3

Notes: A single asterisk denotes statistically significant differences at 0.05 using Pearson’s chi-square test. A double asterisk denotes statistically significant differences at 0.05 using analysis of variance F-test.
1. Includes East Shepparton, Ardmona, Tatura and Kyabram.
2. Includes Invergordon.
3. Includes Tresco, Woorinen and Nyah.
Source: Kaine and Bewsell (2002a: 6)
In the table the average area of orchards in each district and the percentage of orchards in each district planted to different types of fruit trees are reported. Also reported in the table is the average percentage of orchard area under the different types of irrigation systems in each district.

The average area of orchards in each district was not significantly different across districts. However, the percentage of orchards in each district planted to different types of fruit trees was significantly different across districts reflecting different growing environments. The percentage, on average, of orchard area under the different types of irrigation systems was significantly different across districts.

Bay and furrow flood irrigation were the only irrigation techniques available at the time fruit growing commenced in the older districts of Shepparton and Swan Hill. Under-tree knocker sprinklers had been developed when fruit growing began in Cobram. Consequently, flood irrigation in Shepparton and Swan Hill is based on bay or furrow irrigation whereas under-tree knocker sprinklers are the predominant form of flood irrigation in Cobram. The topography in Tumut and Batlow does not suit flood irrigation. Hence, micro-irrigation was the only form of irrigation in these districts.

Growers had converted to different forms of micro-irrigation depending on their location. For example, in Swan Hill growers had mostly converted from furrow irrigation to drip irrigation. In Cobram, growers had mostly converted from under-tree knocker sprinklers to mini-sprinklers. In contrast many Shepparton growers had converted from flood irrigation using bays to micro-jets. Discussions with research and extension staff, and irrigation consultants, indicated that there are a number of reasons for these district differences.

First, when converting older plantings to micro-irrigation, tree spacing may have had an influence on the type of micro-irrigation that is considered most suitable. For example, an older, flood-irrigated pear block may be planted using 20-by-20 metre spacing. The root systems of trees in such blocks will tend to spread away from the tree line into the irrigation bays. Consequently, this type of block would generally be converted to mini-sprinklers or large-area micro-jets so that the root area can be irrigated. This type of tree spacing is typical in Shepparton and Cobram.
Second, the conversion to micro-irrigation may have been influenced by the irrigation infrastructure already in place. For example, in Cobram the conversion to mini-sprinklers was relatively simple as the pumps and piping required for this type of system were already in place for irrigating with under-tree knocker sprinklers.

Third, the climate and soils in a region may have influenced the conversion to micro-irrigation. The drier climate and lighter soils in Swan Hill favour conversion to drip irrigation. Also, as bay irrigation was impractical on the lighter soils in Swan Hill, furrow irrigation along tree lines was the main form of flood irrigation used in the area. This favoured the conversion to drip irrigation as the root systems of fruit trees tended to follow the tree line.

Fourth, the irrigation designers and suppliers of irrigation equipment may also have had some influence over the type of micro-irrigation adopted through their experiences with the performance of different types of micro-irrigation systems in different areas.

Finally, the way in which irrigation water may be ordered could have influenced the type of micro-irrigation installed. Mini-sprinklers and micro-jets require relatively greater volumes of water at higher pressures for shorter periods than drip or trickle irrigation systems. Hence, mini-sprinkler and micro-jet systems are more practical in situations where irrigation water is not supplied on demand and must be ordered in advance.

The period over which growers in each district were irrigating is also reported in the table. The irrigation season in Tumut and Batlow was shorter, on average, than in other districts. In contrast, the irrigation season in Swan Hill was longer, on average, than in other districts. These results matched the experience of extension staff and provide a measure of confidence in the information supplied by the respondents.

Since the installation of pressurised irrigation systems was a prerequisite for the adoption of soil moisture monitoring techniques there was interest in the adoption of pressurised irrigation systems. Consequently, we investigated the adoption of pressurised irrigation systems, using information supplied by respondents on their reasons for installing these systems, before investigating the adoption of soil moisture monitoring.
Adoption of irrigation systems

Interviews with fruit growers in the qualitative stage of this case study revealed that the benefits of using micro-irrigation were:

- Increased production by irrigating a greater number of trees when the supply of irrigation water was limited
- Reduced water use to manage a watertable or salinity problem or when difficulties were experienced with the supply of irrigation water
- Reduced labour demands when irrigating and avoid the constraints flood irrigation imposed on the conduct of other orchard activities such as spraying and picking
- Irrigating orchards that had been developed using high-density planting or trellis planting techniques.

Respondents could not be properly classified into different farm contexts with respect to the adoption of micro-irrigation because information on some elements of the farm system that influenced the benefits to be had from adopting micro-irrigation were not practical to obtain. For example, collecting information that was reliable across different enterprises on the elements in the farm system that determined labour demand for irrigation was problematic. Labour demand can depend on the availability and opportunity costs of family labour, the availability and cost of hired labour, orchard and irrigation layout, mix of tree crops, timing of spraying, picking and transport activities, and so on. However, respondents that used micro-irrigation could be classified into benefit segments based on their reasons for adopting micro-irrigation.

Respondents were asked in the questionnaire to indicate the type of irrigation system they used in their orchards and, if they used a micro-irrigation system, to select from a list those statements which best described their reasons for adopting micro-irrigation (see Table 5.10). Five variables were constructed from the responses to these questions and used to classify fruit growers into benefit segments for micro-irrigation.29

---

29 The classification analysis was conducted using a monothetic divisive clustering algorithm available in CLUSTAN (Wishart 1987) which is specifically designed for use with dichotomous data. The similarity coefficient used was squared Euclidean distance.
For the purpose of the classification analysis, irrigating with under-tree knocker sprinklers was categorised as a type of flood irrigation, along with bay or furrow irrigation. We treated irrigating with under-tree knocker sprinklers as a form of flood irrigation systems because, like bay and furrow irrigation, it imposes constraints on the conduct of other orchard activities such as spraying and picking because each of these systems involve wetting the entire orchard floor.

A scree test indicated that five benefit segments were present in the sample (Aldenderfer and Blashfield 1984). Subsequent inspection of the segments confirmed the five segments were qualitatively different and that further sub-division was not substantively meaningful. The formation of the five segments is illustrated in Figure 5.2 and the profiles of the respondents in each segment, in terms of their reasons for adopting micro-irrigation are presented in Table 5.11.

The benefit of installing micro-irrigation for respondents in the first segment (control and time saving redevelopers) was to irrigate orchards that had been redeveloped to high density planting or plantings on trellis. These respondents also obtained benefits in regard to saving time and labour irrigating, and increasing flexibility in terms of picking and spraying fruit while irrigating. The growers in this segment represented approximately 23 per cent of respondents.

The benefits of converting orchards to micro-irrigation for respondents in the second segment (time-saving converters) were to save time and labour irrigating and to increase their flexibility in terms of picking and spraying fruit while irrigating. The growers in this segment represented approximately 24 per cent of respondents.

The respondents in the third segment (water-saving micro-irrigators) had installed micro-irrigation to manage limited water supplies or because micro-irrigation best suited their soils or topography. The respondents in this segment represented 17 per cent of the sample and approximately half of the respondents in this segment were from Batlow and Tumut.

The respondents in the fourth segment (control redevelopers) had installed micro-irrigation to irrigate orchards they had redeveloped to high-density plantings or plantings on trellis. The respondents in this segment represented approximately 15 per cent of the sample.
Table 5.10 Classification questions for irrigation systems in horticulture

**Questions**

Have you installed micro-irrigation (i.e. trickle, drip, micro-jet or mini-sprinkler)?

Which of the following reasons best describes why:

a) I have been redeveloping blocks to closer plantings or plantings on trellis

b) I have converted to micro-irrigation to save on time and labour spent irrigating

c) I have been installing micro-irrigation because it increases my flexibility in terms of picking and spraying

d) I installed micro-irrigation because of tree health problems due to groundwater, high water tables, or salinity

e) I have installed micro-irrigation because of problems getting water delivered (e.g. because my orchard is on a spur channel).

f) I installed micro-irrigation because it best suits the soil types/ topography of my orchard

g) I installed micro-irrigation because I have limited water supplies

h) Other

Note: The answers to the question on installing micro-irrigation is dichotomous (1 = yes, 0 = no). The responses to the reasons for installing micro-irrigation question were disaggregated to create seven separate dichotomous variables (1 = yes, 0 = no), one variable for each alternative.

Source: Kaine and Bewsell (2002a: 9)
Figure 5.2 Classification of benefit segments for irrigation in horticulture
Source: Kaine and Bewsell (2002a: 11)
<table>
<thead>
<tr>
<th>Segments</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of all respondents</td>
<td>23</td>
<td>24</td>
<td>17</td>
<td>15</td>
<td>22</td>
</tr>
</tbody>
</table>

**Reasons for adopting***:

Redeveloped blocks or planted on trellis

| Reasons for adopting* | 100 | 0  | 25 | 76 | 0  |

Converted to save on time and labour spent irrigating

| Reasons for adopting* | 100 | 100 | 0  | 0  | 0  |

Installed to increase flexibility in orchard

| Reasons for adopting* | 92  | 65  | 12 | 21 | 0  |

Installed because of tree health problems

| Reasons for adopting* | 32  | 31  | 8  | 0  | 0  |

Installed because of problems getting water delivered

| Reasons for adopting* | 4   | 9   | 0  | 0  | 0  |

Installed because it best suited soil or topography

| Reasons for adopting* | 36  | 25  | 62 | 0  | 0  |

Installed because of limited water supplies

| Reasons for adopting* | 25  | 20  | 54 | 0  | 0  |

**Notes:** * Numbers are percentage of respondents in each segment nominating reason.

Segments: 1 – Control and time saving redevelopers; 2 – Time-saving converters; 3 – Water-saving micro-irrigators; 4 – Control redevelopers; 5 – Flood irrigators

Source: Adapted from Kaine and Bewsell (2002a: 12-13)
The growers in the fifth segment (flood irrigators) had not installed micro-irrigation and used bay or furrow flood irrigation or under-tree knocker sprinklers. These growers represented 22 per cent of the sample.

The percentage of growers from the different irrigation segments in each district is reported in Table 5.12. In Shepparton the majority of respondents that had installed micro-irrigation belong to segments one and two. This suggested that the main motivations for installing micro-irrigation in the Shepparton district were to save time irrigating, to increase flexibility in managing orchard activities and to redevelop orchards.

In Cobram a relatively high percentage of respondents used under-tree knocker sprinklers to flood irrigate. Those respondents who had installed micro-irrigation were classified into segment four. This indicated the installation of micro-irrigation in the Cobram district was mainly the result of redeveloping orchards to high-density plantings or plantings on trellis.

A relatively high percentage of respondents in Swan Hill use furrow irrigation. Those respondents in Swan Hill who had installed micro-irrigation were classified into the first and second benefit segments. This suggests that respondents in Swan Hill, like those in Shepparton, have installed micro-irrigation to save time and labour, to increase flexibility in managing orchard activities and when redeveloping orchards.

In Tumut and Batlow most respondents had installed micro-irrigation to save water. Consequently, respondents in this district were classified into segment three.

The percentage of respondents in each segment that had employed a consultant to assist them with their irrigation management is also reported in Table 5.12. A significantly higher percentage of respondents in segment three are likely to have used an irrigation consultant or irrigation service. This result seems plausible given the priority these respondents must place on managing irrigation with limited water supplies.
### Table 5.12: Characteristics of benefit segments for micro-irrigation

<table>
<thead>
<tr>
<th>Segments</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shepparton district&lt;sup&gt;1*&lt;/sup&gt;</td>
<td>30</td>
<td>28</td>
<td>11</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Cobram district&lt;sup&gt;2*&lt;/sup&gt;</td>
<td>10</td>
<td>10</td>
<td>17</td>
<td>34</td>
<td>29</td>
</tr>
<tr>
<td>Swan Hill district&lt;sup&gt;3*&lt;/sup&gt;</td>
<td>26</td>
<td>27</td>
<td>2</td>
<td>9</td>
<td>36</td>
</tr>
<tr>
<td>Tumut and Batlow&lt;sup&gt;*&lt;/sup&gt;</td>
<td>14</td>
<td>20</td>
<td>57</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Used irrigation consultants and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>services&lt;sup&gt;*&lt;/sup&gt;</td>
<td>17</td>
<td>17</td>
<td>37</td>
<td>15</td>
<td>4</td>
</tr>
</tbody>
</table>

Notes: Numbers are percentage of respondents in each region except for use of irrigation consultants and services where numbers are percentage of respondents in each segment. An asterisk denotes a statistically significant difference at 0.05 using Pearson’s chi-square test.

1. Includes East Shepparton, Ardmona, Tatura and Kyabram.
2. Includes Invergordon.
3. Includes Tresco, Woorinen and Nyah.

Segments: 1 – Control and time saving redevelopers; 2 – Time-saving converters; 3 – Water-saving micro-irrigators; 4 – Control redevelopers; 5 – Flood irrigators

Source: Adapted from Kaine and Bewsell (2002a: 15-16)
Adoption of soil moisture monitoring

Interviews with fruit growers in the first stage of the case study revealed that only those fruit growers with micro-irrigation and who have continuous access to irrigation water are in a position to take full advantage of objective monitoring of soil moisture to schedule irrigations.

Growers with bay or furrow irrigation do not have sufficient control over the delivery of irrigation water in the orchard to take advantage of monitoring to routinely schedule irrigations but may have used monitoring to help manage a tree health problem caused by a high water table or salinity.

Growers with under-tree knocker sprinklers may use monitoring to help establish appropriate irrigation frequencies and run times to save pumping costs and to manage tree health problems but again are unable to take full advantage of monitoring because they generally cannot irrigate on demand. Similarly, growers with micro-irrigation that could not irrigate on demand were limited to using monitoring to help establish irrigation frequencies and run times, and to investigate tree health problems.

Consequently, respondents were classified into farm contexts for adopting soil moisture monitoring on the basis of their type of irrigation system and whether they could irrigate on demand. A scree test indicated that three segments were present in the sample (Aldenderfer and Blashfield 1984).

The sample was initially partitioned into three farm contexts. Respondents in context one (micro schedulers) consisted of those respondents with micro-irrigation that had continuous access to water supplies. In principle, these respondents would be able to use monitoring to adjust their irrigation schedules on a daily basis. The respondents with this farm context represented 50 per cent of the respondents in the sample.

Respondents in context two (micro monitors) had micro-irrigation but did not have continuous access to water supplies and so were unable to irrigate on demand. These respondents would be able to use monitoring to help establish irrigation frequencies and run times, and to investigate tree health problems. The respondents in this context represented 22 per cent of the sample.

\[\text{The classification analysis was conducted using a monothetic divisive clustering algorithm available in CLUSTAN (Wishart 1987) which is specifically designed for use with dichotomous data. The similarity coefficient used was squared Euclidean distance.}\]
Respondents in context three (flood monitors) did not have micro-irrigation and did not have continuous access to water supplies. These respondents might be able to use monitoring to investigate tree health problems. These respondents represented 28 per cent of growers in the sample.

There were statistically significant differences in the percentage of respondents in each context that had tried and adopted soil moisture monitoring. As expected, the frequency of adoption of soil moisture monitoring was highest among growers in context one (micro schedulers). Also, as expected, the frequency of adoption of soil moisture monitoring was lowest among growers in context three (flood monitors).

Approximately 46 per cent of the growers with the first type of farm context (micro schedulers) had tried soil moisture monitoring. Approximately 40 per cent of these did so because they had a problem with vigour, high watertables or salinity, or because they were growing dwarf rootstocks. The other 60 per cent used soil moisture monitoring to help schedule their first irrigation, to check irrigation performance or to schedule their irrigations. These growers have significantly larger orchards than those growers who had not tried monitoring (71 hectares compared to 21 hectares). The growers in this context that had tried monitoring were also much more likely to have programmable timers than growers that had not (49 per cent compared to 25 percent). One explanation for these results may be that growers with larger orchards used soil moisture monitoring to periodically check irrigation performance and reprogram their irrigation timers accordingly. Only six per cent of the growers in this context that had tried monitoring did not find it helpful.

Approximately 38 per cent of growers in the second type of farm context (micro monitors) had tried soil moisture monitoring. Of these, 20 per cent had adopted monitoring because they had a problem either with tree vigour, watertables or salinity, or they had planted dwarf rootstocks. Nearly 36 per cent of respondents in this farm context that had tried monitoring found that it was not much use or took up too much time. The remaining growers in this farm context that used monitoring used it primarily to help decide when to start the irrigation season. Only 12 per cent of growers in the third farm context (flood monitors) had tried soil moisture monitoring.

31 The overall rate of adoption of soil moisture monitoring by district was consistent with the results reported by Boland et al (1998).
These results indicate that the population of potential adopters of objective monitoring of soil moisture consisted primarily of fruit growers with a farm system that includes micro-irrigation and continuous access to water: approximately 50 per cent of the respondents in the sample. The penetration of this population is substantial with approximately 46 per cent of these growers having adopted objective monitoring of soil moisture.

**Extension**

The results indicated that respondents in the different benefit segments for micro-irrigation and the different farm contexts for soil moisture monitoring had different information needs but there were some unifying themes from an extension perspective. Extension strategies and priorities were formulated in a workshop with Department staff involved in horticultural extension. In the workshop the results of the case study were combined with the knowledge and experience of Department staff using, as in the case study above, a program logic approach (Mayeske 1994).

Workshop participants identified a number of problems that might cause fruit growers with flood or micro-irrigation to be dissatisfied with their irrigation management. The response to most problems with flood irrigation, such as a shortage of labour or high water tables, was to install micro-irrigation. Consequently, the problems that were identified in the workshop concerned difficulties either in converting from flood to micro-irrigation or difficulties in managing micro-irrigation systems once installed. As a result, many of the problems that were identified were not specific to a particular benefit segment. The factors were classified into the following broad categories:

- Managing change. Growers changing from flood irrigation could experience problems in managing micro-irrigation of young trees if they were redeveloping their orchards or if they were converting established trees to micro-irrigation. There was also potential for problems to occur with poor irrigation designs and with planning the development of the orchard from flood to micro-irrigation systems.

- Technical issues. This category covered problems such as excessive tree vigour, hares chewing lines, post harvest maintenance and soil acidity. It also
included problems with pump failures, blockages of filters and lines, and power supplies.

• Infrastructure issues. Growers may experience difficulties with irrigation management as a result of poor water quality or delays in water deliveries. The workshop participants agreed that the role of an extension program in dealing with infrastructure issues was extremely limited. Infrastructure issues were seen to be the responsibility of the regional water authority.

• Retraining. For some growers there may be a need to retrain staff to manage micro-irrigation systems although the workshop participants agreed that retraining was not a major issue for most growers.

Given these considerations the use of soil moisture monitoring could be encouraged among fruit growers by:

• Promoting soil moisture monitoring as a technique for developing irrigation schedules for newly installed micro-irrigation systems.

• Promoting soil moisture monitoring as a technique for checking irrigation performance, especially among larger growers.

• Promoting soil moisture monitoring as a technique for managing problems with salinity or water tables, excessive tree vigour or dwarf rootstocks.

• Providing advice and assistance in siting and calibrating soil moisture monitoring and in utilising monitoring information more effectively.

Briefly, the extension strategies that emerged from the workshop were that:

• An extension strategy should be developed to facilitate the change from flood to micro-irrigation by providing advice and assistance to fruit growers on the choice and design of micro-irrigation systems. In developing this strategy consideration should be given to the possibility of pursuing this strategy in conjunction with suppliers of irrigation equipment and services.

• An extension strategy should be developed to facilitate the change from flood to micro-irrigation by providing advice and assistance on the management of micro-irrigation systems when they are first installed. In developing this strategy the different information needs of growers will vary. Growers that are
converting established orchards will have different needs compared to growers that are redeveloping their orchards. In developing this strategy consideration should be given to involving suppliers of irrigation equipment and services.

- Strategies for facilitating the change from flood to micro-irrigation include recommendations to growers to use soil moisture monitoring to help establish irrigation schedules for newly installed micro-irrigation systems.

- An extension strategy should be developed to provide assistance to growers in choosing and installing soil moisture monitoring equipment and in interpreting monitoring data.

- An extension strategy should be developed to promote the use of soil moisture monitoring as a technique for managing problems such as high water tables or excessive tree vigour.

- An extension strategy should be developed for promoting the use of soil moisture monitoring as a technique for checking the effectiveness of irrigation schedules.

- Where possible extension strategies for promoting the adoption of soil moisture monitoring should be directed initially toward growers with relatively large orchards and growers with micro-irrigation and continuous access to water supplies

The extension strategies for each irrigation benefit segment are summarised in Table 5.13 and the extension strategies for the farm contexts in relation to soil moisture monitoring are reported in Table 5.14.

The extension strategies were validated by conducting a final round of unstructured interviews with fruit growers from the different benefit segments in the Shepparton district. The growers were identified from the contact details they supplied when completing the survey questionnaire. These interviews were also used to verify the classification of the growers into benefit segments for micro-irrigation and farm contexts for soil moisture monitoring.
Table 5.13 Extension strategies developed for irrigation system benefit segments

<table>
<thead>
<tr>
<th>Segments</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing young trees&lt;sup&gt;2&lt;/sup&gt;</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Managing established trees&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Working with designers to ensure good system design&lt;sup&gt;2&lt;/sup&gt;</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Technical advice&lt;sup&gt;1,2&lt;/sup&gt;</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Notes:
1. Technical advice covers issues such as excessive tree vigour, hares chewing lines etc, particularly emphasising the links between fruit quality, vigour and irrigation management.
2. Fruit growers in segment five should be targeted when converting to one of the other segments.

Segments: 1 – Control and time saving redevelopers; 2 – Time-saving converters; 3 – Water-saving micro-irrigators; 4 – Control redevelopers; 5 – Flood irrigators

Source: Kaine and Bewsell (2002b: 17)
Table 5.14 Extension strategies developed for monitoring farm contexts

<table>
<thead>
<tr>
<th>Contexts</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using monitoring for developing schedules&lt;sup&gt;1,3&lt;/sup&gt;</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using monitoring for predicting schedules&lt;sup&gt;2,3&lt;/sup&gt;</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Promote monitoring as a check for irrigation performance&lt;sup&gt;3&lt;/sup&gt;</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Tool for managing problems (e.g. water tables, salinity)&lt;sup&gt;3&lt;/sup&gt;</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Siting and calibrating advice&lt;sup&gt;3&lt;/sup&gt;</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Notes:
1. These fruit growers will be able to schedule on a daily basis if necessary given they have water on demand.
2. Developing schedules for these fruit growers will have more of a predictive element as these growers do not have water on demand.
3. Fruit growers in context three should be targeted when converting to one of the other segments.

Contexts: 1 – Micro schedulers; 2 – micro monitors; 3 – Flood monitors

Source: Kaine and Bewsell (2002b: 21)
The validation interviews confirmed and reinforced the earlier findings of the case study and the context-specific priorities for extension. All the growers that were interviewed indicated that they had experienced some initial problems with micro-irrigation. The growers also indicated they had overcome these problems within a season or two through trial and error learning and discussions with other growers and with irrigation equipment suppliers. None of the growers indicated that they had experienced any long-term problems and all were satisfied with their current irrigation system and management. These results are consistent with the views expressed by the growers that were interviewed in the first stage of the case study.

Conclusion
At the time this case study was conducted best management practices were being identified to improve the efficiency of water use in irrigated horticulture and the use of objective monitoring of soil moisture was seen to be critical to the successful adoption of these best management practices. However, efficient water use was not identified as a key benefit influencing the adoption of micro-irrigation by the majority of fruit growers.

Hence, efforts to promote the benefits of adopting micro-irrigation, objective monitoring of soil moisture and the associated best management practices should not have simply focused on highlighting gains in water use efficiency. This was especially the case as the growers in Tumut and Batlow, which were most likely to be interested in increasing efficiency to save water, had already adopted micro-irrigation and objective monitoring of soil moisture.

For most growers the key benefits influencing the adoption of micro-irrigation were a need to reduce time spent irrigating, a desire to increase flexibility in managing irrigation, spraying and harvesting activities, and a desire to increase productivity and profitability by redeveloping orchards to closer planting or trellis designs. This meant the population of potential adopters of micro-irrigation was determined by factors that influenced these benefits. Such factors may have included changes in family composition which influenced labour availability, changes in the scarcity of irrigation water and the reliability of delivery of irrigation water, and the development of orchards in areas unsuited to furrow irrigation. Consequently, the role of extension in
increasing the rate of adoption of micro-irrigation was to facilitate the process of changing from flood to micro-irrigation once circumstances prompted growers to make the change.

Generally, interest among growers in objective monitoring of soil moisture was limited because increasing water use efficiency was not a key concern for most growers. Only 50 per cent of growers were in a position to take full advantage of soil moisture monitoring as only they had micro-irrigation and continuous access to water supplies. This indicated that the population of potential adopters of objective monitoring of soil moisture was only likely to change when irrigation infrastructure was up-graded to supply water continuously or when growers installed dams to control the availability of irrigation water. Hence, the return to efforts to increase the rate of adoption of soil moisture monitoring by highlighting gains in water use efficiency were likely to be limited. There may have been some value to promoting soil moisture monitoring equipment as a means of facilitating the change from flood to micro-irrigation. However, most growers appeared capable of establishing irrigation schedules for newly installed micro-irrigation systems without too much difficulty.

The results of this case study support the proposition that the population of potential adopters of micro-irrigation and techniques for the objective monitoring of soil moisture depend on elements in the farm system that influenced the benefits to be had from the adoption of these innovations. The results from the quantitative stage confirmed the findings from the qualitative stage of the approach in that benefit segments were identified for the adoption of micro-irrigation and farm contexts were identified for the adoption of objective monitoring of soil moisture.

The results indicated that, in contrast to the belief that motivated the case study, a relatively high percentage of the potential population of adopters had adopted techniques for objective monitoring of soil moisture. This was consistent with the proposition that irrigation of fruit trees would be highly involving for respondents and, as a consequence, they would be likely to have devoted time and effort to identifying the irrigation system and suite of practices that best suited their circumstances, including the adoption of objective monitoring of soil moisture.
5.3.3 Adoption of sheep breeding technologies

Selection criteria
This case study is an example of the adoption of an agricultural innovation by extensive dryland livestock enterprises. The study was selected as the elements of the farm system that constituted the farm context for the adoption of quantitative techniques for selecting sheep were largely perceptual. The techniques are relatively complex and extremely difficult to trial because errors in ram selection can have severe, long-term consequences that are extremely difficult to reverse. The benefits in terms of improved flock productivity are difficult to observe as they are only apparent after a number of seasons. The breeding principles underpinning these techniques were not always compatible with producer’s experiences. This case study included validation interviews (Kaine and Niall 2001b) and the original Victorian study was repeated and extended in a later, national study (Kaine et al. 2006).

Background
Breeding decisions are crucial management decisions in wool enterprises. Key steps in improving production through a breeding program are the identification and use of the best genetic material to achieve the breeding goal of the wool producer. In the wool industry, there are substantial genetic differences in productivity between sheep studs (Coelli et al. 1996; Pollard et al. 2002). Consequently, many wool producers may be able to improve the productivity of their flocks by changing studs, provided the choice of stud is made with reliable data. A variety of methods have been developed to objectively measure the characteristics of wool, and techniques for using these measures to select the most productive rams for breeding, such as index selection and bloodline comparisons, have been developed. At the time this case study was conducted researchers and extension staff in government and industry organisations were concerned that, although these selection techniques had been available for many years, their adoption was not as widespread as they wished.

---

32 This section is a revision of, and contains material directly reproduced from, Kaine and Niall (2001b) and Kaine et al. (2006). The studies reported in this section were supported by grants from the Australian Research Council, the Victorian Department of Natural Resources and Environment, and Australian Wool Innovations Ltd.
At the same time, an innovative technique for selecting rams for breeding based on subjective assessments of the staple characteristics of their wool had recently been developed. This method had been adopted by many wool producers and was spreading rapidly through the industry.

The objective in this case study was to identify the population of potential adopters of objective techniques for selecting bloodlines and rams, primarily breeding indexes and bloodline comparisons. This knowledge was to be used to develop extension strategies promoting more widespread adoption of objective techniques for selecting rams among wool producers in Victoria.

**Qualitative stage**

Following the approach described in the preceding chapter, convergent interviewing was used in the first stage of the case study to identify the elements in the farming systems of commercial wool enterprises that defined the farm context for adopting the different techniques for choosing studs and selecting rams. In-depth, unstructured personal interviews were conducted with approximately fifty wool producers and were conducted as described in the preceding chapter with two interviewers present at each interview.

The wool producers who took part in the interviews were nominated by research and extension staff of the Victorian Department of Primary Industries, industry consultants and stock and station agents. These producers were selected for interviewing because they purchased rams from studs that used different breeding techniques, and they represented a variety of locations and sheep enterprises of different scales.

The interviews revealed that breeding management generally, and the selection of rams in particular, were highly involving issues for wool producers. The management of breeding was a critical determinant of wool production and farm income, and poor selection choices could severely reduce the productivity of a flock for some years.
Risk factors in selecting studs and rams

From these interviews it emerged that the key issue for wool producers was to reduce the difficulty of predicting the outcome of introducing a stud ram into their commercial ewe flock. Wool producers believed a number of risk factors contributed to their difficulties in predicting these outcomes.

First, wool producers believed that when a stud ram is introduced to a commercial ewe flock the characteristics of the progeny will depend partly on environmental differences between the stud and the wool growing property. Many wool producers believed the influence of the environment is so strong that a superior bloodline in one environment can be decidedly inferior in another environment.

Second, wool producers believed that when a stud ram is introduced to a commercial ewe flock the characteristics of the progeny would also depend on genetic interactions between the stud ram and the ewe flock. Many wool producers believed these interactions can be strong enough to ruin the performance of an apparently superior sire.

Third, wool producers believed that when a stud ram is introduced to a commercial ewe flock the characteristics of the progeny also depend on differences in livestock management between the stud and the commercial woolgrower. Many wool producers believed the influence of management was so strong that a superior bloodline under one management regime can be decidedly inferior under another management regime.

Wool producers varied in their perceptions of how influential these factors were depending on their individual backgrounds and experiences. Most growers believed, for example, that environmental conditions have a major impact on traits such as susceptibility to fleece rot or resistance to internal parasites. However, while some growers believed that environmental conditions have a major impact on the relative fibre diameter and fleece weight of different sheep bloodlines, others discounted this possibility.

The effects on sheep of changing their environment are categorised into two types: scale effects and ranking effects (Woolaston 1987). A scale effect occurs when a change in the environment produces an absolute change in a trait but the relative performance of sheep from different bloodlines remains unchanged. A ranking effect
occurs when a change in environment produces different changes in the traits of sheep such that the relative ranking of different bloodlines is changed.

There is both empirical (Dominik et al 1999; Hatcher et al 1999) and anecdotal evidence for the presence of scale effects. However, while there was widespread acceptance among the wool producers that were interviewed of the presence of ranking effects among bloodlines, this is not entirely supported by the scientific literature. This literature suggests that while ranking effects are present for certain characteristics, such as susceptibility to fleece rot and resistance to parasites, ranking effects do not appear to be significant among bloodlines with respect to fibre diameter and fleece weight. However, there is some doubt as to whether the scientific evidence is conclusive (Woolaston 1987).

Both ranking and scale effects can lead to errors when a selection index is used to make bloodline choices (Woolaston 1987). A selection index is a weighted combination of desirable traits such as fleece weight and fibre diameter that are measurable. The weights are chosen by the sheep breeder and reflect the relative importance the breeder places on each trait (Windsor 2003). Ranking and scale effects can introduce errors into selection index scores because measurements of traits, and the strength of the association between these measurements, will change across environments. As a consequence, selection index scores for different bloodlines will change depending on the environment in which the measurements are taken, thereby changing the relative desirability of different bloodlines.

Fourth, the interviews also revealed that wool producers had different opinions about the reliability of the relationship between skin traits such as wool follicle size and density, and objectively measured characteristics such as fleece weight and fibre diameter. Growers also had different opinions about the strength of the relationship between traits such as follicle size and density, and fleece characteristics such as crimp frequency and definition, and staple structure. Differences in producers’ opinions about these relationships produced differences in their beliefs about the correct criteria for choosing studs and selecting rams, particularly with regard to the relative merits of using objective measures of fleece characteristics and subjective assessments of staple characteristics to select rams.
Producers were convinced that the most fundamental breeding decision they must make was to choose a strategy to counteract the risks and uncertainties involved in comparing rams from different bloodlines under different environments, and choosing a ram that would suit the conditions on their property. The differences among producers in their views on the influence on ram performance of the four factors described meant that they had different views on the risks entailed in comparing the measured performance of bloodlines and in choosing rams.

In the terms of complex decision making, wool producers’ beliefs about these risk factors, and the strategies they use to counteract them, constituted their criteria for evaluating different bloodlines and choosing one that would suit the conditions on their property. This meant that the key to understanding the adoption of new breeding techniques by wool producers lay in understanding their perceptions of these risk factors and the strategies that they choose to combat them, as these strategies determined the set of studs they considered as potential ram suppliers. The strategies also determine the value and relevance to the woolgrower of the various breeding practices and techniques that were available. Each of the strategies for counteracting the risk factors is described next.

Strategies for countering risk factors in selecting studs and rams

The interviews revealed that wool producers employed a number of different breeding strategies depending on whether or not they believed that changing environments created ranking effects with respect to fibre diameter and fleece weight.

Bloodline comparison strategy

Producers who believed that environmental conditions cannot change the ranking of bloodlines, at least in terms of fibre diameter and fleece weight, were likely to believe that the performance of bloodlines could be generalised from one environment to another. The outcome of this belief was that, in principle, rams could be safely purchased from studs outside the producer’s district that operated in different environments. Consequently, these producers indicated they were likely to be interested in techniques for choosing a bloodline that utilised comparisons of bloodlines across different environments. However, measurements of fibre diameter and fleece weight cannot be directly compared across environments because of the
presence of scale effects. Consequently, legitimate comparisons across environments required testing all candidate bloodlines in one environment, or testing subsets of bloodlines in different environments while using at least one bloodline in two or more environments as a link to enable the results for all bloodlines to be standardised across environments.

These producers were likely to regard across-environment bloodline comparisons of using wether trials with link teams (Atkins et al. 1992; Atkins et al. 1995; Casey et al. 1998) and central sire evaluation with link sires, which involves progeny testing, (Coelli 1998; Swan et al. 1998) as useful because sheep at a particular site were being compared under identical management conditions. Producers who believed ranking effects were unimportant were likely to accept the rationale underlying the use of link teams or link sires to make across-site comparisons. Although environmental and management conditions at different sites may differ substantially from conditions on the producer’s property, these differences were regarded as irrelevant in terms of fibre diameter and fleece weight because the focus was on relative performance for these two traits. These producers would need to make allowances, of course, for differences in the impact that environmental and management conditions may have on other traits such as susceptibility to fleece rot.

The purchase of rams using a strategy based on bloodline comparisons across different districts means rams can only be purchased from bloodlines that were entered in appropriately designed wether trials, or had participated in central sire evaluations and were from studs that had adopted performance recording.

**Stable characteristics strategy**

A range of strategies were used by producers who believed that environmental conditions can change bloodline rankings in terms of fleece weight and fibre diameter. One of these strategies was to select rams from a bloodline that the producer believed was relatively insensitive to changing environments. There were two approaches to implementing this strategy.

One approach was to purchase rams from studs whose stock were reputed to perform satisfactorily across a number of districts. Good performance across a number of environments might signal a degree of stability in the performance of the bloodline in different environments. This stability could be interpreted by the producer as
providing a measure of confidence in the performance of the bloodline in the producer’s environment. These producers may have relied on a number of information sources to evaluate bloodlines including central sire evaluations, wether trials, observation at field days, and the opinions of sheep classifiers, wool broker representatives and other growers.

These wool producers were likely to regard across-environment bloodline comparisons of merinos using wether trials and central sire evaluation as useful because sheep at a particular site were being compared under identical management conditions. However, these producers may not have accepted the rationale underlying the use of link teams or link sires to make across-site comparisons. Instead these producers would have tried to identify bloodlines or sires that rank highly in trials across a number of sites. In other words, they would tend to select rams on the performance of bloodlines or sires that appeared in a number of trials. Hence, these producers would tend to focus on comparisons of the performance of link teams or sires. These producers would need to make allowances for differences that the ewe base and environmental and management conditions may have on wool and other traits.

The second approach draws on producers’ beliefs about traits such as the size and density of skin follicles. The production of wool is a function of the size and density of wool follicles in the skin of sheep and the literature suggests that sheep with higher proportions of secondary to primary skin follicles will produce finer wool than sheep with lower proportions of secondary to primary follicles (Hynd 1995; Clarke et al. 1997). However, there was disagreement among producers concerning the best method for selecting sheep with a high follicle density and a high ratio of secondary to primary skin follicles. Some believed that such sheep could be identified using objectively measured fleece characteristics such as fleece weight and fibre diameter. However, others believed that sheep with a high follicle density and a high ratio of secondary to primary skin follicles could not be identified from measures of fleece weight and fibre diameter alone. These producers believed sheep with these skin traits could only be identified using subjective assessments of fleece characteristics such as soft handling, low crimp frequency, high crimp definition, long staples and ‘thin’ locks (Watts 1995; Clarke et al. 1997).
The belief that sheep with a high follicle density and a high ratio of secondary to primary skin follicles can be identified accurately using subjective assessments of fleece characteristics such as handle, crimp frequency and definition, and staple length raises a number of possibilities. First, there was the possibility that producers could use these characteristics to identify sheep that will produce finer, heavier and more uniform fleeces than sheep without these characteristics. That is, producers could use these fleece characteristics to identify what were commonly termed ‘productive’ or ‘elite’ sheep. This belief was independent of beliefs about a change in environment implying a change in the ranking of bloodlines.

The second possibility was that a strategy of purchasing sheep that have relatively high skin follicle density and a relatively high ratio of secondary to primary skin follicles could be used to reduce sensitivity to the scale and ranking effects of changing environments. The reasoning behind this possibility appeared to be as follows. Sheep with primary and secondary follicles of similar size, a high ratio of secondary to primary follicles and a high follicle density will produce finer, heavier and more uniform fleeces than sheep without these characteristics. Sheep with these characteristics will tend to respond to a change in environment mainly through changes in staple length. In principle, the fibre diameter of sheep with these characteristics should be relatively resistant to plausible variation in environmental conditions. Hence, some producers that were interviewed believed that ‘productive’ or ‘elite’ sheep were less sensitive to changing environments as well as being more likely to produce finer, heavier and more uniform fleeces than other sheep. In addition, sheep with these follicle characteristics were also believed to have other desirable attributes such as greater resistance to dust penetration. Hence, the selection of sheep with ‘elite’ characteristics was seen by some producers as an alternative approach to reducing the risk of changes in bloodline rankings due to changing environments.

Note that some producers purchased rams from studs that selected sheep on the basis of subjective assessments of skin traits simply because they believed that wool processors favoured the type of wool these sheep produced – wool that was bold, deep-crimping and long-stapled. They believed that processing margins on these wools should be lower because they produce a more even, stronger yarn with fewer breakages. They also believed these wools produced softer, more comfortable fabrics.
Some producers believed that, to reach their full potential, sheep with highly
developed skin traits need a high level of nutrition. Consequently, some of these
producers believed it was not worthwhile adopting this approach to breeding because
they were unable to offer appropriate levels of nutrition.

Note that, in principle, beliefs about the reliability of the relationships between
subjectively-assessed and objectively-measured fleece characteristics and important
skin traits such as follicle size and density were independent of beliefs about the
ranking effects of environmental conditions. Hence, producers could change their
beliefs about the reliability of the relationships between subjectively-assessed and
objectively-measured fleece characteristics and desirable skin traits without
modifying their beliefs about the ranking effects of environmental conditions.
Producers could also switch to breeding ‘elite’ sheep without changing their beliefs
about the potential to breed sheep that were less sensitive to environmental change
than others by identifying sheep that suit a wide range of conditions. Hence, the shift
to breeding sheep with ‘elite’ characteristics did not require producers to reverse any
of their other beliefs about the risk factors in sheep breeding.

**Same environment strategy**

Another strategy to deal with the influence of environment was to purchase rams only
from studs located in the producer’s district. A variant of this strategy was to
purchase rams from studs outside the district that have sold rams to other producers in
the district that have performed well. Another possibility was simply to purchase
rams from studs in any district with an environment that was judged to be similar to
that of the producers.

The producers who followed these types of strategies were likely to be uncomfortable
with selection techniques that involved comparing sheep across environments. They
would discount for example, the results of bloodline comparisons based on wether
trials or centralised sire evaluation. These producers were sceptical of such
comparisons because the rationale underlying the use of link teams and link sires to
make comparisons across environments contradicted their beliefs that changing
environments changes bloodline rankings and that bloodlines could not be bred that
were insensitive to plausible differences in environments. On the other hand, these
producers may have regarded bloodline comparisons, such as wether trials conducted
in their district, as useful. This was because such trials were conducted under local conditions and management. These producers would need to make allowances for differences in their ewe base and management conditions compared to the studs.

**Stud reputation strategy**

Some producers who believed the environment had an important influence on the ranking of bloodlines followed a strategy of selecting a bloodline simply on the basis of reputation. These producers were relying on the commercial success of a stud over an extended period of time as a signal that the bloodline generally performed well. Indicators of success included a distinguished bloodline history, awards at shows, and continued high prices for rams. High demand for the progeny of a stud over a sustained period of time suggested that many producers had a high regard for the performance of the bloodline. This strategy might be especially effective for those producers that wished to limit the time and effort spent on choosing a bloodline.

The producers who followed these types of strategies were likely to be uncomfortable with practices that involve directly comparing sheep across environments. They may have regarded bloodline comparisons such as wether trials conducted in their district as useful.

**Progeny testing strategy**

In principle, woolgrowers could compare the merits of different bloodlines by undertaking on-farm progeny testing (Roberts 1997). This involved testing the performance of rams that have been purchased from a stud by evaluating the characteristics of their progeny. Sires that produce progeny with unsatisfactory characteristics were culled. Sires producing progeny with satisfactory characteristics were retained and used as flock rams.

Since rams from different bloodlines were performing under identical conditions they could be compared free of any scale and ranking effects due to differences between the farm and stud environments. As the comparisons were based on evaluations of their progeny these comparisons also incorporated the effects of genetic interactions between ewes and rams. Basically, progeny testing on-farm is a method for comparing rams from different bloodlines or studs. However, it does not provide a strategy for choosing which studs to compare.
Although on-farm progeny testing can be undertaken by commercial wool producers, many producers who were interviewed indicated that they did not have a flock of suitable size, the appropriate farm layout or sufficient time and labour to conduct such tests. In addition, progeny should be evaluated as hoggets (Roberts 1997). This means stud rams would be three years old, and running on the farm for nearly two years, before the decision to keep or cull them was reached. This would limit the commercial life of stud rams on the property to only three or four years. Also, progeny testing on-farm generally did not allow reliable comparisons of bloodlines under typical commercial conditions. This was because few commercial producers purchased sufficient numbers of rams within a season for reliable comparisons to be made. These constraints meant that relatively few commercial producers used progeny testing.

**Genetic interactions between rams and ewes**

Producers indicated that there were two principal strategies for counteracting the risks associated with genetic interactions between rams and ewes. One strategy was to purchase rams from a stud that had limited the introduction of new bloodlines into its flock for many years. Such studs were often termed ‘closed’ studs. This strategy was based on the idea that consistent selection pressure applied over many years had reduced the genetic variation in a flock. Consequently, rams from such a stud would perform similarly with a given ewe flock because they had similar genetic histories.

The second strategy was to purchase rams from studs of the same bloodline as the ewe flock. In this way woolgrowers could approximate the genetic base of the target bloodline. Consequently, rams purchased from the target bloodline should perform similarly with the grower’s ewe flock because they had similar genetic histories. Growers wishing to change bloodlines purchased cast-for-age ewes from the same bloodline as the rams they wished to purchase.

The value of using index selection in a ewe flock depended largely on the quality of the flock, and on culling percentages which were determined by the lambing rates. Typically, the culling rates in commercial wool growing enterprises are fairly low (Casey 1997). Consequently, most culls were easily identified using visual appraisal. The majority of culls were identified on the basis of poor feet, conformation, growth or presence of black or hairy fibres in the fleece. The limited capacity to cull ewes
meant that visual assessment of gross characteristics was the only practical approach to ewe selection. In such circumstances, genetic improvement of the flock depended largely on the characteristics of the rams purchased by the producer.

Where culling rates were higher the value of index selection depended on the diversity of the characteristics of ewes in the flock. The greater the variety in the flock, the more likely culls could be reliably identified using visual assessment and the less likely expenditure on objective measurement could be justified (Casey 1997). The more uniform the flock the more likely that culls could not be determined solely by visual assessment. Selection on the basis of objective measurements of fleece weight and fibre diameter may have been justified. However, the more uniform the flock, the smaller the gain from culling. Consequently, a cast-for-age culling policy may have been warranted. Where the flock was reasonably uniform the greatest potential for genetic improvement of the flock again lay with the characteristics of the rams purchased by the producer.

**Management differences**

Producers knew that livestock management could dramatically affect the characteristics of rams and ewes. Whether they distinguished these effects into scale effects and ranking effects was not clear. Producers recognised that the reliability of measurements of fibre diameter depended on factors such as the age of the sheep at the time the measurements were taken, and management practices. Consequently, they treated measures of fibre diameter and fleece weight with caution. They realised direct comparisons between studs could not be made because differences in management could disguise bloodline differences. Even comparisons of rams within the same stud had to be made with care because misleading differences in characteristics between generations could arise from changes in management over time.

In the interviews producers indicated that there were few tactics they could use to offset the effects of differences in management. One tactic was to seek out studs that had a reputation for running rams under management conditions that were similar to the conditions under which commercial flocks are run. A second was to assess the performance of the studs’ commercial flock. A third was to purchase rams from studs that had comparable pasture systems and cropping systems.
Quantitative stage

A mail survey based on the findings from the interviews was developed, piloted and then distributed to wool producers in Victoria. The purpose of the survey was to obtain estimates of the population of potential adopters of techniques for choosing studs and selecting rams, especially in regard to central sire evaluation and subjective assessment of the staple characteristics.

Preliminary versions of the questionnaire were trialled with 25 wool producers. Comments and advice on the questionnaire was also obtained from staff of the Victorian Department of Natural Resources and Environment. The revised questionnaire was piloted with a further 21 wool producers before being distributed. The survey questionnaire was mailed to producers in the form of a 16-page booklet. The booklet was accompanied by a covering letter describing the purpose of the survey and providing contact details.

The questionnaire was divided into three sections. In the first section information was sought on basic property and enterprise characteristics such as property area and district, rainfall, numbers of rams, wethers and ewes, lambing and weaning percentages, wool cut per head, and so on. The second section was designed to elicit information on risk factors such as respondents’ beliefs about the presence of ranking effects with respect to fibre diameter and fleece weight and the criteria respondents used when choosing studs. Respondents’ answers to the questions in this section were to be used to classify them into farm contexts with respect to the adoption of ram selection techniques. The third section was designed to elicit information on issues such as respondents’ beliefs about the relative merits of visual characteristics, objective measurements, indexes and district wether trials as aids in selecting sheep. Respondents’ answers to the questions in this section were used to validate the results of the classification analysis.

Some 3,900 surveys were distributed by mail throughout Victoria during July 2000 using a mailing list of wool producers selected at random that was supplied by a market research company. A reminder was posted four weeks later. The mailing list included specialist lamb producers as well as wool producers. A total of 1,117 surveys were returned within some ten weeks of the initial mailing. Over 680 surveys were returned because the recipients were not wool producers. A further 436 surveys were returned completed. If all non-respondents were wool producers then the
response rate among wool producers was only 14 per cent. However, if the proportion of producers among non-respondents was similar to the proportion among respondents, then the response rate among wool producers was 29 per cent.

The general characteristics of the sample are reported in Table 5.15. Merino wool production was the major enterprise on most farms in the sample and approximately 20 per cent of farms in the sample were sheep studs. The majority of respondents, over 60 per cent, were wool producers from the Western Districts of Victoria. Another 20 per cent of respondents were from central and northern Victoria with the remaining respondents being producers from Gippsland and the Wimmera.

The respondents reported that they produced wool that ranged in diameter from 15 microns to 28 microns, averaging 20 microns. The wool cut per head reported by the woolgrowers in the sample ranged from 2 to 9 kilograms per head, averaging 5.2 kilograms per head. This was consistent with an average fleece weight of 4.0 kilograms per head reported for the Victorian flock in 1998/99 (ABARE 1999).

Altogether, the sample represented about 2.8 per cent of wool and lamb producers in Victoria running approximately 4.3 per cent of the State flock and producing over 5.7 per cent of the State’s wool (derived from ABARE 1999).

**Farm contexts for stud choice and ram selection**

Interviews with producers indicated that their choice of breeding strategy was governed by their beliefs about the risks involved in introducing a stud ram into a commercial ewe flock. The most important risk factors identified were:

- The impact of environment on the ranking of bloodlines in terms of fibre diameter and fleece weight
- The likelihood that fleece characteristics such as crimp definition and frequency and aligned fibres are more reliable indicators of traits such as wool follicle size and density than are objective measurements of fibre diameter and fleece weight
- Genetic interactions between rams and ewes
- Differences in livestock management between the stud and the commercial producer.
Table 5.15 Characteristics of wool enterprises

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sheep flock:</strong></td>
<td></td>
</tr>
<tr>
<td>Mean number of Merino rams used each year</td>
<td>25</td>
</tr>
<tr>
<td>(head)</td>
<td>(0 – 230)</td>
</tr>
<tr>
<td>Merino wethers (head)</td>
<td>1,429</td>
</tr>
<tr>
<td></td>
<td>(0 – 10,000)</td>
</tr>
<tr>
<td>Merino ewes (head)</td>
<td>2,013</td>
</tr>
<tr>
<td></td>
<td>(0 – 14,414)</td>
</tr>
<tr>
<td><strong>Breeding:</strong></td>
<td></td>
</tr>
<tr>
<td>Number of ewes to be joined (head)</td>
<td>1,574</td>
</tr>
<tr>
<td></td>
<td>(0 – 13,500)</td>
</tr>
<tr>
<td>Weaning percentage (%)</td>
<td>80.1</td>
</tr>
<tr>
<td></td>
<td>(25.0 – 105.0)</td>
</tr>
<tr>
<td>Culling rate for maiden ewes (%)</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td>(0.0 – 80.0)</td>
</tr>
<tr>
<td><strong>Wool production:</strong></td>
<td></td>
</tr>
<tr>
<td>Average fibre diameter of flock (micron)</td>
<td>19.9</td>
</tr>
<tr>
<td></td>
<td>(15.5 – 28.0)</td>
</tr>
<tr>
<td>Average wool cut per head (kg)</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>(2.0 – 9.0)</td>
</tr>
</tbody>
</table>

Note: Values in parentheses are ranges.
Source: Kaine and Niall (2001b: 23)
Respondents were questioned about these risk factors and the strategies they employed to counteract them in the survey. With regard to beliefs about the ranking effects of the environment, respondents were provided with a scenario in which testing had shown that sheep from one bloodline produced significantly finer wool than sheep from another bloodline. A series of four statements were provided which were designed to elicit information on the conditions under which respondents believed it would be valid to infer that the relative performance of the two bloodlines would remain the same (see Table 5.16). A similar scenario concerning ranking effects on fleece weight was also included in the survey.

Respondents’ beliefs about the other risk factors in sheep breeding were elicited by asking them to rate the importance of a list of reasons for choosing a stud (see Table 5.17). These reasons reflected the various strategies that were identified by producers for counteracting the risk factors in sheep breeding. Hence, they provided an insight into respondents’ perceptions of these factors. The results indicated that there was a wide range of opinions among growers about what reasons were very important in choosing a stud. This was consistent with past studies such as Butler et al. (1995).

The reasons that were nominated most frequently as being very important when choosing a stud were a longstanding reputation for producing quality rams, an emphasis on skin traits and a reputation for breeding productive sheep. A relatively high percentage of respondents also nominated an emphasis on skin traits and a reputation for breeding sheep that will do well under most conditions as being very important.

The only reason that the majority of respondents rated as being unimportant was location in producer’s own district. A substantial percentage of respondents indicated they believed selling rams to other producers in the district and selling to producers across a number of districts were not important in choosing a stud.

There was a general consensus among respondents that similarity of climate, reputation for quality, an emphasis on skin traits, the use of selection indexes and participation in bloodline performance analysis and sire evaluation schemes were important influences on stud choice. Yet, more than one third of respondents
**Table 5.16** Ranking scenario for ranking affects and fibre diameter

Suppose a friend of yours has used rams from two different bloodlines. The progeny of one bloodline, Pharaoh Park, test significantly finer than the progeny of the other, Caesar Station. You have not seen sheep from either bloodline and you have no other information about them.

Do you agree or disagree with the following statements?

*(Please tick the box that comes closest to how you feel about each statement)*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you used these bloodlines on your property the Pharaoh Park progeny will always be finer than the Caesar Station progeny.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>It would be very difficult to predict which bloodline’s progeny would be finer on your farm.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provided they stay in a similar environment the Pharaoh Park progeny will continue to be finer than the Caesar Station progeny.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Even though the Pharaoh Park progeny may be finer and cut a similar fleece weight to the Caesar Station progeny, it is impossible to predict which are the better sheep for your farm.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Kaine and Niall (2001b: 63)
Table 5.17 Respondents ratings of criteria for choosing studs

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Very important</th>
<th>Important</th>
<th>Not important</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like to buy from a stud in my own district</td>
<td>11</td>
<td>34</td>
<td>55</td>
</tr>
<tr>
<td>I like to buy from a stud in a district with a climate similar to my own.</td>
<td>31</td>
<td>51</td>
<td>18</td>
</tr>
<tr>
<td>I like to buy from a stud with a longstanding reputation for producing quality rams.</td>
<td>53</td>
<td>35</td>
<td>12</td>
</tr>
<tr>
<td>I like to buy from a stud that sells rams to woolgrowers across a number of districts because I can be pretty sure their rams will do well under most conditions.</td>
<td>21</td>
<td>41</td>
<td>38</td>
</tr>
<tr>
<td>I like to buy from a stud that sells rams to woolgrowers in my district so I can be confident their rams are suited to my area.</td>
<td>16</td>
<td>44</td>
<td>40</td>
</tr>
<tr>
<td>I like to buy from a stud that places an emphasis on skin traits and has a reputation for breeding productive sheep.</td>
<td>51</td>
<td>40</td>
<td>9</td>
</tr>
<tr>
<td>I like to buy from a stud that uses a selection index to combine a number of fleece and fibre measurements into a single value to select their rams.</td>
<td>29</td>
<td>45</td>
<td>26</td>
</tr>
<tr>
<td>I like to buy from a stud that places an emphasis on skin traits and has a reputation for breeding sheep that will do well under most conditions.</td>
<td>41</td>
<td>46</td>
<td>13</td>
</tr>
<tr>
<td>I like to buy from a stud that has entered rams in a Central Sire Evaluation Scheme or has performed well in Merino bloodline performance analysis.</td>
<td>26</td>
<td>39</td>
<td>35</td>
</tr>
</tbody>
</table>

Notes: Values are percentage of respondents giving a rating.
Source: Adapted from Kaine and Niall (2001b: 24)
indicated that they believed that participation in a central sire evaluation scheme or bloodline performance analysis was unimportant while one quarter of respondents indicated they believed the use of a selection index by a stud was unimportant.

Respondents were classified into farm contexts for sheep breeding based on their beliefs about the impact of environment on the ranking of bloodlines, the possibility of breeding sheep that were less sensitive to changing environment, and the reliability of objective measures of fleece weight and fibre diameter as indicators of desirable skin traits. The classification was conducted using a hierarchical approach employing an elimination-by-aspects procedure where the ordering of the aspects (variables) in the procedure reflected the logical interdependencies between them that were revealed by the interviews with producers and which are described below. Using this approach respondents were classified into six farm contexts that appeared to account for different strategic approaches to sheep breeding previously identified in the interviews with producers.

First, respondents were categorised according to their beliefs about the impact of changing environment on the ranking of bloodlines. Those respondents who did not believe that changing environments affected rankings were then classified into farm contexts one (elite bloodline comparison) and two (mainstream bloodline comparison) according to their beliefs about the reliability of objective measures of fleece weight and fibre diameter as indicators of desirable skin traits (see Figure 5.3).

Those respondents who did believe that changing environments affected rankings were then distinguished according to their beliefs about the possibility of breeding sheep that were less sensitive to changing environment. These respondents were then classified into one of four farm contexts according to their beliefs about the reliability of objective measures of fleece weight and fibre diameter as indicators of desirable skin traits. The profiles of the respondents in each farm context, in terms of their beliefs about the risk factors in sheep breeding, are reported in Table 5.18.

**Contexts one and two**

The woolgrowers in these two contexts represented 22 per cent of respondents in the sample. They believed that changing environments did not change the ranking of bloodlines in terms of fibre diameter and fleece weight, though there may be scale effects (see Table 5.18). Consequently, these respondents saw no need to pursue a
Believe that changing environment can change bloodline rankings in terms of fibre diameter and fleece weight

Yes

Believe that there are bloodlines that are less sensitive to environmental change than other bloodlines

Yes

Believe that fleece characteristics such as handle, crimp and staple structure are more reliable indicators of skin traits than fleece weight and fibre diameter alone

Context 3
Elite stable characteristics

Context 4
Mainstream stable characteristics

Context 5
Elite same environment

Context 6
Mainstream same environment

No

Yes

Believe that fleece characteristics such as handle, crimp and staple structure are more reliable indicators of skin traits than fleece weight and fibre diameter alone

Context 1
Elite bloodline comparison

Context 2
Mainstream bloodline comparison

No

Yes

Believe that fleece characteristics such as handle, crimp and staple structure are more reliable indicators of skin traits than fleece weight and fibre diameter alone

No

Yes

Believe that changing environment can change bloodline rankings in terms of fibre diameter and fleece weight

No

Figure 5.3 Classification of contexts for sheep breeding
Source: Kaine and Niall (2001b: 71)
Table 5.18 Farm context profiles on criteria for choosing studs

<table>
<thead>
<tr>
<th>Scenario statements:¹</th>
<th>Context</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
<th>Six</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No ranking effect³</td>
<td></td>
<td>100</td>
<td>100</td>
<td>15</td>
<td>19</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>2. Very difficult to predict performance*</td>
<td></td>
<td>19</td>
<td>7</td>
<td>69</td>
<td>82</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>3. Can predict performance in a similar environment *</td>
<td></td>
<td>91</td>
<td>86</td>
<td>65</td>
<td>64</td>
<td>56</td>
<td>63</td>
</tr>
<tr>
<td>4. Impossible to predict which sheep are the better*</td>
<td></td>
<td>55</td>
<td>27</td>
<td>78</td>
<td>75</td>
<td>84</td>
<td>75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stud criteria:²</th>
<th></th>
<th>70</th>
<th>40</th>
<th>47</th>
<th>86</th>
<th>53</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like to buy from a stud with a longstanding reputation for producing quality rams*</td>
<td></td>
<td>42</td>
<td>6</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I like to buy from a stud that sells rams to woolgrowers across a number of districts because I can be pretty sure their rams will do well under most conditions³</td>
<td></td>
<td>88</td>
<td>27</td>
<td>82</td>
<td>66</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes: 1. Values are percentage of respondents agreeing
2. Values are percentage of respondents giving a rating of very important
3. Variables used to classify respondents into contexts
* indicates statistically significant differences between contexts at p ≤ 0.05 using Pearson’s chi-squared test.
Contexts: 1 – Elite bloodline comparison; 2- Mainstream bloodline comparison; 3 – Elite stable characteristics; 4 – Mainstream stable characteristics; 5 – Elite same environment; 6 – Mainstream same environment
Source: Kaine and Niall (2001b: 27-35)
# Table 5.18 Farm context profiles on criteria for choosing studs (continued)

<table>
<thead>
<tr>
<th>Stud criteria:</th>
<th>Context</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
<th>Six</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>I like to buy from a stud that uses a selection index to combine a number of fleece and fibre measurements into a single value to select their rams</em></td>
<td>Elite bloodline comparison</td>
<td>45</td>
<td>28</td>
<td>30</td>
<td>40</td>
<td>15</td>
<td>21</td>
</tr>
<tr>
<td><em>I like to buy from a stud that places an emphasis on skin traits and has a reputation for breeding sheep that will do well under most conditions</em></td>
<td>Elite stable characteristics</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>69</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>I like to buy from a stud that has entered rams in a Central Sire Evaluation Scheme or has performed well in Merino bloodline performance analysis</em></td>
<td>Elite same environment</td>
<td>45</td>
<td>38</td>
<td>18</td>
<td>35</td>
<td>11</td>
<td>18</td>
</tr>
</tbody>
</table>

Notes:  
1. Values are percentage of respondents agreeing  
2. Values are percentage of respondents giving a rating of very important  
3. Variables used to classify respondents into contexts  
* indicates statistically significant differences between contexts at p ≤ 0.05 using Pearson’s chi-squared test.  
Contexts: 1 – Elite bloodline comparison; 2 – Mainstream bloodline comparison; 3 – Elite stable characteristics; 4 – Mainstream stable characteristics; 5 – Elite same environment; 6 – Mainstream same environment

Source: Kaine and Niall (2001b: 27-35)
strategy based on breeding sheep for stability in their performance across differing environments in terms of fibre diameter and fleece weight. These respondents did not believe that it was difficult to predict the relative performance of bloodlines under different conditions.

As expected, a higher percentage of respondents in these contexts use techniques such as index selection and bloodline comparisons, involving cross-environment progeny testing using link sires, than respondents in other contexts (see Table 5.18 and 5.19).

The respondents in context one (elite bloodline comparison) represented approximately 8 per cent of the sample. These respondents also believed that fleece characteristics such as crimp frequency and aligned fibres were more reliable indicators of important skin traits such as wool follicle size and density than objective measurements of fibre diameter and fleece weight alone.

Consequently, these respondents rated an emphasis on skin traits for breeding productive sheep and skin traits for breeding sheep that will do well under most conditions as very important criteria for choosing a stud.

The respondents in context one were more likely than respondents in context two to rate using visual assessment of the fleece, to establish skin traits, as critical. Although respondents in both contexts may employ bloodline comparisons using link sires to choose studs, the respondents in context one will limit their choices to those studs that use ‘productive’ or ‘elite’ breeding principles.

Having screened for studs on this basis, respondents in context one then used bloodline comparisons and index selection procedures to finalise their choice of stud and ram. Consistent with this, respondents in context one were significantly more likely than those in context two to believe that it was impossible to predict which bloodline would perform better on their farm simply on the basis of fleece weight and fibre diameter measurements.

The respondents in context two (mainstream bloodline comparison) represented 14 per cent of respondents. These respondents also believed that changing environments does not change the ranking of bloodlines in terms of fibre diameter and fleece weight. Consequently, they would be more likely to accept the rationale underlying bloodline comparisons involving cross-environment progeny testing using link sires.
### Table 5.19 Farm context profiles on breeding techniques

<table>
<thead>
<tr>
<th>Context</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
<th>Six</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visual assessment:</strong> *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Essential</td>
<td>70</td>
<td>52</td>
<td>73</td>
<td>69</td>
<td>64</td>
<td>48</td>
</tr>
<tr>
<td>Useful</td>
<td>84</td>
<td>80</td>
<td>89</td>
<td>82</td>
<td>94</td>
<td>82</td>
</tr>
<tr>
<td>Misleading</td>
<td>24</td>
<td>15</td>
<td>10</td>
<td>10</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td><strong>Objective measurement:</strong> *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Useful</td>
<td>21</td>
<td>27</td>
<td>9</td>
<td>14</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>Backed by visual assessment</td>
<td>82</td>
<td>67</td>
<td>87</td>
<td>83</td>
<td>80</td>
<td>82</td>
</tr>
<tr>
<td><strong>Visual assessment of fleece to establish skin traits:</strong> *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Essential</td>
<td>61</td>
<td>32</td>
<td>53</td>
<td>35</td>
<td>41</td>
<td>23</td>
</tr>
<tr>
<td>Critical</td>
<td>73</td>
<td>35</td>
<td>58</td>
<td>42</td>
<td>56</td>
<td>18</td>
</tr>
<tr>
<td>Useful</td>
<td>55</td>
<td>62</td>
<td>56</td>
<td>44</td>
<td>52</td>
<td>64</td>
</tr>
<tr>
<td><strong>Index selection:</strong> *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td>27</td>
<td>35</td>
<td>9</td>
<td>16</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>Efficient</td>
<td>39</td>
<td>31</td>
<td>21</td>
<td>20</td>
<td>15</td>
<td>22</td>
</tr>
</tbody>
</table>

Notes: Values are percentage of respondents agreeing with statement

* indicates statistically significant differences between contexts at p ≤ 0.05 using Pearson’s chi-squared test.

Contexts: 1 – Elite bloodline comparison; 2 - Mainstream bloodline comparison; 3 – Elite stable characteristics; 4 – Mainstream stable characteristics; 5 – Elite same environment; 6 – Mainstream same environment

Source: Adapted from Kaine and Niall (2001b: 42-44)
However, the respondents in context two did not believe that fleece characteristics such as crimp frequency and aligned fibres were reliable indicators of important skin traits. These respondents were less likely to rate a stud’s reputation for producing quality rams or productive sheep as very important criteria in choosing a stud (see Table 5.18).

These respondents were more likely to employ index selection and to use bloodline comparisons using link sires to choose studs than respondents in other contexts, except for respondents in context one (see Tables 5.18 and 5.19).

**Contexts three and four**

The growers in these contexts represented approximately 39 per cent of respondents. These respondents believed that changing environments caused both ranking effects and scale effects in terms of fibre diameter, fleece weight and other traits. However, they also believed that they could counter these effects to some extent by breeding sheep with characteristics that were relatively stable across environments.

The growers in context three (elite stable characteristics) represented 22 per cent of the sample and sought to breed sheep with characteristics that were relatively stable across environments by purchasing sheep from studs that emphasised skin traits and had a reputation for breeding sheep that would do well under most conditions.

Presumably, these respondents were seeking to select sheep that had relatively high skin follicle density and a relatively high ratio of secondary to primary skin follicles because they believed sheep with these traits were less responsive to changes in environmental conditions. Consistent with this proposition, the respondents in this context did not rate as a very important criterion for choosing a stud the fact that the stud sells rams across a number of districts because their rams were expected to do well under most conditions.

The respondents in context three may have employed bloodline comparisons based on cross-environment progeny testing using link sires to identify bloodlines that performed consistently under a range of conditions. However, in principle, these respondents would only consider bloodlines that were present in trials at different sites so they may directly evaluate their performance under a range of conditions. Ultimately, however, they would only purchase rams from studs breeding sheep with ‘elite’ characteristics.
The respondents in context four (mainstream stable characteristics) were 17 per cent of the sample. These respondents sought to identify bloodlines with characteristics that were stable across environments by purchasing from studs whose rams were reputed to perform well across a range of environments. They may have employed data from central sire evaluation schemes to identify bloodlines or sires that performed consistently across a number of environments. Like the respondents in context three, the respondents in context four would tend to select a bloodline from amongst those bloodlines that were present in a number of trials at different sites. They would be sceptical of bloodline comparisons made across different environments using data from link sires alone.

**Contexts five and six**

The respondents in these contexts represented approximately 39 per cent of the sample. They believed that changing environment does have ranking effects and scale effects in terms of fibre diameter, fleece weight and other traits. These respondents believed that it was very difficult to predict the relative performance of bloodlines even when they remained in similar environments. They were not convinced these effects can be overcome by breeding for sheep with stable characteristics across environments. Instead, they believed that the most reliable strategy was to purchase rams that were reputed to perform well. These rams may have been obtained from a stud in the respondent’s district or from a stud outside the district that supplied rams that were reputed to perform well in the respondent’s district. Or they may simply have purchased rams from a long established, highly reputable stud.

The respondents in contexts five and six would be unlikely to use bloodline comparisons based on cross-environment progeny testing using link sires to identify a preferred bloodline because the principles underpinning this selection technique were not consistent with their beliefs about the risk factors in sheep breeding (see Table 5.18). In principle, these respondents may have used the results of such comparisons to identify a bloodline that performed well in a site with conditions similar to those in their district.

The respondents in context five (elite same environment), like those in contexts one and three, regarded an emphasis on skin traits and breeding productive sheep as a very
important criterion in choosing a stud (see Table 5.18). This suggests that the respondents in context five believed that sheep with ‘elite’ characteristics were likely to produce relatively heavier and finer fleeces compared to sheep that did not have these characteristics. Consequently, these respondents would only purchase rams from studs supplying rams with ‘elite’ characteristics. The respondents in context five represented 11 per cent of the sample.

The respondents in context six (mainstream same environment) represented 28 per cent of the sample. These respondents did not necessarily believe that sheep with ‘elite’ characteristics were likely to produce relatively heavier and finer fleeces compared to other sheep. Some respondents in this context believed that wool that was bold, deep crimping and long stapled would attract a processing premium and aimed to breed sheep producing wool with these characteristics. Other respondents in this context may have believed that traditional wool characteristics such as high crimp frequency and style were the key determinants of premiums. Consequently, these respondents may have relied on subjective assessment to judge fleece characteristics but may also have used objective measurement to help select for characteristics such as fibre diameter and fleece weight.

Nearly half of the respondents in context six did not rate any criterion as very important in choosing a stud. Those that did nominate a criterion as very important selected either having a reputation for breeding quality rams, a similar climate, use of a selection index or participation in a sire evaluation or bloodline analysis. These respondents, like those in the other contexts, rated most of the other criteria as important in choosing a stud.

Farm contexts and enterprise characteristics

There were no statistically significant relationships between context membership and the biophysical characteristics of sheep enterprises such as location and rainfall, size of ewe and wether flocks, or number of rams used. The percentage of respondents that also managed a beef enterprise was the same across the contexts, as was the percentage of respondents that managed a cropping enterprise.

Approximately 21 per cent of respondents managed sheep studs and this percentage did not vary significantly across the segments. This finding was consistent with the
possibility that studs tend to specialise in servicing the needs of wool producers in a particular market segment as defined by their context. In other words, this finding was consistent with the possibility that studs tend to follow a focus differentiation strategy (Porter 1985). A focus differentiation strategy is successful in circumstances where different purchasers of a product are interested in different attributes in a product and so employ different purchase criteria. In the case of sheep breeding, different studs specialise in selling rams to producers in each breeding context.

Extension

The results of the case study indicated that the different farm contexts of respondents influenced the propensity of wool producers to use selection techniques such as index selection and bloodline comparisons based on cross-environment progeny testing using link sires. The results of the case study also indicated that the different farm contexts of respondents influenced the manner in which wool producers used selection techniques such as bloodline comparisons based on cross-environment progeny testing using link sires, and objective measurement and visual assessment of wool and fleece characteristics.

For instance, the results of the case study indicated that wool producers in context two (mainstream bloodline comparison) were the only producers whose beliefs about the risk factors in sheep breeding were fully consistent with using the results of bloodline comparisons based on cross-environment progeny testing with link sires in accord with the theory of quantitative genetics. This meant that, strictly speaking, the population of potential adopters of this technique was only 8 per cent of the sample.

Wool producers in context one (elite bloodline comparison) were constrained in their use of results of bloodline comparisons based on cross-environment progeny testing with link sires by their belief that objective measures of wool characteristics were not reliable indicators of sheep with desirable skin traits. These producers would restrict their use of the results of bloodline comparisons to comparisons among bloodlines known for breeding sheep with ‘elite’ characteristics. These producers would be similarly constrained in limiting their use of index selection and objective measurement to the selection of sheep with ‘elite’ characteristics. Given this constraint, the population of potential adopters of techniques such as cross-
environment progeny testing with link sires could be viewed as consisting of the producers in contexts one and two, that is, 22 per cent of the sample.

Wool producers in the other contexts may use the results of bloodline comparisons based on cross-environment progeny testing with link sires but in ways that are inconsistent with the principles underpinning the technique. This was because the principles underpinning bloodline comparisons were not consistent with their beliefs about the risk factors in sheep breeding; in particular, their belief that changing environments can change the ranking of bloodlines in terms of fibre diameter and fleece weight.

The findings indicated that there were three options for an extension program to influence the breeding decisions of wool producers. The first option was to seek to change woolgrowers’ beliefs that the environment has an important impact on the ranking of bloodlines in terms of fibre diameter and fleece weight. In principle, the rate of genetic gain in the industry is maximised when growers select from among the widest possible range of bloodlines. However, the results of the case study indicated that most growers select from a restricted range of bloodlines. This is the result of their beliefs about the risks involved in sheep breeding. This implies that the rate of genetic gain in the industry might be accelerated by modifying these beliefs of producers.

Changing producers’ beliefs about the ranking effects of changing environments would involve extension activities such as conducting demonstration trials using the same bloodlines over a wide range of environmental conditions to demonstrate the absence of ranking effects.

The second option involves altering producers’ beliefs about the strength and validity of the relationship between subjectively-assessed and objectively-measured fleece characteristics and important skin traits such as follicle size and density. There was considerable evidence that many producers had changed, or were changing, their beliefs about this relationship. There was debate within the industry as to the scientific merit of the relationship between subjectively-assessed fleece characteristics, such as crimp frequency and aligned fibres, and skin traits. The presence of the debate signalled a need for further research to establish the validity or otherwise of these beliefs and the merit of this strategy.
The third strategy was to assist producers in each context to improve their breeding decisions within the context of their beliefs by promoting the outcomes of research and extension activities in ways that were tailored to the reasoning of producers in each context. For example, workshops on the use of Estimated Breeding Values could be targeted at producers in contexts one (elite bloodline comparison) and two (mainstream bloodline comparison) as such values are derived from across flock comparisons. Workshops on using subjectively-assessed fleece characteristics reflecting skin traits in conjunction with objective measurements might be targeted at producers in contexts one (elite bloodline comparison), three (elite stable characteristics) and five (elite same environment).

In this regard, efforts to conduct extension activities such as workshops that were intended to cater for all contexts were likely to be counter-productive. Such activities, by definition, would contain material that was irrelevant much of the time for many participants.

This tailored extension option also involved promoting the outcomes of research and extension activities in ways that were tailored to each context. Consider, for example, the results of wether trials across a number of sites using link sires. The results from such trials could be reported as comparative data on bloodline performance which is primarily of interest to producers in contexts one and two. The results could be useful to producers in contexts three (elite stable characteristics) and four (mainstream stable characteristics) if presented as data from a set of separate, consistently run wether trials. The results might also be useful to a proportion of producers if presented simply as data from wether trials in their district. The results could be made more relevant to producers in contexts one, three and five if they incorporated data such as subjective assessments of the characteristics of ‘elite’ wools.

These inferred extension options were validated by conducting a final round of unstructured interviews with twenty wool producers from across the different farm contexts. The producers were identified from the contact details they supplied when completing the survey questionnaire. These interviews were also used to verify the classification of producers into farm contexts for breeding techniques based on quantitative genetics.
The interviews revealed that a major research project to test that changing environments changes the ranking of bloodlines was of little interest to producers. Producers from contexts three to six were strongly of the opinion that changes in rankings occurred and their opinion had developed after extensive experience with sheep breeding. Producers were quite confident that their opinions were valid and a research project into ranking effects would be a waste of resources, as they were confident that the research would not change their opinions. Similarly, there appeared to be very little enthusiasm among the producers who were interviewed for a demonstration project on ranking effects.

Interviewees were interested in changing bloodlines to improve productivity but felt that there was an unacceptable level of risk involved despite the strategies that they employed to ameliorate this risk. Consequently, they were very interested in any trials that would enable them to increase their confidence in a bloodline before they committed themselves and purchased rams. However, their views on the conduct and evaluation of the trials differed, and these differences reflected their beliefs about the risk factors in sheep breeding. For instance, some interviewees simply wished to test bloodlines under local conditions while others wished to test bloodlines across a number of environments.

Producers were clear that any extension project must be managed so that they could evaluate bloodlines according to their own beliefs. This is consistent with the third option for extension described above. Producers were not interested in the evaluation of bloodlines which they already believed would not suit their conditions.

The results of the validation interviews supported the view that changing producers opinions on the impact of changing environments on bloodline rankings would require a substantial extension effort. This suggested that the population of potential adopters of selection techniques based on bloodline comparisons made across sites with link sires (contexts one and two) was unlikely to be considerably changed by extension activities, at least in the short term. In conclusion, the validation interviews confirmed and reinforced the earlier findings of the case study.

The results from this case study contributed to the establishment of an extension program pursuing option three. The program involved comparisons of bloodline performance using wether trials with link sires across a number of sites in Victoria.
(Brien et al 2004). The purpose of the program was to increase the availability of reliable genetic information on Merino studs commonly used in Victoria. The program was designed to address the perceived risk for wool producers from testing new genetic material on their properties. The program was also designed to assist wool producers make better breeding decisions given their existing beliefs and strategies rather than attempt to change their beliefs in the short term. The results of the program were distributed to producers in a variety of formats that were tailored to the views of producers from each context (Brien et al 2004).

**Replication**

This case study was repeated and extended to include all Australian wool producing regions in a project commissioned by Australian Wool Innovations (AWI) in 2005. The motivation for this national project was a desire on the part of AWI to ensure that the greatest benefits be obtained from the planned development of a national genetics database for the wool industry. The database was to assist wool producers in making breeding decisions by supplying Estimated Breeding Values for wool characteristics.

**Qualitative stage**

Following the approach described in the preceding chapter, convergent interviewing was used to identify the elements in the farming systems of commercial wool enterprises that defined the farm context for adopting different techniques for choosing studs and selecting rams. In-depth, unstructured personal interviews were conducted with seventy wool producers across Australia and were conducted as described in the preceding chapter with two interviewers present at each interview.

Two findings emerged from the interviews. The first was that the beliefs of the producers who were interviewed in regard to the key risk factors involved in sheep breeding, and the strategies they followed in choosing studs from which to purchase rams as a consequence of those beliefs, were similar to those identified in the original case study by Kaine and Niall (2001b) and reported above. This finding suggested that the sheep breeding contexts identified by Kaine and Niall (2001b) for Victoria were present among commercial wool producers in other regions.

The second finding was that some producers believed their choice of bloodlines and studs was particularly restricted because they believed their environment was so
different from other environments that sheep from other environments would not be able to survive and thrive in their environment. Sheep from other environments might, for example, be particularly susceptible to fly strike, fleece rot, and so on. These producers constituted a farm context that had not been identified by Kaine and Niall (2001b). Apart from believing sheep from other environments would not survive and thrive in their environment, these producers had similar beliefs to other producers in regard to the key risk factors in sheep breeding.

These wool producers appeared to follow one of two strategies when choosing bloodlines and studs. One strategy was to only purchase rams from studs in their district. The other strategy was to purchase rams from studs outside the district that were known to supply rams that performed well for other producers in their district.

**Quantitative stage**

A questionnaire was developed from the interview results for the purposes of statistically verifying the farm contexts for sheep breeding techniques and quantifying the proportion of woolgrowers in each context. Given the similarity in the findings in the qualitative stage of both studies, the preliminary version of the national questionnaire was adapted from that used by Kaine and Niall (2001b). The questionnaire was piloted before being distributed to a random sample, stratified by size and state, of 3000 wool producers throughout Australia including Victoria. The sample was drawn from records held by Australian Wool Innovations. It is possible that some of the producers in the sample were participants in the original Victorian study.

The questionnaire was mailed to producers in April 2006 in the form of a 16-page booklet. The booklet was accompanied by a covering letter describing the purpose of the survey and providing the contact details of the project team. A reminder was posted 4 weeks later.

The survey response rate was approximately 28 per cent assuming all non-respondents were wool producers. However, if the distribution of Merino and non-Merino producers among non-respondents was similar to that among respondents then the response rate was approximately 40 per cent. There was no significant difference in the response rates among the regions.
Merino wool production was the major enterprise of approximately 60 per cent of respondents. Approximately 14 per cent of respondents ran a sheep stud. The average fibre diameter and fleece weight reported by respondents was consistent with the average reported for the national flock in 2004–2005 (ABARE 2005; AWI 2006). Using the flock numbers and average fleece weight reported by respondents, the sample represented approximately 4.5 per cent of the national wool clip (ABARE 2005).

**Farm contexts for stud choice and ram selection**

The national survey contained the same scenario-based questions as in Kaine and Niall (2001b) for eliciting producers’ beliefs about the effect of changing environment on the ranking of bloodlines for fibre diameter and fleece weight. The responses of the Victorian respondents in the national study were not statistically significantly different from the responses obtained in the original Victorian study. Furthermore, the responses to the scenarios of Victorian respondents in the national sample were not significantly different from the responses for the national sample as a whole.

Respondents in the national sample were classified into farm context in regard to breeding techniques based on their beliefs about the risk factors in sheep breeding using the elimination-by-aspects procedure described previously. The beliefs used in the procedure were those used in the original Victorian study together with the additional belief that producers were restricted in their choice of stud because the conditions in their environment were such that sheep from other environments would not survive in their environment. The classification is presented diagrammatically in Figure 5.4.

The major difference between the national and the original Victorian classifications was the initial partitioning of respondents on the basis of the belief that producers were restricted in their choice of stud because the conditions in their environment were such that sheep from other environments would not survive in their environment. The profiles of the respondents in each farm context, in terms of their beliefs about the risk factors in sheep breeding, are reported in Table 5.20.
Figure 5.4 Classification of contexts for sheep breeding (National)

Source: Kaine et al. (2006: 15)
### Table 5.20 Farm context profiles on criteria for choosing studs - National

<table>
<thead>
<tr>
<th>Scenario statements:</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
<th>Six</th>
<th>Seven</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No ranking effect¹</td>
<td>100</td>
<td>100</td>
<td>15</td>
<td>19</td>
<td>9</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>2. Very difficult to predict performance*</td>
<td>19</td>
<td>7</td>
<td>69</td>
<td>82</td>
<td>80</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>3. Can predict performance in a similar environment *</td>
<td>91</td>
<td>86</td>
<td>65</td>
<td>64</td>
<td>56</td>
<td>63</td>
<td>63</td>
</tr>
<tr>
<td>4. Impossible to predict which sheep are the better*</td>
<td>55</td>
<td>27</td>
<td>78</td>
<td>75</td>
<td>84</td>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>

Notes:  
1. Values are percentage of respondents agreeing  
2. Values are percentage of respondents giving a rating of very important  
3. Variables used to classify respondents into contexts  
* indicates statistically significant differences between contexts at p ≤ 0.05 using Pearson’s chi-squared test.  
Contexts: 1 – Elite bloodline comparison; 2 - Mainstream bloodline comparison; 3 – Elite stable characteristics; 4 – Mainstream stable characteristics; 5 – Elite same environment; 6 – Mainstream same environment; 7 – Restricted environment  
Source: Adapted from Kaine et al. (2006: 21-39)
Table 5.20 Farm context profiles on criteria for choosing studs – National (continued)

<table>
<thead>
<tr>
<th>Stud criteria</th>
<th>Context</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
<th>Six</th>
<th>Seven</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like to buy from a stud with a longstanding reputation for producing quality rams*</td>
<td>57</td>
<td>30</td>
<td>50</td>
<td>68</td>
<td>60</td>
<td>37</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>I have to buy from a stud in my district because sheep from other districts will not survive</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>I can only buy from a stud that supplies rams to woolgrowers in my district so I can be confident they will survive and do well</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>I like to buy from a stud that sells rams to woolgrowers across a number of districts because I can be pretty sure their rams will do well under most conditions</td>
<td>18</td>
<td>3</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>37</td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. Values are percentage of respondents agreeing
2. Values are percentage of respondents giving a rating of very important
3. Variables used to classify respondents into contexts
* indicates statistically significant differences between contexts at p ≤ 0.05 using Pearson’s chi-squared test.
Contexts: 1 – Elite bloodline comparison; 2- Mainstream bloodline comparison; 3 – Elite stable characteristics; 4 – Mainstream stable characteristics; 5 – Elite same environment; 6 – Mainstream same environment; 7 – Restricted environment
Source: Kaine et al. (2006: 85-86)
Table 5.20 Farm context profiles on criteria for choosing studs - National (continued)

<table>
<thead>
<tr>
<th>Stud criteria: ³</th>
<th>Context</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
<th>Six</th>
<th>Seven</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like to buy from a stud that places an emphasis on skin traits and has a reputation for breeding productive sheep ³</td>
<td>77</td>
<td>16</td>
<td>79</td>
<td>70</td>
<td>100</td>
<td>0</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>I like to buy from a stud that places an emphasis on skin traits and has a reputation for breeding sheep that will do well under most conditions ³</td>
<td>100</td>
<td>0</td>
<td>100</td>
<td>72</td>
<td>0</td>
<td>0</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>I like to buy from a stud that uses a selection index to combine a number of fleece and fibre measurements into a single value to select their rams*</td>
<td>35</td>
<td>24</td>
<td>25</td>
<td>35</td>
<td>20</td>
<td>15</td>
<td>33</td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1. Values are percentage of respondents agreeing  
2. Values are percentage of respondents giving a rating of very important  
3. Variables used to classify respondents into contexts  
* indicates statistically significant differences between contexts at p ≤ 0.05 using Pearson’s chi-squared test.  
Contexts: 1 – Elite bloodline comparison; 2- Mainstream bloodline comparison; 3 – Elite stable characteristics; 4 – Mainstream stable characteristics; 5 – Elite same environment; 6 – Mainstream same environment; 7 – Restricted environment  
Source: Kaine et al. (2006: 85-86)
Table 5.20 Farm context profiles on criteria for choosing studs - National (concluded)

<table>
<thead>
<tr>
<th>Stud criteria: ²</th>
<th>Context</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Five</th>
<th>Six</th>
<th>Seven</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like to buy from a stud that places an emphasis on traits such as conformation and ‘doing ability’*</td>
<td>57</td>
<td>27</td>
<td>57</td>
<td>76</td>
<td>43</td>
<td>31</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>I like to buy from a stud that has entered rams in genetic benchmarking schemes (e.g. Central Sire Evaluation Scheme, MGS or Merino Benchmark) or has performed well in Merino Bloodline Evaluation*</td>
<td>43</td>
<td>31</td>
<td>30</td>
<td>36</td>
<td>28</td>
<td>17</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>I like to buy from a stud that provides comparative measures on individual traits (such as EBVs or data relative to the mean of the drop or flock) *</td>
<td>43</td>
<td>37</td>
<td>30</td>
<td>32</td>
<td>23</td>
<td>24</td>
<td>38</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Values are percentage of respondents agreeing
2. Values are percentage of respondents giving a rating of very important
3. Variables used to classify respondents into contexts
* indicates statistically significant differences between contexts at \( p \leq 0.05 \) using Pearson’s chi-squared test.

Contexts:
1 – Elite bloodline comparison; 2- Mainstream bloodline comparison; 3 – Elite stable characteristics; 4 – Mainstream stable characteristics; 5 – Elite same environment; 6 – Mainstream same environment; 7 – Restricted environment

Source: Kaine et al. (2006: 85-86)
Broadly speaking, the results from the national study were consistent with the results of the original study. The profiles of respondents in the six original contexts were broadly similar in both studies with similar percentages of respondents in each context (see Table 5.20). Hence, the interpretation of respondents’ beliefs in contexts one to six was the same in the national study as in the Victorian study.

The profile on respondents in the new context, context seven (restricted environment), represented approximately nine per cent of the national sample. Respondents were classified into this context because they rated as very important buying from a stud in their district because sheep from other districts would not survive, or buying from a stud that supplies rams to producers in their district so they can be confident they would survive and do well.

Producers who were interviewed with these beliefs were of the opinion, for example, that sheep which were not from a high rainfall area would be highly susceptible to fleece rot or sheep from outside pastoral areas might be highly susceptible to dust and vegetable-matter contamination. These beliefs suggest the respondents in this context would tend to purchase rams from studs in their district or purchase rams from a stud that supplies rams with a similar climate (see Table 5.20). Alternatively, they may purchase rams from studs outside the district that were known to supply rams that performed well to other producers in their district (see Table 5.20).

A relatively high percentage of respondents in this context believed it was very important to purchase rams from a stud that emphasises traits such as conformation and ‘doing ability’ (see Table 5.20). In addition, the respondents in this context reported weaning percentages that were significantly lower than the percentages for other contexts. This result was consistent with the possibility that environmental conditions on properties in this context were harsher than most. It would seem that this was the basis for the concern of these producers with the robustness of sheep from other locations.

Concern about the effect of changing environment on the ranking of bloodlines for fibre diameter and fleece weight would be less important for producers in context seven because of their restricted choice of bloodlines. However, these woolgrowers must still choose a bloodline or stud from among those that meet the criterion of producing sheep that would survive in their environment. In this regard they may select from a variety of strategies that mirrored those followed by producers in other contexts.
There were no statistically significant relationships between context membership and the biophysical characteristics of sheep enterprises such as region, size of ewe and wether flocks, or number of rams used. The percentage of respondents that also managed a beef enterprise was the same across the contexts, as was the percentage of respondents that managed a cropping enterprise.

**Conclusion**

At the time the original Victorian case study was conducted there was a concern that the adoption of breeding techniques based on quantitative genetics by wool producers was lower than desirable. There was a particular concern regarding the adoption of information obtained from bloodline comparisons using trials at a number of sites with link sires.

Using the methods described in the preceding chapter the farm contexts for the use of such techniques were identified. The method revealed that the majority of wool producers believed that changing environments would change the ranking of bloodlines with regard to fibre diameter and fleece weight. This belief was inconsistent with the principles underpinning the comparison of bloodlines using link sires to connect data from different sites. As a consequence, the method revealed that only approximately 22 per cent of respondents were likely to use data from bloodline comparisons to select studs and sires in the way intended, and that many of those respondents would restrict their choices to studs that produced sheep with ‘elite’ characteristics.

Similar concerns about the adoption of breeding techniques motivated the national study where the interest was in the use of Estimated Breeding Values (EBVs). The calculation of such values is based on the premise that changing environments does not change bloodline rankings for fibre diameter and fleece weight. The farm contexts identified in the national study were similar to those identified in the original study in Victoria with the exception of one additional context. The national study also indicated that a minority of respondents would use data from bloodline comparisons or EBVs to select studs and sires in the way intended. Again, many of those respondents would restrict their choices to studs that produced sheep with ‘elite’ characteristics.

These results support the proposition that the population of potential adopters of bloodline selection techniques using quantitative genetics depends on elements in the farm system that influenced the benefits to be had from the adoption of these techniques. In this instance, the
elements in the farm system that influenced the perceived benefits of these techniques were the producer’s perceptions of the key risk factors in sheep breeding and the possibilities for ameliorating those risks.

The results indicate that, in contrast to the belief that motivated the case study, the population of potential adopters of bloodline selection techniques using quantitative genetics was only a relatively small percentage of wool producers. The results also indicated that a reasonably high percentage of this population rated the use of these techniques as very important.

5.3.4 Adoption of enterprise decision aids

Selection criteria
This case study is an example of the adoption of an agricultural innovation by extensive dryland cropping and livestock enterprises. The study was selected as the elements of the farm system that constituted the farm context for the adoption of planning aids for managing enterprise mix were identified using theoretical arguments rather than elicited directly from producers using convergent interviewing (Kaine et al. 1994b).

Planning aids vary in their complexity but all are difficult to trial because errors in enterprise choice can have severe, long-term consequences that are extremely difficult to reverse. Furthermore, the benefits of using a particular planning aid in terms of improved farm profitability are difficult to observe as such benefits may only become apparent after a number of seasons. The principles underpinning some planning aids were not always compatible with producers’ experiences. For instance, the application of linear programming to choosing enterprise mix requires assuming that the distributions of expected commodity prices are stable over the term of the planning horizon. Many producers may have learnt, on the basis of their experience, that this assumption cannot be justified (Wright 1983). The study was also replicated some years later (Kaine et al. 2001; Kaine et al. 2003a; Kaine et al. 2003b; Kaine et al. 2004a).

33 This section is a summary of, and contains material reproduced from, Kaine et al (1994b) and Kaine et al (2001). The studies in this section were supported by grants from the Rural Industries Research and Development Corporation.
Background
In the two decades prior to the millennium the business environment of broad-acre agriculture changed significantly in Australia with the deregulation of markets for agricultural commodities, the deregulation of financial and capital markets and changes in government policy with respect to agriculture and the environment. These changes markedly increased the degree of uncertainty that pervaded the operating environment of agricultural producers. This had resulted in extension personnel and policy makers placing an increased emphasis on the importance of financial planning and risk management in the running of farm businesses. At the time this case study was conducted researchers, extension staff and policy makers in government and industry organisations were concerned that the use of more advanced planning aids such as gross margins, partial budgets, parametric budgeting and linear programming by producers was not as widespread as they wished. Yet these aids had been available for many years.

The objective in this case study was to explore the relationship between producers’ perception of control over farm business performance and the use of planning aids. The case study was based on the hypothesis that the benefits to be had from planning aids depended on the extent to which producers believed they could influence the performance of their farm businesses through their own actions. These beliefs were thought to determine the strategies producers employed towards managing the risk of poor performance and by extension the relevance of planning aids. Hence, the intention in the case study was to identify the population of potential adopters of business planning aids among broad-acre, mixed crop and livestock enterprises in south-eastern Australia.

Quantitative stage
Unlike the other case studies, the qualitative stage of the method using convergent interviewing that was described in the preceding chapter was not used to identify the elements in the farm system that influenced the benefits to be had from adopting the various planning aids of interest here. Instead, a theoretical analysis of the operating environment of broad-acre farm businesses was conducted drawing primarily on Ashby (1956), Emery and Trist (1965), and Wright (1983; 1986).

This analysis led to the conclusion that commodity prices and seasonal conditions were critical sources of risk for mixed cropping and livestock enterprises. Furthermore, these prices
and conditions could not be forecast with any degree of reliability which meant the financial performance of these businesses would fluctuate, and that efforts to control performance should not be based on too-specific forecasts or expectations about the future behaviour of prices and conditions. Hence, the appropriate strategic objective for these businesses was to reduce exposure to financial ruin. This meant that trying to exert control over performance by constantly altering and adjusting enterprise mix on the basis of price forecasts could be counter-productive. Not only could such forecasts be misleading, the process of constantly changing enterprise mix would increase production costs and could hamper the pursuit of technical efficiency (Wright 1986).

These conclusions resulted in the hypothesis that producers who believed that they could exert control over their operating environment as a whole would be more likely to employ formal planning aids than producers who did not. These producers would be expected to actively seek information that they believed would increase their control (Sims and Baumann 1972). Hence, these producers were likely to believe that financial planning and risk management was a useful process and therefore would be more likely to employ planning aids that would assist them in making frequent and substantive changes to their enterprise mix.

Producers who believed that they could not exert control over their operating environment as a whole were more likely to believe that they had relatively little control over financial performance and therefore would be less likely to make frequent and substantial changes to their enterprise mix. Consequently, they would be expected to regard the benefits from such planning, and the use of planning aids, as problematic.

Producers are likely to differ in their perceptions of the control they can exert over business performance. Some producers may perceive, for example, that they can control costs by planning ahead; others may not. These differences in perceptions of control arise as the result of differences in learning, experience and knowledge (Rotter 1966; Bandura 1997). Presumably, differences in producers’ perceptions of control over business performance would lead to differences in business and farming objectives, and differences in the types of strategies they followed to achieve those objectives.

A number of conceptualisations have been developed of individuals’ perceptions of control and the influence of these perceptions on behaviour. Of these, Rotter’s (1966) concept of locus of control most closely resembled the concept of control of interest here. Locus of control is a personality predisposition and describes an individual’s perception of their ability
to change a situation. It refers to a set of beliefs about behaviour and success or failure (McNairn and Mitchell 1992). A belief in external control means a person believes an event is largely the product of forces beyond their control. A belief in internal control means a person believes an event is contingent upon their behaviour or actions. Locus of control has been shown to influence behaviour in areas as diverse as physical and mental health, alcoholism, intellectual achievement among schoolchildren, and producers’ aspirations (Lefcourt 1981; Sia et al. 1985; Hines et al. 1986; van Kooten et al. 1986).

Although locus of control is a personality predisposition, it is multi-dimensional (Lefcourt 1981). This means that, while an individual has a general predisposition to exhibit an internal or external locus of control, their locus may vary from one subject area to another depending on their learning, experience and knowledge. In short, an individual’s locus of control in a particular context depends partly on their general predisposition to be internally or externally oriented, and partly on the learning, experience and knowledge they possess that is relevant to that context. Hence, a distinction can be drawn between locus of control in a specific context and locus of control as a personality predisposition (Lefcourt 1981); that is, generalised locus of control.

A scale measuring locus of control was developed for broad-acre, mixed cropping and livestock enterprises, specifically wheat and sheep enterprises by Kaine et al (1994b) based on the their knowledge of such enterprises and extensive piloting with producers. The scale consisted of a series of 27 forced-choice questions concerning perceptions of control over tactical aspects of the farm business, such as management of production, through to strategic issues such as management of costs and planning.

The scale was included in a mail questionnaire distributed to 1500 producers in the wheat-sheep zone of New South Wales, Victoria and South Australia in the autumn of 1993. The names and addresses of the producers were randomly selected from the entries in the ‘graziers’ and ‘farmers’ categories in the Yellow Pages™. In addition to the scale measuring locus of control the survey contained questions relating to the demographic characteristics of producers, their use of decision aids such as gross margins and partial budgets, and the characteristics of their enterprises.

A total of 624 questionnaires were returned giving a response rate of 41 per cent after allowing for errors in addresses and so on. After excluding questionnaires returned by

---

34 Ken Edwards, a farm management colleague from Roseworthy Campus, University of Adelaide collaborated in the development of the scale.
respondents who were not wheat-sheep producers, and those that were incomplete, 426 questionnaires were available for analysis.

**Control as a multi-dimensional construct**

As noted above, locus of control is a multi-dimensional construct. Consequently, an individual’s perceptions of control may vary from one domain to another (Gregory 1981). This means that producers’ perceptions of control may vary from one area of farm management to another. This possibility was investigated by conducting a factor analysis of responses to the locus of control scale.

Twelve items in the scale where more than 80 per cent of respondents had selected the same alternative were excluded from the analysis (Tabachnik and Fidell 1989). Ten of these items concerned the technical specifics of crop and livestock production (weed control and weaning rates for example) where 90 per cent or more of respondents had selected the alternative indicating an internal locus of control. One item relating to obtaining information about farming was excluded for the same reason while another relating to the purchase of plant and equipment and taxation was excluded because the item did not correlate with any other item. The fifteen items remaining for analysis are reported in Table 5.21.

In Table 5.22 the results of a solution of four factors are reported.\(^{35}\) Factors were interpreted on the basis of correlations with items of 0.30 or greater (Tabachnik and Fidell 1989). The first factor represented perceptions of control in relation to planning and budgeting. The second related to perceptions of control arising from manipulating enterprise mix. Both of these factors were correlated with item three, which concerned the adoption of innovations.

The third factor consisted of perceptions of control in relation to costs while the fourth factor concerned perceptions of control in relation to business expansion. There were substantial correlations between the factors and the four factors collapsed into a single factor when a higher-order factor analysis was conducted. These results suggest that respondents’ perceptions of control over their farm business did vary across different areas of farm management, and the four factors represented different sub-dimensions of respondents’ locus of control with respect to their farm business overall.

\(^{35}\) The analysis was conducted using the maximum likelihood procedure with oblique rotation available in SPSS (1988).
Table 5.21 Locus of control statements used in the factor analysis

<table>
<thead>
<tr>
<th>Item</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>On my farm the combination of location, climate and markets just about restricts me to one combination of enterprises. <em>Despite a farm’s location, climate, and markets, I believe there are always opportunities to alter and adapt the combination of enterprises on that farm.</em></td>
</tr>
<tr>
<td>2</td>
<td>For a farm like mine, it is just not worth trying to juggle a range of enterprises. <em>In my experience, juggling a combination of enterprises can be worthwhile because you can usually balance one enterprise against another.</em></td>
</tr>
<tr>
<td>3</td>
<td>I generally find that most new ideas that come out don’t really apply to my farm. <em>For most new ideas, I generally find that with a lot of time and effort I can get them to work on my farm.</em></td>
</tr>
<tr>
<td>4</td>
<td>Economic conditions these days make it very difficult for you to increase the size of your farming or grazing area. <em>Even in today’s economic conditions there is often scope for you to increase the size of your farming or grazing area.</em></td>
</tr>
<tr>
<td>5</td>
<td>For my farm operation, overhead costs are a burden that you really just have to put up with. <em>In my situation, I can usually find ways of reducing overheads.</em></td>
</tr>
<tr>
<td>6</td>
<td>For the sorts of things I buy for my farming operations, there’s not a lot I can do about unexpected cost increases. <em>I generally find in my situation that I can reduce costs by planning ahead.</em></td>
</tr>
<tr>
<td>7</td>
<td>In these tough times I would rather pay my way as I go because I reckon it is too risky to borrow money. <em>Even though times have been tough, I still reckon it is sensible to go into debt when you have a proposition that looks promising.</em></td>
</tr>
<tr>
<td>8</td>
<td>I feel you tend to be at the mercy of the banks if you borrow money. <em>To me, banks are just like other businesses, so it pays to spend some time negotiating with them.</em></td>
</tr>
</tbody>
</table>

Notes: 1. Statements in italics denote internal locus of control.  
2. Items were scored as dichotomous variables.

Table 5.21 Locus of control statements used in the factor analysis (continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>Statement</th>
</tr>
</thead>
</table>
| 9    | For a farm like mine, its market value is something that you really don't have much influence over.  
     | *As the owner of a farm I can usually have some influence on its market value.* |
| 10   | In my experience, there are so many things that are beyond your control when you go into off-farm investments that they are really not worth the trouble.  
     | *To me, off-farm investments give a good balance to the investments I make in my farm.* |
| 11   | Because farming is such an uncertain business, I find it's best to follow fairly closely the plan I have used in recent years.  
     | *Because each year is different from the last, I prefer to set up a new plan each year.* |
| 12   | For a farm business like mine, working out its strengths in great detail wouldn't help me much because so much of what happens outside the farm gate is out of my hands anyway.  
     | *In my experience, working out the strengths of my farm business in some detail can often give me useful leads for the future.* |
| 13   | For a farm business like mine, working out the threats and opportunities wouldn't help me much because you can't do much about what happens outside the farm gate anyway.  
     | *In my experience, identifying the threats and opportunities facing my farm business can often give me a good idea of the direction I should be going.* |
| 14   | For my situation, things can change so much that putting a lot of effort into drawing up farm plans is not really a worthwhile thing to do.  
     | *Mostly, it doesn't worry me that things often turn out differently to my farm plans — I still find the effort put into the plans and re-adjusting them is generally repaid.* |
| 15   | In my situation, budgets aren't very useful as so many things can change during a year.  
     | *I generally find that budgeting is a help in running my farm even though things may not turn out as I thought.* |

Notes:  
1. Statements in italics denote internal locus of control.  
2. Items were scored as dichotomous variables.  

Source: Kaine et al. (1994b: 23-24)
### Table 5.22 Statistical summary of factor analysis

#### Pattern Matrix

<table>
<thead>
<tr>
<th>Item</th>
<th>Planning</th>
<th>Enterprise Mix</th>
<th>Cost Control</th>
<th>Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 One combination of enterprises</td>
<td>0.03</td>
<td>-0.82</td>
<td>0.07</td>
<td>-0.06</td>
</tr>
<tr>
<td>2 Not worth juggling enterprises</td>
<td>0.01</td>
<td>-0.69</td>
<td>-0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>3 New ideas don’t apply</td>
<td>0.30</td>
<td>-0.31</td>
<td>-0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>4 Difficult to increase size</td>
<td>-0.07</td>
<td>-0.02</td>
<td>0.08</td>
<td>0.34</td>
</tr>
<tr>
<td>5 Overheads are a burden</td>
<td>-0.01</td>
<td>0.04</td>
<td>0.70</td>
<td>-0.06</td>
</tr>
<tr>
<td>6 Cannot control costs</td>
<td>0.04</td>
<td>-0.08</td>
<td>0.51</td>
<td>0.07</td>
</tr>
<tr>
<td>7 Too risky to borrow</td>
<td>0.10</td>
<td>-0.07</td>
<td>-0.19</td>
<td>0.68</td>
</tr>
<tr>
<td>8 Mercy of banks if you borrow</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
<td>0.59</td>
</tr>
<tr>
<td>9 Cannot influence farm value</td>
<td>0.15</td>
<td>0.00</td>
<td>0.25</td>
<td>0.17</td>
</tr>
<tr>
<td>10 Off-farm investments are trouble</td>
<td>0.08</td>
<td>-0.04</td>
<td>0.33</td>
<td>0.02</td>
</tr>
<tr>
<td>11 Follow same plan</td>
<td>0.00</td>
<td>-0.19</td>
<td>0.22</td>
<td>0.16</td>
</tr>
<tr>
<td>12 Knowing strengths is no help</td>
<td>0.72</td>
<td>-0.01</td>
<td>0.04</td>
<td>0.10</td>
</tr>
<tr>
<td>13 Knowing threats is no help</td>
<td>0.53</td>
<td>-0.07</td>
<td>0.16</td>
<td>-0.01</td>
</tr>
<tr>
<td>14 New plans are not worthwhile</td>
<td>0.61</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.09</td>
</tr>
<tr>
<td>15 Budgets are not useful</td>
<td>0.55</td>
<td>0.04</td>
<td>0.01</td>
<td>0.08</td>
</tr>
</tbody>
</table>

#### Factor correlation matrix

<table>
<thead>
<tr>
<th></th>
<th>Planning</th>
<th>Enterprise Mix</th>
<th>Cost Control</th>
<th>Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enterprise Mix</td>
<td>-0.42</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Control</td>
<td>0.41</td>
<td>-0.36</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Expansion</td>
<td>0.41</td>
<td>-0.38</td>
<td>0.35</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes: 1. Item numbers correspond to locus of control item numbers in table 5.21
Source: Kaine et al. (1994b: 25)
Classification of farm contexts

Respondents were classified into farm contexts in regard to the adoption of planning aids using their responses to seven items in the locus of control scale.\(^{36}\) The items were selected because they were directly related to the hypotheses to be tested. These items concerned respondents’ perceptions of control over outcomes through planning (items 12, 13, 14), management of production costs (item 6), manipulation of enterprise mix (items 11, 2), and adoption of innovations (item 3). In the original study respondents were classified into six clusters representing three farm contexts, with two variants on each of the three contexts. In a similar study that was conducted some years later, which is reported below, respondents were only classified into the three farm contexts – results for the variants were not reported. Consequently, to simplify comparisons between the two studies only the results for the three contexts will be reported for the original study.

The respondents in the first farm context (prospectors) expressed an internal locus of control over most aspects of their farm business (see Table 5.23).\(^{37}\) These respondents were producers who believed that they could influence the performance of their farm business through planning. They believed that they could improve performance by analysing the strength and weakness of their farm businesses, identifying opportunities and threats and setting directions for their businesses accordingly. These respondents indicated that they could influence business performance by constantly revising plans and adjusting enterprise mix. The respondents in the first farm context would be expected to respond rapidly to signals from their business environment, being constantly alert to new prospects and opportunities. These respondents represented 28 per cent of the sample.

The respondents in the second farm context (analysers) believed that they could influence the performance of their farm business through planning. However, they also believed that product prices were so unpredictable that the constant revision of plans and adjustment of enterprise mix was self-defeating (see Table 5.23). Consequently, these respondents appeared to prefer to operate from a relatively stable platform in terms of farm resource allocation and enterprise mix, making only occasional, incremental changes to the latter.

\(^{36}\) The classification analysis was conducted using a monothetic divisive clustering algorithm available in CLUSTAN (Wishart 1987) which is specifically designed for use with dichotomous data. The similarity coefficient used was squared Euclidean distance.

\(^{37}\) Following Miles and Snow (1978), the terms ‘prospectors’, ‘analysers’ and ‘defenders’ were used by Kaine et al. (1994b) to describe the three contexts they identified.
Table 5.23 Profiles for internal locus of control

<table>
<thead>
<tr>
<th>Internal locus of control item</th>
<th>Context One</th>
<th>Context Two</th>
<th>Context Three</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relevance of planning:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In my experience, working out the strengths of my farm business in some detail can often give me useful leads for the future.</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>In my experience, identifying the threats and opportunities facing my farm business can often give me a good idea of the direction I should be going.*</td>
<td>98</td>
<td>85</td>
<td>39</td>
</tr>
<tr>
<td>Mostly, it doesn’t worry me that things often turn out differently to my farm plans — I still find the effort put into the plans and re-adjusting them is generally repaid.*</td>
<td>94</td>
<td>92</td>
<td>56</td>
</tr>
<tr>
<td><strong>Cost control and productivity:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I generally find in my situation that I can reduce costs by planning ahead.*</td>
<td>72</td>
<td>52</td>
<td>31</td>
</tr>
<tr>
<td>For most new ideas, I generally find that with a lot of time and effort I can get them to work on my farm.*</td>
<td>82</td>
<td>67</td>
<td>40</td>
</tr>
<tr>
<td><strong>Revision of plans and enterprise mix:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Because each year is different from the last, I prefer to set up a new plan each year.</td>
<td>100</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>In my experience, juggling a combination of enterprises can be worthwhile because you can usually balance one enterprise against another.*</td>
<td>95</td>
<td>77</td>
<td>62</td>
</tr>
</tbody>
</table>

Notes: 1. Values are percentage of respondents that agreed with the item.  
2. * indicate differences in percentages are significant at $p \leq 0.05$ using Pearson’s chi-squared test.  
   Contexts: 1 - Prospectors; 2 – Analysers; 3 - Defenders

Adapted from Kaine et al. (1994b: 31-36)
The pattern of locus of control expressed by these respondents was the most consistent with the causal structure of the operating environment inferred in the theoretical analysis. These respondents represented 39 per cent of the sample.

The respondents in the third farm context (defenders) reported a degree of control over farm production but believed the financial performance of their farm business was largely determined by external environmental factors (see Table 5.23). Hence, they believed that the benefits from planning were very limited. These respondents appeared to prefer to operate from a very stable platform in terms of farm resource allocation and enterprise mix, making only marginal adjustments in response to market signals. These respondents represented 33 per cent of the sample.

Farm context and planning aids
In drawing inferences about the use of planning aids by respondents in each farm context there was a distinction to be made between production planning and farm planning in terms of enterprise mix. Respondents in contexts two and three may well devote similar time and effort to the planning of production as respondents in context one. Hence, they may well employ aids to assist them in the management of production such as paddock recording and feed budgeting, or reproduction recording to assist in breeding and culling livestock. However, the respondents in contexts two and three were expected to be less likely to employ planning aids that guided the selection of enterprise mix.

In Table 5.24 the percentage of respondents in each context reporting the use of a variety of planning aids is presented. As expected, for those aids where frequency of use was significantly different across the contexts, the frequency was highest among respondents in context one (prospectors) and lowest among respondents in context three (defenders). Note that the frequency of use of aids for analysing changes in enterprise mix such as gross margins was generally lower than the frequency of use of general indicators of business performance such as profit and loss statements and balance sheets. The relatively high and reasonably uniform use of cash books, profit and loss statements and balance sheets was probably a reflection of taxation accounting and banking requirements.
Table 5.24 Frequency of use of planning aids

<table>
<thead>
<tr>
<th>Planning aid</th>
<th>Context One</th>
<th>Context Two</th>
<th>Context Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm cash book</td>
<td>0.66</td>
<td>0.71</td>
<td>0.53</td>
</tr>
<tr>
<td>Profit and loss statement*</td>
<td>0.69</td>
<td>0.57</td>
<td>0.46</td>
</tr>
<tr>
<td>Balance sheet*</td>
<td>0.68</td>
<td>0.66</td>
<td>0.43</td>
</tr>
<tr>
<td>Cash flow budgets*</td>
<td>0.77</td>
<td>0.69</td>
<td>0.38</td>
</tr>
<tr>
<td>Gross margin*</td>
<td>0.41</td>
<td>0.22</td>
<td>0.11</td>
</tr>
<tr>
<td>Partial budgets</td>
<td>0.24</td>
<td>0.25</td>
<td>0.17</td>
</tr>
<tr>
<td>Computer packages*</td>
<td>0.21</td>
<td>0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>Non-users*</td>
<td>0.18</td>
<td>0.31</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Notes: 1. Values are percentage of respondents
2. * indicate differences in percentages are significant at $p \leq 0.05$ using Pearson’s chi-squared test
3. Percentage of producers reporting that did not employ cash flow budgets, gross margins or partial budgets
4. Computer packages includes using one or more of the planning aids on a personal computer
5. Non-users were respondents that did not use any of the planning aids

Contexts: 1 - Prospectors; 2 – Analysers; 3 - Defenders

Adapted from Kaine et al. (1994b: 41)
We speculated that the similarity in the reported use of partial budgets across the contexts may have reflected ambiguity in the meaning of ‘partial’. Some respondents may have interpreted partial to mean an informal, simplified budget rather than the formal technique described in farm management texts.

The use of gross margins and computer-based planning aids such as parametric budgeting and linear programming was confined to participants in context one (prospectors) and, to a lesser extent, respondents in context two (analysers), as hypothesised. Note that a relatively high percentage of respondents in context three (defenders) did not employ any of the aids for planning enterprise mix. These results suggested that producers’ perceptions of control over the various management domains within their farm business, and the strategic posture they adopt toward manipulating enterprise mix based on those perceptions, were critical elements of the farm context for the adoption of aids for planning changes in enterprise mix among wheat-sheep producers.

These results also suggested that the population of potential adopters of aids for planning changes in enterprise mix consisted of producers in contexts one and two (66 per cent of respondents). The more sensitive planning aids were to market signals, the more the population of potential adopters would become confined to producers in context one (28 per cent of respondents). This was because persistent responsiveness to market signals was inconsistent with the perceptions and business strategies of the producers in contexts two and three. This implies that the idea that more sophisticated and detailed planning aids would be more useful to producers generally may have been mistaken.

**Replication**

The findings from the study into the adoption of planning aids for enterprise management prompted a subsequent study into the interactions between producers’ locus of control, and producers’ propensity to adopt innovations and participate in extension programs. If traits such as locus of control do influence producers’ behaviour in terms of choice of farm strategy, propensity to adopt innovations and participation in extension programs, then extension programs promoting improved farm business management techniques may need to incorporate educational elements designed to influence producers’ perceptions of control.

The data used in this subsequent study were obtained from a mail questionnaire that was distributed to primary producers in the wheat-sheep zone of south-east Australia. The
questionnaire was produced in a booklet form and consisted of a number of sections. In the first section information on the characteristics of farm enterprises and producers’ age and education was sought. Indicators of the financial performance of the farm business were also included in this section. These indicators consisted of producers’ equity in the farm business, an economic hardship scale developed by Bultena et al. (1986), and information on producers’ plans to develop their property, expand or scale back farming operations, and change enterprise mix.

In the second section of the questionnaire we sought information on producers’ perceptions of control over the performance of their farm business. This was measured using the instrument developed in the earlier study. Since producers’ responses to these statements were to be aggregated to obtain a measure of their general predisposition in terms of locus of control, another scale for measuring control beliefs, the Personal Mastery scale developed by Pearlin and Schooler (1978), was included in this section as a validation measure (Lefcourt 1991).

Information was also sought in the second section of the questionnaire on producers’ willingness to participate in extension activities. This was measured using a scale developed specifically for this study that was derived from a scale developed by Kapferer and Laurent (1985) and Laurent and Kapferer (1986).

In the third section of the questionnaire information was sought from producers on the level of stress they were experiencing and the ways in which they coped with stress. Stress was measured using a scale of chronic sources of stress in farm enterprises (Walker and Walker 1987). Means of coping with stress were identified using the scale developed by Lazarus and Folkman (1984). This scale was included in the survey as a means of validating or checking that producers’ responses to stress were consistent with their predisposition in terms of locus of control. In the final section of the survey producers’ propensity to be innovative was measured using a condensed version of a scale developed by Hurt, Joseph and Cook (1977).

The questionnaire was distributed with a cover letter and reply paid envelope to primary producers in the wheat-sheep zone of Queensland, Victoria and New South Wales during the summer of 2001. Addresses were drawn from a random sampling of entries in the ‘graziers’ and ‘farmers’ categories of the Yellow Pages™ in postcodes corresponding to the wheat-sheep zone. A reminder postcard was distributed four weeks after the initial mailing.

Surveys were distributed to 3039 addresses. A total of 783 mixed enterprise producers responded to the survey giving a response rate of 32 per cent after allowing for surveys that
were incorrectly addressed, or were sent to producers that did not manage a livestock or grain enterprise.

The average size of farms in the sample was 2,700 hectares with approximately 500 hectares being cropped. The average herd size was 300 cattle and the average flock size was 2,500 sheep. ABARE (2000) reports for the wheat-sheep zone, an average farm size of 1,800 hectares with approximately 400 hectares being cropped, an average herd size of 200 cattle and an average flock size of 1,500 sheep. Hence, the farms in the sample were larger than average for the wheat-sheep zone and had correspondingly higher than average livestock numbers.\(^{38}\)

The relatively large size of farms in the sample may be due to the fact that a reasonably high percentage of responses may have originated from properties in the pastoral zone. Some 24 per cent of responses were from producers managing livestock enterprises only. Approximately 33 per cent of responses were from producers managing cropping, cattle and sheep enterprises. Only 6 per cent of responses were from producers managing cropping enterprises only.

The age of respondents varied between 20 and 89 years. The average age of respondents was 54 years, which matched the average age of farmers reported by ABARE (2000). Most respondents had some form of formal secondary education. Approximately 25 per cent had undertaken a course at a TAFE, technical or agricultural college while 16 per cent had attended university or a college of advanced education. Approximately 31 per cent of farmers in the sample had completed some form of post-school study. These results were similar to those reported by Kilpatrick et al. (1999).

**Control as a multi-dimensional construct**

The reliability of the results of the earlier study findings was tested by repeating the factor and cluster analyses. First, the factor analysis of the perception of control statements concerning planning, finance, business expansion and growth undertaken was repeated using responses to the same statements used in the original factor analysis.\(^{39}\)

\(^{38}\) Unfortunately, these averages were not reported for the original study.

\(^{39}\) The same maximum likelihood factor analysis with oblique rotation in SPSS (1988) was used.
The results of the factor analysis with the new sample are reported in Table 5.25. Again, the data supported a solution of four factors.

The four factors corresponded closely with those reported by Kaine et al (1994b). The first factor represented a control dimension relating to strategic and tactical planning and budgeting. The second factor represented a control dimension with respect to influencing business performance by manipulating enterprise mix. The third factor corresponded to control over farm costs while the fourth factor related to producers’ perceptions of the risks involved in borrowing and enterprise expansion.

The similarity between these results and those reported in the earlier study was tested by estimating coefficients of congruence for the structure loadings in the two analyses (Rummel 1970). The coefficient of congruence is a correlation-like measure that has a maximum of 1 if the structure loadings are positively identical, a value of zero for completely dissimilarity and a minimum of −1 if the structure loadings exhibit perfect negative similarity. The estimated coefficients for the four factors were 0.99, 0.97, 0.97 and 0.98 indicating the structure matrices were almost identical. These results were evidence that the relationships between the perception of control statements and each factor were stable across different samples of respondents.

The correlations between the factors were also stable across the two analyses. The coefficient of congruence for the correlations between the factors was 0.98. These results were evidence that the dimensions underlying producers’ perceptions of control over farm business performance were stable across different samples of producers.

**Classification of farm contexts**

In the earlier study producers were classified into three farm contexts for the adoption of planning aids for managing enterprise mix using seven pairs of locus of control statements. These statements had been identified on theoretical grounds as defining the key elements that determine control over farm business performance. These statements described producers’ perceptions of influence over production outcomes, financial outcomes, business expansion and growth. The application of the same clustering procedure to the responses in the new sample to these statements generated the same typology of farm contexts.
Table 5.25 Statistical summary of factor analysis

### Pattern Matrix

<table>
<thead>
<tr>
<th>Item</th>
<th>Planning</th>
<th>Enterprise Mix</th>
<th>Cost Control</th>
<th>Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 One combination of enterprises</td>
<td>0.13</td>
<td>-0.50</td>
<td>0.10</td>
<td>-0.01</td>
</tr>
<tr>
<td>2 Not worth juggling enterprises</td>
<td>-0.02</td>
<td>-0.86</td>
<td>-0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>3 New ideas don’t apply</td>
<td>0.33</td>
<td>-0.11</td>
<td>0.02</td>
<td>0.09</td>
</tr>
<tr>
<td>4 Difficult to increase size</td>
<td>0.08</td>
<td>0.00</td>
<td>0.22</td>
<td>0.26</td>
</tr>
<tr>
<td>5 Overheads are a burden</td>
<td>0.04</td>
<td>-0.02</td>
<td>0.53</td>
<td>0.05</td>
</tr>
<tr>
<td>6 Cannot control costs</td>
<td>0.10</td>
<td>0.10</td>
<td>0.66</td>
<td>-0.01</td>
</tr>
<tr>
<td>7 Too risky to borrow</td>
<td>0.01</td>
<td>0.06</td>
<td>0.05</td>
<td>0.79</td>
</tr>
<tr>
<td>8 Mercy of banks if you borrow</td>
<td>-0.04</td>
<td>-0.09</td>
<td>-0.05</td>
<td>0.68</td>
</tr>
<tr>
<td>9 Cannot influence farm value</td>
<td>0.01</td>
<td>-0.06</td>
<td>0.41</td>
<td>0.04</td>
</tr>
<tr>
<td>10 Off-farm investments are trouble</td>
<td>0.06</td>
<td>-0.19</td>
<td>0.29</td>
<td>-0.07</td>
</tr>
<tr>
<td>11 Follow same plan</td>
<td>0.03</td>
<td>-0.18</td>
<td>0.23</td>
<td>0.10</td>
</tr>
<tr>
<td>12 Knowing strengths is no help</td>
<td>0.59</td>
<td>0.04</td>
<td>0.26</td>
<td>0.01</td>
</tr>
<tr>
<td>13 Knowing threats is no help</td>
<td>0.64</td>
<td>-0.03</td>
<td>0.10</td>
<td>-0.09</td>
</tr>
<tr>
<td>14 New plans are not worthwhile</td>
<td>0.71</td>
<td>-0.03</td>
<td>-0.05</td>
<td>-0.02</td>
</tr>
<tr>
<td>15 Budgets are not useful</td>
<td>0.64</td>
<td>0.04</td>
<td>-0.08</td>
<td>0.08</td>
</tr>
</tbody>
</table>

### Factor correlation matrix

<table>
<thead>
<tr>
<th></th>
<th>Planning</th>
<th>Enterprise Mix</th>
<th>Cost Control</th>
<th>Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enterprise Mix</td>
<td>-0.43</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost Control</td>
<td>0.57</td>
<td>-0.45</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Expansion</td>
<td>0.39</td>
<td>-0.25</td>
<td>0.35</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes: 1. Item numbers correspond to locus of control item numbers in table 5.21. Source: Kaine et al. (2001: 15)
In addition, the profiles of respondents in each farm context with respect to locus of control were not significantly different between the studies (see Table 5.26). This result suggests that the farm contexts identified in the original study were stable across different samples of producers.

_Farm context, innovativeness and extension_

The propensity of producers to be innovative was measured using a condensed version of a scale developed by Hurt, Joseph and Cook (1977). The condensed scale consists of eleven statements describing a person’s willingness to try new ideas and methods. Responses to the scale were coded such that higher scores corresponded to a greater propensity to exhibit innovative behaviour. To assist interpretation scores on the scale were standardised. The scale exhibited a high degree of internal consistency indicating it was a reliable indicator of respondents’ perceptions of control over their environment (Carmines and Zeller 1979).

Producers’ willingness to participate in extension activities such as field days was measured using a scale developed specifically for this study. Producers’ propensity to participate in extension activity was measured rather than their actual participation because participation in extension activities could be influenced by a number of mediating factors including the volume of relevant extension activity and the timing of activities in an area (Kilpatrick et al. 1999).

The scale was derived from the multi-dimensional involvement scale of Kapferer and Laurent (1986) and Laurent and Kapferer (1985). As discussed extensively in Chapter 3, involvement is a motivational construct indicating the cognitive effort that will be devoted to an activity. Here, the greater the involvement a producer places on extension activities, the greater will be their willingness to participate in those activities. Actual participation will depend on the kind of activities that are taking place, their timing and their location.

---

40 T-tests were conducted for differences between the studies for each context in terms of the mean percentage of producers that agreed with each internal locus of control statement. No significant differences were found.

41 Cronbach’s $\alpha = 0.82$. 
**Table 5.26** Profiles for internal locus of control

<table>
<thead>
<tr>
<th>Internal locus of control item</th>
<th>Context One</th>
<th>Context Two</th>
<th>Context Three</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relevance of planning:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In my experience, working out the strengths of my farm business in some detail can often give me useful leads for the future.</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>In my experience, identifying the threats and opportunities facing my farm business can often give me a good idea of the direction I should be going.*</td>
<td>96</td>
<td>95</td>
<td>49</td>
</tr>
<tr>
<td>Mostly, it doesn't worry me that things often turn out differently to my farm plans — I still find the effort put into the plans and re-adjusting them is generally repaid.*</td>
<td>94</td>
<td>86</td>
<td>46</td>
</tr>
<tr>
<td><strong>Cost control and productivity:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I generally find in my situation that I can reduce costs by planning ahead.*</td>
<td>73</td>
<td>65</td>
<td>26</td>
</tr>
<tr>
<td>For most new ideas, I generally find that with a lot of time and effort I can get them to work on my farm.*</td>
<td>78</td>
<td>72</td>
<td>44</td>
</tr>
<tr>
<td><strong>Revision of plans and enterprise mix:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Because each year is different from the last, I prefer to set up a new plan each year.</td>
<td>100</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>In my experience, juggling a combination of enterprises can be worthwhile because you can usually balance one enterprise against another.*</td>
<td>90</td>
<td>77</td>
<td>58</td>
</tr>
</tbody>
</table>

Notes: 1. Values are percentage of respondents that agreed with the item.
2. * indicate differences in percentages are significant at $p \leq 0.05$ using Pearson’s chi-squared test.

Contexts: 1 - Prospectors; 2 – Analysers; 3 - Defenders

Source: Kaine et al. (2001: 20-22)
Involvement has a number of antecedents including interest, perceived risk, reward or pleasure value, and status signalling (Laurent and Kapferer 1985; Kapferer and Laurent 1986). These antecedents can combine in various ways depending on the nature of the activity in question and the skills, attitudes and preferences of the individual. A scale consisting of three pairs of statements designed to capture the interest, reward and perceived risk antecedents of involvement in extension activity was developed. The statements described the level of interest in attending extension activities, the value or reward derived from attending these activities, and the degree to which ideas and methods promoted at extension activities translated into actions on the farm. The scale exhibited a high degree of internal consistency indicating the scale was a reliable indicator of respondents’ propensity to participate in extension activities (Carmines and Zeller 1979).

There were statistically significant differences across the farm contexts with respect to innovativeness and propensity to participate in extension activities. Specifically, innovativeness was highest amongst respondents in context one and lowest among respondents in context three. A similar pattern was evident with respect to propensity to participate in extension activity.

Further analysis revealed that interest and reward were the major factors contributing to differences among the participants in their propensity to participate in extension activity. Respondents in context three were substantially less likely than other respondents to be interested in extension activities and less likely to think such activities were worthwhile. A significantly lower percentage of these respondents indicated that they believed they were able to integrate ideas and techniques demonstrated at extension events into their farming operations.

*Locus of control, mastery, stress and coping*

Theoretically, the four factors identified in the factor analysis are sub-dimensions of a single, higher-order factor that reflects the general predisposition of respondents in terms of locus of control. If this is the case, then the higher-order factor should be correlated with respondents’ sense of mastery.

---

42 Cronbach’s α = 0.71.
A second-order factor analysis was conducted using respondents’ scores on the planning dimension, enterprise mix, cost control, and enterprise expansion factors. These four factors collapsed into a single, second-order factor termed ‘generalised locus of control’. We found that producers’ scores on this generalised locus of control were significantly and highly correlated with their scores on the mastery scale. This result was evidence that locus of control as a personality predisposition was associated with respondents’ perceptions of control over farm business performance.

Significant associations were found between generalised locus of control, farm context and respondents’ innovativeness and propensity to participate in extension activities. Respondents in farm contexts one and two exhibited significantly higher scores for generalised locus of control and mastery than did respondents from farm context three. Generally, the correlations between respondents’ generalised locus of control score, and their innovativeness score and their score for propensity to participate in extension activity were significant and high. The correlation between respondents’ innovativeness and their score for propensity to participate in extension activity was also significant and high.

These results suggested respondents who exhibited a high degree of innovativeness as measured by the Hurt, Joseph and Cook (1977) scale also exhibited a strong sense of mastery and highly internalised locus of control. They were also more likely to report a greater propensity to participate in extension activities. In contrast, respondents that exhibited a weak sense of mastery and highly externalised locus of control also exhibited a low degree of innovativeness and were less likely to be motivated to participate in extension activities.

The condensed ‘ways of coping’ scale developed by Lazarus and Folkman (1984) was included in the survey as a means of further validating the scale measuring producers’ locus of control. This scale consisted of thirteen statements describing ways of coping with problems. Respondents were asked to indicate how often they responded to difficulties or problems as described in the statements using a four-point rating.

---

43 The regression procedure available in SPSS was used to generate the factors scores.
44 Pearson r = 0.45, p < 0.01.
45 Pearson r = 0.52, p < 0.01 for locus of control and innovativeness and r = 0.41, p < 0.01 for locus of control and propensity to participate in extension.
46 Pearson r = 0.36, p < 0.01.
scale ranging from ‘never’ through to ‘often’. Responses were coded such that a high score indicated a response was used more frequently. To assist interpretation scores on the scale were standardised. Given the various ways of interpreting this scale (Edwards and O’Neill 1998) we chose to treat the responses to each statement separately rather than to aggregate the responses across all statements into a single measure.

As anticipated, respondents who had an internal locus of control tended to use different methods of coping with problems and difficulties compared to respondents who had an external locus of control. Respondents who coped with problems by talking with relatives or friends, seeking professional help, trying to analyse problems, seeking information and making a plan of action were likely to exhibit an internal locus of control. These results seemed consistent with the proposition that producers with an internal locus of control believed that they could influence many events in their lives through the exercise of their skills and knowledge.

Respondents who coped with problems by trying to forget them, avoid being with people, and accepting what cannot be changed were more likely to exhibit an external locus of control. These results seemed consistent with the proposition that producers with an external locus of control believed that the exercise of their skills and knowledge would have little influence on events in their lives and that the success of peer group leaders was atypical. These results were consistent with the proposition that producers’ locus of control over their farm businesses were partly an outcome of skills and experiences in farming, and partly an outcome of locus of control as a personality predisposition.

Locus of control and demographics

A significant negative correlation was found between the age of respondents and their generalised locus of control scores. Respondents with higher levels of formal education reported a greater sense of generalised locus of control. In particular, respondents who had not received a secondary school education reported levels of generalised locus of control that were significantly lower than average. On the other hand, respondents with some tertiary education reported significantly higher than

---

47 Pearson r = - 0.25, p < 0.01.
average levels of generalised locus of control. The relationships between generalised
locus of control and age and education were mainly thought to reflect differences in
the life experiences and socialisation of people from different age cohorts (Schieman
2001).

Conclusion
At the time the original case study was conducted the business environment of mixed
cropping and livestock enterprises had become more than usually unpredictable.
Researchers, extension staff and policy makers were concerned that, despite this
unpredictability, the use of more advanced planning aids such as gross margins,
partial budgets, parametric budgeting and linear programming by producers was not
widespread, even though these aids had been available for many years.
The objective in the case study was to explore the relationship between producers’
perception of control over farm business performance and their use of planning aids
for managing enterprise mix on the hypothesis that the benefits to be had from using
planning aids depended on the extent to which producers believed they could
influence the performance of their farm businesses through their own actions. Hence,
the intention in the case study was to identify the population of potential adopters of
business planning aids among broad-acre, mixed crop and livestock enterprises in
south-eastern Australia.
Respondents to a mail survey were classified into three farm contexts based on their
perceptions of control over various management domains within their farm business.
The use of planning aids for managing enterprise mix such as gross margins, cash
flow budgets and computer programs was significantly different across the contexts.
These results supported the proposition that producers’ perceptions of control over the
various management domains within their farm business, and the strategic posture
they adopt toward manipulating enterprise mix based on those perceptions, were
critical elements of the farm context for the adoption of aids for planning changes in
enterprise mix among wheat-sheep producers.
These results indicated that the population of potential adopters of aids for planning
changes in enterprise mix consisted primarily of producers in context one
(prospectors) and, to a lesser extent, context two (analysers). A relatively high
percentage of respondents in context one reported that they used planning aids such as gross margins. The more sensitive planning aids were to market signals, the more the population of potential adopters would become confined to producers in context one. This was because persistent responsiveness to market signals was inconsistent with the perceptions and business strategies of the producers in contexts two (analysers) and three (defenders).

The findings from the earlier study prompted a subsequent study into the interactions between producers’ locus of control, and producers’ propensity to adopt innovations and participate in extension programs. The results confirmed the relationships identified in the earlier study in regard to producers’ perceptions of control over the various management domains of the farm business. The results also confirmed the presence among wheat-sheep producers of the three farm contexts identified in the earlier study.

Theoretically, producers’ perceptions of locus of control should be partly a function of their locus of control as a personality predisposition. The results of the subsequent study supported this proposition with a generalised measure of respondents’ locus of control being correlated with their sense of mastery. In addition, the generalised measure of respondents’ locus of control was associated in psychologically appropriate ways with respondents’ coping styles.

Finally, the generalised measure of respondents’ locus of control was correlated with measures of respondents’ innovativeness and their propensity to participate in extension activities.

The findings from this case study indicated that, while some personality predispositions such as innovativeness play a role in the diffusion of an innovation, others such as locus of control or sense of mastery can be critical determinants of the farm context for an agricultural innovation, and therefore influence the population of potential adopters of an innovation. In this instance, locus of control as a personality predisposition was found to influence producers’ strategic perceptions of control over farm inputs, outputs and performance.

This raises the possibility that, given sufficient investment of time and resources, extension activities might alter the population of potential adopters of planning aids by influencing producers’ perceptions of control over their farm businesses.
Differences in perceptions of control arise as the result of differences in learning, experience and knowledge. Techniques such as skills instruction, feedback, modelling behaviour rehearsal, social reinforcement and experiential education in various combinations have been shown to change individuals’ locus of control in certain situations (Ollendick and Hersen 1979; Hattie et al. 1997). Whether such investment would be justified is a matter for further investigation.

5.4 Discussion

A number of conclusions emerge from the results of the four case studies described in this chapter. First, the application of the method described in the previous chapter for identifying the population of potential adopters of an agricultural innovation appears to have merit. In each of the case studies the sets of elements in farm systems that were identified as influencing the benefits of adopting an agricultural innovation appeared logically cohesive and consistent. The richness of the results of the convergent interviewing process was particularly striking in this regard. The use of this dialectical process to trace the reasoning of producers, and to identify and explore similarities and differences in their reasoning, provided powerful insights into the sometimes subtle interplay between the elements in a farm system that influenced the benefits of adopting an innovation. The sheep breeding case study was exemplary in this regard as the process provided internally consistent explanations for the different ways in which wool producers interpreted and employed information from bloodline comparisons using trials at different sites with link sires.

Confidence in the theory and the method was considerably increased when the elements identified through the convergent interviewing process were validated in subsequent quantitative analyses of large scale surveys. In each case study, statistically significantly associations were obtained between the farm context and the frequency of adoption of the innovation of interest.

Second, efforts to verify results by conducting follow-up interviews with survey respondents and by replication were successful. In the dairy, fruit and wool case studies interviews with survey respondents confirmed the classification of farm contexts, and the relevance of extension activities developed for those contexts.
The similarity in the results of both the qualitative and quantitative stages of the method in the two studies into the adoption of techniques for choosing studs and rams in the wool industry increases confidence in the validity of the method. The same may be said for the stability of the results from the case study into farm contexts for farm business strategy and planning, although theoretical arguments were employed in this case study to identify the elements in the farm system that constituted the farm context. The results of the method have been verified in other studies such as Kaine and Bewsell (2003) and Kaine and Bewsell (2005b) for example, where benefit segments were identified for micro-irrigation in horticulture that were similar to those described in the second case study in this chapter.

Third, the method has generated plausible and insightful results across different industries and agricultural innovations that differed in their diffusion characteristics. The case studies described here included intensive irrigated and extensive dryland agricultural industries, cropping and livestock industries, and perennial cropping industries. On one hand, the case studies included innovations such as sub-surface drainage in dryland dairying and soil moisture monitoring in horticulture that were relatively simple, easy to trial and quickly generated easily observable benefits. On the other, the case studies included innovations such as stud and ram selection techniques and enterprise planning aids that were relatively complex, difficult to trial and generated benefits that could only be detected over longer periods.

The case studies on stud and ram selection techniques and enterprise planning aids also illustrated the way in which the population of potential adopters was limited by the incompatibility of innovations with the experiences of producers. In the case of stud and ram selection techniques the population of potential adopters was limited by the incompatibility between the principles underpinning the innovations and the perceptions of most wool producers in regard to the effect of changing environment on the ranking bloodlines. In the case of planning aids for manipulating enterprise mix the population of adopters was limited by the incompatibility between the sensitivity of some aids to market signals and producers’ perceptions of control over farm business performance.

Fourth, the case studies included the four dimensions of farm context and illustrated the ways in which the mix of these dimensions in the farm context varies from one innovation to another. In the case of sub-surface drainage in dryland dairying the farm
context consisted entirely of biophysical elements in the farm system. The farm contexts for micro-irrigation in horticulture consisted of varying combinations of biophysical elements (water scarcity), technology and practice (high density planting), and labour and lifestyle components (reduced labour on irrigation). The farm contexts for stud and ram selection techniques consisted of producers’ beliefs about biophysical elements in the farm system such as beliefs about environment and ranking effects and beliefs about desirable skin traits and fleece characteristics. In regard to planning aids the farm contexts consisted of producers’ beliefs about the extent of managerial control over farm inputs, outputs and goal achievement.

Fifth, the results of the case studies signalled that the estimated population of potential adopters of each innovation was a proportion, sometimes a small proportion, of the producers in the industry and regions. The results of the case studies also suggested that, relatedly, the diffusion of the innovations through the population of potential adopters was more advanced than was commonly believed and that diffusion outside this population was lower than was commonly believed. For instance, the adoption of sub-surface drainage among the population of potential adopters in dryland dairying was estimated to be approaching 70 per cent. The adoption of objective techniques for soil moisture monitoring among the population of potential adopters in irrigated horticulture was estimated to be approaching 50 per cent. The adoption of aids for managing enterprise mix among the population of potential adopters in wheat-sheep farming was estimated at more than 30 per cent.

High involvement implies producers invest time and effort in making adoption decisions. If such decisions were motivated by considerations of benefit, and benefit is determined by farm context, then the diffusion of an innovation that has been readily available for many years among the population of potential adopters as defined by farm context would be expected to be high. Conversely, the diffusion of an innovation that has been readily available for many years outside that population would be expected to be low. Hence, in exhibiting this pattern the results of the case studies were consistent with the assumption that the adoption of agricultural innovations is highly involving for primary producers and the hypothesis that the benefits to be had from adopting an agricultural innovation are primarily influenced by the farm context. In other words, agricultural innovations are adopted by producers for whom the innovation offers a relevant and compatible technical improvement.
5.5 Conclusion

In the previous chapter an approach was described for quantifying the population of potential adopters of an agricultural innovation based on the assumption that the adoption of agricultural innovations is a highly involving decision for primary producers and the hypothesis that the benefits to be had from adopting an agricultural innovation are primarily influenced by the farm context.

In this chapter four case studies have been described in which the population of potential adopters of agricultural innovations were estimated through the identification of the farm context for the innovations. The case studies included intensive irrigated and extensive dryland agricultural industries, cropping and livestock industries, and perennial cropping industries. The case studies covered innovations with different diffusion characteristics ranging from relatively simple and easy-to-trial innovations such as sub-surface drainage to innovations that were more complex and difficult trial such as ram and stud selection practices and the use of planning aids for managing enterprise mix. The case studies included the four dimensions of farm context and illustrated the ways in which the mix of these dimensions in the farm context varies from one innovation to another.

In conclusion, the results of the case studies indicate that the hypothesis was supported and the method that was described in the previous chapter for identifying and quantifying the population of potential adopters of an agricultural innovation has merit. The results from the case studies indicate that the methods described in this thesis for identifying the farm context for agricultural innovations and identifying the population of potential adopters of agricultural innovations is generalisable across agricultural industries, innovations that differ in their diffusion characteristics, and the different dimensions of the farm system that may shape the benefits to be had from an innovation.
CHAPTER SIX

Conclusions and Implications

This paper reviews and synthesizes this past research in order to identify those independent variables that regularly explain adoption, and thereby facilitate policy prescriptions to augment adoption around the world. While a disaggregated analysis of a subset of commonly used variables reveals some underlying patterns of influence, once various contextual factors […] are controlled, the primary finding of the synthesis is that there are few if any universal variables that regularly explain the adoption of conservation agriculture across past analyses. Given the limited prospect of identifying such variables through further research, we conclude that efforts to promote conservation agriculture will have to be tailored to reflect the particular conditions of individual locales.

(Knowler and Bradshaw 2007: 25)

6.1 Introduction

Technological change and innovation has been, and continues to be, a fundamental force shaping our lifestyles, our culture and our future. As a nation we devote a substantial proportion of our wealth to research activities that span all areas of society, including agriculture. We make this investment primarily to create wealth and conserve our natural resources.

The return to our investment in agricultural research depends, in part, on the extent to which primary producers adopt the products of that research. Consequently, maximising the return to our investment in agricultural research involves identifying what research products are likely to be adopted by primary producers, by how many, and identifying processes to ensure diffusion is as rapid as possible. All these depend on a detailed understanding of how the products of research can contribute to better
satisfying the needs of primary producers in the conduct of their agricultural enterprises.

The case was put that the established schools of thinking on the adoption behaviour of primary producers do not provide a rigorous, explicit procedure for discovering how innovations can contribute to satisfying the needs of primary producers as managers of agricultural enterprises. As a consequence, policy makers and investors in research and extension have lacked a rigorous method for identifying the population of potential adopters of agricultural innovations. This means policy making and investment in research and extension have sometimes lacked a thoroughly defensible foundation for setting priorities for agricultural research, and for designing and evaluating programs for promoting the adoption of agricultural innovations.

The aim in this thesis was to describe a framework for discovering how agricultural innovations contribute to satisfying the needs of primary producers as managers of agricultural enterprises. Meeting this objective required describing a method for properly specifying the population of potential adopters of agricultural innovations. Drawing on consumer behaviour theory and farming systems theory a method was constructed based on the assumption that the adoption of agricultural innovations is a highly involving decision for producers and the hypothesis that the benefits to be had from adopting an agricultural innovation are influenced by particular elements in a farming system that are specific to each innovation. These elements were termed the farm context for an innovation. The method allowed the population of potential adopters to be classified into segments on the basis that producers with different farm contexts obtained different benefits from an agricultural innovation.

The method was tested by application in case studies in which the population of potential adopters of agricultural innovations was estimated through the identification of the farm context. The case studies included intensive irrigated and extensive dryland agricultural industries, cropping and livestock industries, and perennial cropping industries. The case studies covered innovations with different diffusion characteristics ranging from relatively simple and easy-to-trial innovations to innovations that were more complex and difficult to trial. The case studies spanned the four dimensions of farm context (strategic, labour and lifestyle, technology and practice, and biophysical) and illustrated the ways in which the mix of these dimensions in the farm context differs across innovations. The results of the case
studies supported the hypothesis and demonstrated that the method for identifying and quantifying the population of potential adopters of an agricultural innovation by identifying the farm contexts for an innovation has merit. The results from the case studies also indicated that the method was generalisable across agricultural industries, innovations that differed in their diffusion characteristics, and the different dimensions of the farm system that shaped the benefits to be had from an innovation.

6.2 Theories of the adoption of agricultural innovations

The method for identifying the population of potential adopters of an agricultural innovation was founded on the proposition that agricultural production is highly involving for producers. Involvement is a motivational trait that signals willingness to invest time and cognitive effort in an activity because that activity contributes substantively to the achievement of an individual’s utilitarian, social, and hedonistic goals. As a consequence, the adoption of agricultural innovations will be highly involving to the extent that their adoption has the potential to affect the achievement of producers’ utilitarian, social, and hedonistic goals as managers of agricultural enterprises. The intensity of producers’ involvement will be heightened to the degree that there are risks associated with the adoption of the innovation.

6.2.1 Diffusion theory

The proposition that the adoption of agricultural innovations is highly involving simply means adoption is motivated by the degree to which producers perceive innovations as creating benefits by contributing to the achievement of their utilitarian, social and hedonistic goals. This proposition lays at the heart of all the various schools of thinking on the adoption of agricultural innovations that were reviewed including diffusion theory, farming systems research and participatory approaches to agricultural research and extension, and farming styles theory. This is consistent, for instance, with Rogers (1995) conceptualisation of relative advantage as a key factor influencing innovation diffusion. It is also consistent with the evidence from a number of reviews of studies into the adoption of agricultural innovations. As Lindner (1987: 150) observed in regard to the findings in the agricultural economics literature:

“... there is compelling empirical support for the emerging consensus that the final decision to adopt or reject is consistent with the
producer’s self-interest. The finding that the rate of adoption as well as the ultimate adoption level is determined primarily by the actual benefits of adoption to the potential adopters is by far and away the most important result to be culled from the empirical literature on adoption and diffusion.”

The consumer behaviour approach, by taking the needs of producers as the starting point for evaluating the advantages and disadvantages of innovations, is consistent with participatory approaches to research and extension such as the ‘farmer first’ approach espoused by Chambers et al. (1989).

The theory of the population of potential adopters presented in this thesis was consistent with the concepts employed in the classical theory of innovation diffusion proposed by Rogers (1995) as the population was defined using the very same concepts. The population of potential adopters of an agricultural innovation was defined as consisting of those producers for whom the innovation offers a relative advantage. Relative advantage was defined as the extent to which an innovation can assist producers as managers of agricultural enterprises to better achieve their utilitarian, social and hedonistic goals, relative to current technology and practice. The population of potential adopters consists of those producers for whom the innovation offers a relevant and compatible technical improvement. Hence, the concept of relative advantage defines the population of potential adopters as well as being a critical factor influencing the rate of adoption (Rogers 1995).

Given that relative advantage is the result of the interaction between the characteristics of the innovation and the relevant properties of a farm system, the diffusion of an agricultural innovation through the population of potential adopters may be influenced by individual differences in the farm context as well as by the characteristics of the individual producer, such as their propensity to innovativeness. This raises the possibility that the pressure of circumstance, as measured by the intensity of relative advantage, may be sufficiently powerful to motivate producers to act in a manner contrary to their general predisposition to innovativeness. In other words, contextual pressures may be sufficient to influence producers to adopt an innovation earlier, or later, than their personal predisposition to innovativeness might otherwise have indicated.

This means that relative advantage influences the adoption of agricultural innovations in three ways. To begin with relative advantage defines the population of potential
adopters. Next, differences in relative advantage across individuals within that population may influence the timing with which individuals adopt the innovation relative to others in the population. Producers may adopt some innovations earlier than they otherwise would where their farm context is such that the relative advantage offered by those innovations is high relative to other producers. Conversely, producers may adopt some innovations later than they otherwise would where their farm context is such that the relative advantage offered by those innovations is low relative to other producers. Finally, differences in relative advantage across innovations influence the rate at which they diffuse through the population of potential adopters (Rogers 1995).

Given that relative advantage will vary between innovations for a producer, the possibility exists that producers will switch between adopter categories from one innovation to the next. Extension efforts to accelerate the diffusion of innovations among producers by building their capacity to learn, plan and make decisions may facilitate such switching.

6.2.2 Farming systems research and participatory theory

The emphasis placed in the definition of the population of potential adopters on the contribution of the innovation to the achievement of producers’ goals is consistent with farming systems research and participatory approaches to research and extension. The participation of producers is fundamental to the successful conceptualisation, development and commercialisation of innovations. Producers should be involved as both consultative participants in the research process by providing information about their needs and as functional or interactive participants in the research process through contribution of local knowledge to the development of innovative solutions to those needs (Pretty 1995).

The conceptualisation of farm context is consistent with, and complements, the concept of recommendation domains in farming systems research. As Reece et al. (2004: 28) observed:

“The idea of matching technology with potential users is well established in agricultural research. Within farming systems research, for example, the notion of a ‘recommendation domain’ was widely used, with these domains usually being defined in terms of differences in farm size and agro-ecology […]. However, while farm size and agro-ecology certainly relate to the two dimensions in which
agricultural diversity is apparent, the social-economic and physical 
(soils, rainfall) environments, they are far too narrow to provide a 
reliable basis for targeting technology development."

The methods presented in this thesis offered a resolution to the difficulty in defining the scope of a recommendation domain in regard to the adoption of an innovation by providing a conceptually sound procedure for classifying farms within a farming system into categories that are meaningful with respect to the adoption of an innovation. In farming systems research farms are categorised to facilitate identification of a constraint that is shared by most farms in a category. The logical next step is to partition farms within a category into groups based on the variety of contexts into which a proposed solution to that constraint must fit, or be adapted. This needs to be done bearing in mind the possibility that the solution to a constraint in one farming system may also offer a solution to a different constraint in another farming system.

To the degree that the elements in the farm system that influence the benefits and costs of adopting an innovation, that is, the relative advantage of an innovation, are different for different innovations, the choice criteria used to evaluate innovations will change accordingly. This means that choice criteria are frequently innovation-specific and often cannot be generalised across innovations. This is consistent with the observations of Gibon et al. (1999), Dorward et al. (2003) and other farming system researchers that the adoption of an innovation within a farming system often depends on a set of technical, economic and social characteristics that tend to be highly specific to that innovation.

The adoption of agricultural innovations was assumed to be a highly involving activity for producers because adoption decisions entail consideration of novel situations and usually have important but, to some degree unpredictable, financial and social consequences for producers. Accordingly, producers were characterised as investing time and effort in identifying relevant elements in their farm systems, actively searching for information on the characteristics of innovations, and establishing, in some form, causal descriptions of the potential consequences that might flow from adopting innovations. They were assumed to devote time and effort to formulating choice criteria, evaluating innovations and making decisions and to have some capacity for adaptation and change and to possess key knowledge and
learning skills, though not necessarily to a uniform degree. This characterisation is consistent with Salmon’s (1981) cognitive approach to attitude change which views farmers as self-directed learners who seek out knowledge that is most relevant to their current needs and problems and integrate that knowledge into their own frame of reference.

Experience with farming systems research has resulted in the view that the adoption of agricultural innovations is driven by the self-interest of producers as expressed by their objectives (Lindner 1987; Cary 1992; Collinson 2001; Norman 2002). Farming systems research has discovered that producers: have a thorough knowledge of their local environment including spatial and temporal variability; have an intimate understanding of their farm systems, problems, and priorities; have criteria for evaluation of options; and actively engage in experimentation as part of their farming routine (Norman 2002; Sumberg et al. 2003). Hence, extensive experience in farming systems research is consistent with the proposition that the adoption of agricultural innovations is a highly involving activity for producers and with the characterisation of producers as effortful, discriminating and methodical purchasers of agricultural innovations.

6.2.3 Farming styles theory

The definitions of the population of potential adopters and farm context are also consistent with the concept of farming styles to the degree that such styles exist and can be defined with respect to an innovation. Farming styles theory proposes that producers exhibiting a particular style will exhibit similar values and goals, and they are expected to have fashioned their farm systems similarly. Hence, producers that exhibit a particular farming style should be potential adopters of an agricultural innovation if that innovation offers a technical improvement that is relevant to the objectives, and compatible with the values, of producers with that farming style (Howden and Vanclay 2000; Commandeur 2006).

Given this interpretation of farming styles theory then the definition of the population of potential adopters of an agricultural innovation proposed here is, in principle, consistent with the general intent of farming styles theory. In proposing that the population of potential adopters consists of producers for whom the innovation offers a relative advantage the definition appears to include, and is limited to, those
producers who are members of the set displaying farming styles for which the innovation offers a relevant and compatible technical improvement.

This thesis advances farming styles theory by drawing on consumer behaviour theory and farming systems theory to provide a theoretically sound and practical method for identifying the population of potential adopters.

### 6.3 Implications for the adoption of agricultural innovations

The proposition that the benefits to be obtained from adopting agricultural innovations depend on the farm context, together with the idea that producers find the adoption of innovations to be highly involving decisions, raises a number of theoretical, methodological and practical implications for explaining and predicting the adoption and diffusion of agricultural innovation.

#### 6.3.1 Theoretical Implications

First, this proposition logically implies that the population of potential adopters of innovations can be defined by identifying the farm context for an innovation. The population of potential adopters is defined by the set of producers whose farm system is such that the innovation offers a relevant, compatible technical improvement. That is, it is the set of producers whose farm system have characteristics such that the innovation would offer the producer a potential relative benefit. The decision of an individual within that population to consider adopting the innovation may be triggered by a range of cues, some external to the farm enterprise, such as promotion through extension, others internal to the farm enterprise, such as changes in financial circumstances or seasonal conditions. The rate at which innovations will diffuse through their population of potential adopters will depend on the characteristics identified by Rogers (1995), which includes the intensity of relative advantage.

Second, this proposition logically implies that the population of potential adopters can be categorised into different farm contexts, and their associated benefit segments, based on differences in the key elements in the farming system that influence the benefits to be had from an innovation. For example, with respect to the adoption of micro-irrigation in horticulture, different benefit segments were identified in relation
to increasing the efficiency of water use, reducing labour requirements, increasing operational flexibility in the orchard, and irrigating orchards planted to high density trellis systems (Boland et al. 2005).

Third, the membership of the potential population of adopters and segments within that population will change in response to changes in farm context. Changes in farm context may be the result of changes within the farm enterprise. For example, the retirement of a senior family member from active participation in orchard activities may trigger the need to adopt labour-saving technologies such as micro-irrigation technology. It would be easy, in this instance, to misinterpret the timing of adoption as evidence that the senior family member was conservative and preventing younger, apparently more innovative members of the family, from adopting the technology.

Changes in farm context may also be the result of changes outside the farm enterprise; for instance, changes to regional irrigation infrastructure that may change the farm context of grape growers with respect to the supply of irrigation water and thereby trigger the adoption of soil moisture monitoring (Kaine and Bewsell 2000b; Kaine and Bewsell 2002d; Kaine and Bewsell 2002e).

The population of potential adopters of innovations will also change should the utilitarian, social and hedonistic objectives of producers change. For instance, changes in the lifestyle aspirations of producers may result in a desire to reduce the time and effort expended on farm activities such as irrigation leading to the adoption of labour-saving technologies such as automatic irrigation (Kaine and Bewsell 2000a; 2004a).

Fourth, the stability of the population of potential adopters of innovations, and segments within that population, will vary depending on the dimensions of the farm system that define farm context. For example, the population will be relatively stable where farm contexts are defined by relatively fixed biophysical characteristics such as soil type and topography as was the case with sub-surface drainage in the dryland dairy industry (Kaine and Niall 1999; 2001a). Where the farm context is defined by other dimensions such as technologies and practices, and labour and lifestyle, the size of the population may be less stable. For example, the size of the population will be less stable where farm contexts are defined by relatively variable characteristics such as family composition which influence labour availability or government policy.
which may influence access to agricultural inputs such as water or power (Kaine and Bewsell 2001a; Kaine and Bewsell 2001b; Kaine and Bewsell 2002c).

Fifth, agricultural innovations may be adopted by producers to realise benefits other than those for which innovations were designed. The characteristics of producers and farming systems are such that variety will emerge in the uses to which agricultural innovations may be put (Kaine and Higson 2006). For example, micro-irrigation systems were adopted by some horticulturalists primarily to save time rather than water (Boland et al. 2005). Reuse systems were adopted by some dairy farmers primarily to improve control over irrigation management rather than to capture irrigation run-off while automatic irrigation was adopted by some dairy farmers primarily to reduce the effort involved in irrigations rather than to reduce the risk of irrigation run-off (Kaine and Bewsell 2000a; 2004a).

Sixth, agricultural innovations will be abandoned by producers should the relative advantage they offer vanish. This is a truism when innovations are superseded. However, some innovations may be adopted and used for only a limited period of time because the relative advantage they offer is intrinsically short-lived. For example, some fruit growers adopt technologies for monitoring soil moisture to assist them in establishing a new irrigation regime when they adopt micro-irrigation. Once these growers become familiar with the new regime, once they have calibrated the operation of the new irrigation system with their previous experience, the advantage offered by the monitoring technology vanishes and the technology is abandoned (Kaine and Bewsell 1999). Distinguishing farm contexts where the relative advantage offered by an innovation is short-lived from farm contexts where relative advantage is more enduring may be critical to properly evaluating the success of the innovation and any associated extension activities.

Seventh, the adoption of agricultural innovations has been proposed to be a highly involving activity for producers. Consequently, producers were characterised as investing time and effort in identifying relevant elements in their farm systems, actively searching for information on the characteristics of innovations, and establishing causal descriptions of the potential consequences that might flow from adopting innovations. This is consistent with the assessment in farming systems research that producers are intentionally rational in the way they manage their farming operations, including their choice of technology (Cramb 2005).
At the same time, this characterisation is also consistent with the views expressed by Campbell (1995), Murray-Prior (1994), Wright (1983) and others that producers are not, and need not be, hyper-rational agents engaged in optimising behaviour. As Crouch (1981) observed, the decision to adopt an innovation is often a matter of practical sense as the scope to adopt innovations is restricted by the mix of technologies and practices adopted previously, resource constraints, and management strategies of the producer. This suggests that, in many instances, agricultural innovations will fail to pass the compatibility screening associated with producers’ strategic image (Beach and Connolly 2005). Consequently, the decision not to adopt an innovation is often a simple matter of elimination rather than a question of optimisation based on finely balanced criteria.

Furthermore, the complex interrelationships between technologies, practices, resources and strategies in farming systems means producers must be confident that the benefits an innovation appears to offer will be realised in order to justify the necessary investment in adjustments to their farm systems as well as investment in the innovation itself. Hence, innovations that appear to offer only a marginal relative advantage are unlikely to be considered as deserving candidates for adoption.

In addition, the complexity of farming systems, together with the inherent unpredictability of elements that are critical to performance such as commodity prices and seasonal conditions, means that there is a perceived risk associated with the adoption of any agricultural innovation. Consequently, agricultural innovations that only offer a marginal benefit in terms of relative advantage must be perceived as virtually risk free to merit consideration for adoption. This is most likely to be the case with incremental innovations which, by definition, are likely to be highly compatible with the farming system (Henderson and Clark 1990). Hence, the decision to adopt incremental innovations that offer a marginal relative advantage is more likely to depend on simple calculation rather than complicated, finely balanced optimisation.

A systems perspective on the adoption of agricultural innovations supports the conclusion that producers need not be hyper-rational in this regard. From this perspective the adoption of agricultural innovations is largely a matter of system improvement rather than system design (Van Gigch 1974). Consequently, the adoption and integration of agricultural innovations into a farm system is a process of
identifying and realising infra-marginal gains rather than optimisation of marginal benefits through refinement of system design.

Finally, the purchase of any input for an agricultural enterprise will be *situationally* involving for the producer to the degree that the input is perceived by the producer as contributing to satisfying their utilitarian, social, or hedonic goals as managers of agricultural enterprises. Involvement will be intensified to the extent that the purchase is perceived by the producer to have the potential for undesirable psychological, social and functional outcomes. The higher the level of involvement and the greater the perceived risks, the greater the effort producers will be prepared to invest in, and the more extensive will be, the purchase decision. Involvement may become *enduring* for inputs that are perceived as high risk and must be purchased repeatedly.

In such situations producers may choose to purchase the input repeatedly from the same supplier as long as the input performs satisfactorily. The potential benefit of switching suppliers is outweighed by the perceived risk of poor performance. Hence, producers will only switch suppliers should the performance of the input become consistently disappointing. This kind of risk management behaviour has been observed in relation to the choice of stud and purchase of rams by commercial wool producers (Kaine and Niall 2001b; Kaine et al. 2006) and the choice of pest and disease management techniques in horticulture (Kaine and Bewsell 2003; Bewsell and Kaine 2004; Kaine and Bewsell 2004b; Kaine and Bewsell 2005b).

### 6.3.2 Methodological Implications

A number of methodological implications follow from the finding in this thesis that the population of potential adopters of an innovation is defined by the set of producers with farm contexts for which the innovation offers a relative advantage. The first implication is, as described in Chapter Two, that the results of regression analyses of the adoption of innovations will be biased where the sample includes producers that are members of the population of potential adopters who have not yet adopted the innovation. This may explain the disappointingly weak and often contradictory results of such analyses. This bias may be avoided by following an estimation procedure that allows the effects of the characteristics of producers that influence the spread of an innovation through a population to be incorporated in the analysis.
The results of regression analyses of the diffusion of innovations will also be biased where the sample includes producers that are not members of the population of potential adopters. This bias can only be corrected by the identification and exclusion of these producers from the sample.

A second related implication is that the results of regression analyses of the adoption of innovations will be biased where the sample includes producers that are members of different segments of the population of potential adopters. The results of the case studies reported in Chapter Five demonstrated that different elements in the farm system combine to define each farm context for an innovation. This means the relationship between relevant elements in a farm system and the adoption of the innovation will be non-linear where the sample of producers under investigation contains producers drawn from more than one farm context. In such situations, linear regression analyses may be expected to have limited explanatory power, to underestimate the magnitude of relevant parameters, and to be biased towards Type 1 errors (Judge et al. 1982). Non-linear procedures are required to reduce such biases; hence, the use of procedures such as cluster analyses in the case studies.

A third, related implication concerns the inference of causality in regression models of the adoption of agricultural innovations based on cross-sectional data. Doss (2003) drew attention to the fact that studies using cross-sectional data only establish a correlation between the current use of a technology and the characteristics of adopters. The presence of a correlation does not indicate the existence or the direction of causality between use and characteristics. For instance, a positive correlation between farm size and adoption may be interpreted as indicating producers with larger farms are more likely to adopt the innovation. Alternatively, the correlation may be interpreted as indicating that producers can develop larger farms as a result of adopting the innovation. Another alternative is that both interpretations are correct. The extent of this ambiguity depends on the degree to which the elements in the farm system that constitute that farm context for an innovation may be influenced by the producer. For instance, many of the elements that comprise the biophysical dimension of farm context are fixed irrespective of the outcomes of adoption decisions.

The methods for identifying the elements in a farm system that influence the benefits to be had from an innovation provide means of resolving inferences about causality in cross-sectional studies of adoption behaviour. The reliance on personal interviews
with producers to elicit their farm contexts provides the opportunity for causality to be explored with the producer. And the laddering process used in interviews allows causal relationships to be revealed. Furthermore, the dialectical nature of the convergent interviewing process allows alternative causal relationships to emerge and forces the researcher to seek explanations that reconcile these alternatives.

A fourth implication concerns bias in quantitative models of adoption decision-making. In professions such as health as well as in agriculture, social psychological models such as the Theory of Reasoned Action (Fishbein and Ajzen 1975) and its variants are the most popular models of behaviour change. In these models a change in behaviour, such as the adoption of an innovation, is thought to be influenced by behavioural intentions which are a function of personal attitudes towards the innovation and social norms about the adoption of the innovation. The variants of the Theory of Reasoned Action model differ in the other factors that are thought to influence intention and behaviour such as self-efficacy, habit and locus of control (Ajzen 1991; Ajzen 2001; Ajzen 2002).

In principle, these models are similar to the complex decision making model in their conceptualisation of the types of factors, such as functional, social and hedonic benefits for example, that influence behaviour. However, these psychological models do not explicitly allow for the possibility that an innovation may differentially suit a range of farm contexts. As a consequence, the quantitative specification of the relationship between attitudes and intentions in these models is linear whereas the presence of a variety of contexts suggests that these relationships may be more functionally complex (at least across the potential population of adopters as a whole). Further, these models do not clearly distinguish between different types of decision making processes and the circumstances that elicit each type. For example, they do not distinguish readily between complex decision making and inertia which are mutually incompatible types of decision processes. In fact, the two are conflated in some applications of the Theory of Reasoned Action (Ajzen 2001). This adds to the difficulty of identifying and interpreting relationships between behaviour, intentions, attitudes and norms.

There is a tendency with these models to focus on identifying and describing individuals’ attitudes and social norms towards an innovation without a corresponding
effort to identify the contextual factors that are the source of the differences in individuals’ attitudes (see Ajzen 1991; Sparks and Guthrie 1998; Armitage and Conner 2001). To the extent that contextual factors are incorporated in these models, they are often treated as explaining variation in intentions beyond that explained by beliefs and norms rather than antecedents of beliefs (Perugini and Bagozzi 2001; Kuther 2002). This limits the contribution these models can make to explaining and predicting the adoption of agricultural innovations.

A fifth implication that follows from the finding that the population of potential adopters of an innovation is defined by the set of producers with farm contexts for which the innovation offers a relative advantage is that the innovativeness of producers cannot be measured using scales based on counting the number of agricultural innovations they have adopted. As Crouch (1981) concluded, such scales will be biased because producers with farm contexts that do not suit one or more of the innovations will appear less innovative than producers with farm contexts that suit all of the innovations irrespective of their predisposition to be innovative. Such scales will also be biased to the extent that the innovations differ in the rate at which they spread through the population of potential adopters because they differ on the characteristics that influence their diffusion. Furthermore, such scales will also be biased to the extent that innovations have not fully penetrated the population of potential adopters because of limited promotion and differences in the characteristics of producers, other than their innovativeness, that influence the timing of the adoption of innovations.

A sixth, and related implication, is that the adoption of agricultural innovations by producers cannot be treated as a criterion for making the judgment that some producers are necessarily better managers of their farm business than others. The failure of producers to adopt an innovation may merely mean that the innovation is unsuited to their farm context at that point in time. To judge such producers as incompetent or conservative without a proper understanding of their farm system is mistaken, misleading and unjustly pejorative. To claim that producers who have adopted innovations are superior to, or more innovative than, those who have not is,

48 Examples of such scales being interpreted as indicative of ‘higher’ or more ‘intense’ adoption of innovations are Ridgley and Brush (1992) and Shennan et al. (2001).
without a proper understanding of their farm system, equally mistaken and misleading and, perhaps, a self-serving exaggeration.

\section*{6.3.3 Practical Implications}
A number of practical implications follow from the findings of this thesis in regard to agricultural research, extension and policy. These will be discussed in turn commencing with the implications for agricultural research.

\textit{Agricultural research}

The first implication is that the population of potential adopters tends to be over-estimated even where relatively rigorous procedures are used to identify such populations as is the case with the identification of recommendation domains in farming systems research. The experience in farming systems research, together with the findings in the case studies described in the previous chapter and the findings from similar studies reported in that chapter, suggest that the population of potential adopters of an innovation is typically a proportion, sometimes only a minor proportion, of the producers in a particular industry and region.

The evidence may thus suggest that there is a tendency among researchers, and possibly those that invest in research, to be overly optimistic in their estimates of the population of potential adopters. Consequently, the method presented here for identifying the population of potential adopters of an innovation offers investors in research a more rigorous means of assessing the scope for adoption of the products of research programs.

The second implication concerns the tailoring of research to target producers with different farm contexts (Erbaugh et al. 2002). Knowledge of similarities and differences in the farm contexts of the producers that constitute the population of potential adopters of an agricultural innovation can be used to partition the population into benefit segments such that the producers within a segment are similar in the benefits they seek from an innovation, while producers from different segments are dissimilar in the benefits they seek. This means producers from different benefit segments will likely use different choice criteria to evaluate an innovation and so may favour different attributes in an innovation.
The possibility emerges that the products of research may be tailored to better satisfy the different choice criteria that will be used by producers from different benefit segments to evaluate an innovation. Whether there is merit in doing so will depend on the relative size of segments, the value to each segment of the customised features, and the costs of tailoring the features of innovations. In this regard, knowledge of the different farm contexts for an innovation may assist farming systems researchers to more precisely define the point at which prototypes of innovations may be released to producers for subsequent modification and adaptation (Collinson 2001; Douthwaite et al. 2002; Sumberg 2005).

The third implication concerns the recruitment of producers as collaborators in research and development activities. The participation of producers is obviously critical to the successful conceptualisation, development and commercialisation of innovations. However, the theory described here, supported by the case studies, has highlighted that the benefits producers seek from an innovation differ depending on their farm contexts. To the extent that producers from different contexts may favour different attributes in the innovation, researchers must be careful to ensure producers from each of the target farm contexts are recruited to collaborate in the development of the innovation. Hence, using the methods described for identifying the set of farm contexts for an innovation may have merit as a means of ensuring collaborating producers are recruited from the appropriate farm contexts.

**Agricultural extension**

The first implication of the findings is that the penetration of agricultural innovations tends to be under-estimated because the population of potential adopters tends to be over-estimated. Typically, apparently low rates of adoption are equated with low penetration. The findings that the population of potential adopters of an innovation is typically a proportion of the producers in a particular industry and region implies directly that apparently low rates of adoption are, in fact, higher when calculated with reference to the actual population of potential adopters.

Hence, the method for identifying the population of potential adopters of an innovation offers extension managers and evaluators a more rigorous means of assessing the success of extension programs. In the absence of information on the
criteria producers use to evaluate an innovation, extension managers have little to guide them in assessing the extent to which an innovation has diffused among a population of adopters. A relatively small number of adopters may actually represent a high level of diffusion if the population of potential adopters is relatively small. On the other hand, a relatively high number of adopters may actually represent a low level of diffusion if the population of potential adopters is relatively large. Similar logic can be applied to attempting to judge the success of extension programs by levels of attendance at events such as field days and workshops. The method provides a means of resolving these difficulties by providing a sound procedure for judging relative rates of adoption.

The second implication concerns the tailoring of extension messages to target producers with different farm contexts. Given that knowledge of similarities and differences in the farm contexts of the producers that constitute the population of potential adopters of an agricultural innovation can be used to partition the population into benefit segments, extension messages may be tailored to appeal to the specific choice criteria used by producers in a benefit segment to evaluate an innovation. This offers the possibility that targeting extension activities may become a practical reality by enabling the alignment of extension messages and tailored research products with the choice criteria of producers in a segment and their associated preferences regarding the attribute of the innovation, respectively. Whether there is merit in doing so will depend on the relative size of segments, the value to each segment of the customised features, and the costs of tailoring the extension effort.

In this regard the results of the case studies reported in Chapter Five indicated that the elements in the farm system that have a critical influence on the benefits to be had from an agricultural innovation are typically few in number. In other words, the farm context for agricultural innovations is usually composed of several elements at most. Furthermore, there is a logical structure to the associations between these elements as illustrated by the classifications reported in the case studies. This means that the messages that are required to promote extension activities and signal relevance to producers in a benefit segment are likely to be simple and straightforward. This also means that, given knowledge of these elements, producers may be easily classified into benefit segments given their responses to a few simple questions.
The third implication concerns producer participation in extension activities and self-selection. In this thesis producers have been portrayed as active, self-directed learners and seekers of information about agricultural innovations because the adoption of these innovations is highly involving. Producers will invest time and effort in search activities directed towards identifying and evaluating the critical elements in their farm system that will influence the benefits to be had from adopting innovations, and obtaining information on the relevant features of the innovations themselves. Hence, it is to be expected that producers will seek information on innovations from a range of sources and will make discriminating judgements about the credibility of those sources.

The purpose of extension programs is to facilitate and accelerate change by reducing the effort that producers must invest in searching for information and, when required, acquiring new skills. This means that, to be successful, managers of extension programs must signal the relevance of their programs to producers, provide information in an accessible, timely and useful way, and offer appropriate training. While there is a substantial literature in extension devoted to providing information and training, there is little on the notion of signalling relevance. In the absence of comprehensive and reliable information on the benefits producers are seeking from an innovation, and the criteria they use to evaluate the innovation, the program manager has limited capacity to attract producers by signalling the relevance to them of an extension activity.

Producers participating in extension activities will self-select on the basis of their perceptions of the potential relevance of the innovation being promoted. Such perceptions will be based in part on any signals the producer detects regarding the likely potential benefits to be had from the innovation. Such perceptions may also be based on a partial understanding of the innovation and subject to producers’ judgements about the credibility and utility of extension activities based on past experience. Such judgements may be mistaken on occasion but the producer has no other information on which to make an assessment of the activity with limited effort. Besides, there is rarely a need to adopt agricultural innovations rapidly.

On the other hand, knowledge of the benefits motivating producers to consider adoption and the criteria they use to evaluate an innovation provides the manager of an extension program with information to design a message signalling to producers
the various benefits the innovation may offer. Such signals may enable the target audience to easily and rapidly identify the relevance of an extension activity and self-select appropriately.

For example, micro-irrigation was promoted to grape growers in northern Victoria, Sunraysia and Murrumbidgee Irrigation area as a means of saving water. Given that, at the time, many growers in these areas had ample water supplies, participation in extension programs was limited. Growers were adopting micro-irrigation to save labour and to create capacity to improve grape quality. Hence, efforts to attract growers to extension activities may have been more successful if these activities were promoted as opportunities for grape growers to learn how to improve grape quality (Burrows et al. 2003; Kaine and Bewsell 2002e).

The fourth implication concerns distinguishing market saturation from signal or delivery failure in relation to extension programs. Producers may stop attending extension events because most potential adopters have acquired the information and skills required to adopt the innovation. Consequently, the extension program is no longer required. Second, producers may not attend extension events because the program manager has made a mistake in signalling the relevance of the program to the target audience of producers. Third, producers may not attend extension events because the program does not meet producers’ learning and training needs.

While the program manager may be able to identify the third possibility using accepted evaluation procedures, the manager cannot distinguish between the first and second possibilities in the absence of information on the factors motivating adoption and estimates of the population of potential adopters. This does raise the interesting possibility that the best measure of success of a program is relative popularity, that is, numbers of participating producers relative to the population of potential adopters.

The fifth implication concerns the dynamics of the membership of the population of potential adopters and its constituent benefit segments. As noted above, the population of potential adopters is likely to be relatively stable for innovations where the relevant dimensions of farm context are enduring biophysical and strategic elements. Where the population is relatively stable the participation of producers in extension activities may be expected to follow the classical diffusion curve.
The population of potential adopters is likely to be relatively variable for innovations where the relevant dimensions of farm context are labour and lifestyle elements and less enduring elements of technology. Where the population is relatively variable the participation of producers in extension activities may be expected to depart from the classical diffusion curve. Discontinuous changes in producers’ participation may occur independently of extension activities due to changes in the farm contexts of producers. These changes may be provoked by changes in the family composition of producers, changes in producers’ objectives, the emergence of novel technologies and practices that are functionally related to the innovation of interest, or changes in policy relating to regional infrastructure such as power or irrigation delivery.\(^\text{49}\)

The method for identifying the population of potential adopters offers extension personnel a more defensible method of assessing changes in the participation of producers in an extension program. In the absence of comprehensive information on the factors motivating adoption of an innovation the task of identifying the causes of changes in the rate of adoption of an innovation, or the causes of changes in participation rates in extension activities, becomes problematic. Changes in the rate of participation in an extension program may be provoked by a change in the producers’ environment that substantially changes the attractiveness of an innovation. For example, the rapid diffusion of biological control of mites and pheromone mating disruption techniques for codling moth in fruit growing in Australia was triggered by severe problems with chemical resistance (Kaine and Bewsell 2003). It would be easy to form the impression that the institution of a novel extension program was responsible for the rapid adoption of these technologies. Such an impression confuses the factors motivating change with the factors motivating participation in a change management program.

The sixth implication concerns the mechanism by which extension may influence the population of potential adopters of an agricultural innovation. In other words, extension programs may raise awareness, disseminate information, and foster skill acquisition resulting in higher rates of diffusion than would otherwise be the case. As Rogers (1995) discusses, this involves the extension manager or agent coming to an understanding of the producer’s circumstances in relation to an innovation (their farm

\(^{49}\) Climate change would seem to have the capacity to provoke unpredictable and discontinuous changes in the farm systems of producers.
context), bringing the innovation and its features to the attention of the producer, and possibly assisting the producer in their deliberations on the benefits of adopting the innovation. In short, the role of extension is to accelerate the diffusion of the innovation by changing producers’ perceptions of the merits of the innovation given the farm context of the producer.

In most instances, extension does not itself change the population of potential adopters. However, extension may be able to influence the population of potential adopters in circumstances where producers’ perceptions of their farm context are mistaken. Such circumstances are likely to be unusual and may be problematic. Examples are producers’ perceptions of the influence of changing environment on the ranking of merino bloodlines in terms of fleece weight and fibre diameter (Kaine and Niall 2001b; Kaine et al. 2002; Kaine et al. 2006), and producers’ perceptions of control over farm business performance (Kaine et al. 2001). In such instances extension may, in principle, influence the population of potential adopters by changing producers’ perceptions of farm context rather than changing their perceptions of the characteristics of the innovation.

Changing producers’ perceptions of their context is likely to be a difficult task and may be problematic. Producers’ perceptions of their farm context are based on a thorough knowledge of their local environment. This includes their experience of spatial and temporal variability. They have an intimate understanding of their farm systems, problems, and priorities. They actively engage in experimentation as part of their farming routine and have well-established criteria for the evaluation of options as a result of that experimentation (Norman 2002; Sumberg et al 2003). Hence, the task of persuading producers to change their perceptions of their farm systems involves contradicting their own extensive experience with their farming systems. This suggests that such changes may only be established through highly sophisticated, expensive extension programs that may even need to be tailored to the circumstances of individual producers (Kaine et al. 2002; Kaine et al. 2001; Kaine et al. 2003a; Kaine et al. 2003b; Kaine et al. 2004a).

The final implication for extension of the findings that will be considered concerns group extension. The proposition that the population of potential adopters of an agricultural innovation is composed of benefit segments based on differences in farm contexts requires that managers of extension programs be sensitive to the ways in
which these differences may influence the interactions between producers in group situations.

For example, workshops involving producers from a variety of segments may be useful in producing lists of elements in the farm system that influence the benefits to be had from an innovation. However, such workshops must be managed carefully if the causal interactions between these elements across different farm contexts are to be described with sufficient clarity to reveal the contexts. Kaine et al. (2003c) provide an example where workshops were used to identify the various elements in the farm context that influence producers’ preferences for different mechanisms for administering animal health products. Producers identified a number of contradictory items. Subsequent application of the method for identifying the population of potential adopters resolved these contradictions by revealing that these elements functioned in different ways depending on the presence of other elements in the farm context.

Managers of extension programs must be sensitive to the ways in which differences in farm contexts may influence the interactions between producers in group situations in that there is no compelling reason to suppose that producers from different farm contexts will necessarily understand the reasons for their different perspectives. Misunderstandings among producers about the functioning of different farm contexts may partly explain producers’ constructions of apparently fictional farming styles and their judgements about those styles (Howden and Vanclay 2000).

This suggests that the diffusion of an agricultural innovation through the population of potential adopters may be a more complicated process than popularly imagined. Diffusion may be more accurately described as occurring concurrently, though not always independently, within each farm context or benefit segment. In principle, differences may arise between contexts in the rate of diffusion because of differences across farm contexts in the intensity of relative advantage. Differences in diffusion rates may also arise as the result of differences across farm contexts in the apparent complexity or compatibility of the innovation. For instance, the rate of diffusion of micro-irrigation among fruit growers that have converted from flood or furrow irrigation may be considerably different from the rate of diffusion among those that have converted to micro-irrigation from pipe and riser irrigation. And the rate of diffusion of micro-irrigation is most likely to be different again among fruit growers
who have installed micro-irrigation because they have redeveloped their orchards to high density planting (Kaine and Bewsell 1999; Kaine and Bewsell 2002a; Kaine and Bewsell 2002b).

The diffusion of an innovation among producers in one farm context may influence the diffusion of the innovation among producers in another farm context. Where a particular benefit is common to one or more farm contexts, the rate of diffusion in those contexts may be influenced by the sharing of knowledge and experiences between producers from different contexts. Alternatively, the logical interrelationships between farm contexts may influence the rate of diffusion of an innovation among them.

For instance, using Kaine et al. (2002), the spread of superior ram genetics through the national sheep flock could be hypothesised to occur in stages. First, the superior ram genetics are identified and adopted by producers who follow a breeding strategy that is consistent with selecting rams using data from across-flock bloodline comparisons such as Estimated Breeding Values. Second, the successful use of these superior rams may subsequently encourage neighbouring producers who follow a strategy of sourcing rams from studs that are proven to be successful in their district to consider and in due course adopt the superior rams. Third, the success of the superior rams in wether trials in different districts eventually results in their adoption by producers who follow a strategy of sourcing rams from studs that are proven to be successful across a number of districts.

Relatedly, managers of research and extension programs should be aware that producers will self-select to participate in, and advise on, the design of these programs. To the degree that these producer representatives are drawn from a sub-set of the farm contexts in the population of potential adopters, and cannot properly represent farm contexts other than their own, their advice cannot fully represent the preferences and requirements of each farm context. This may constrain the development of innovations such that the research program subsequently fails to provide innovations that are sufficiently flexible in their design to appeal to the producers in all contexts. Similarly, the framing of extension messages may be constrained and consequently fail to signal the relevance of the innovation and the extension program to producers in some contexts.
Relatedly, managers of extension programs must consider carefully the consequences of mounting extension events with activities that may appeal to producers from different farm contexts. Unless carefully managed there is every possibility that all producers attending such events will find some, perhaps many, activities irrelevant.

Agricultural policy
Three implications for agricultural policy follow from the findings. The first implication is that the findings draw attention to the limits to the effectiveness of extension as a policy instrument for promoting voluntary behaviour change. Extension can facilitate or accelerate voluntary change by reducing the effort and time producers need to spend in searching for information and acquiring skills. In other words, extension can assist agricultural innovations to disseminate through a population of potential adopters more rapidly than would otherwise be the case. However, as discussed above, extension cannot, of itself, change the population of potential adopters except in unusual and problematic circumstances. This means that other policy instruments must be employed in conjunction with extension in circumstances where voluntary change by the population of potential adopters will not achieve a policy outcome.

The second and related implication is that policy makers should be sensitive to the distinction between policy instruments that accelerate the diffusion of agricultural innovations and policy instruments that change the population of potential adopters. The population of potential adopters is defined by the set of farm contexts for an agricultural innovation. Hence, the population of potential adopters of an agricultural innovation can be changed by changing the farm contexts for the innovation. Policy instruments that can change farm context and thereby the population of potential adopters include research, incentives and charges (provided they are of sufficient magnitude), changes in property rights, changes in regulations and changes in public infrastructure and utilities. Each of these has the capacity to change the population of potential adopters by modifying the farm context of producers and, thereby the benefits they are seeking and the choice criteria they use to evaluate an innovation. Examples include restrictions on pesticides (Kogan 1998; Jeger 2000), changes to regional irrigation infrastructure (Kaine and Bewsell 1999; Kaine and Bewsell 2000b; Kaine and Bewsell 2001a; Kaine and Bewsell 2001b; Kaine and Bewsell 2002a;
Policy instruments that can change the rate of diffusion of agricultural innovations are extension, research, and incentives and charges. Research may change the rate of diffusion by offering innovations with features that are better tailored to the requirements of producers, or innovations that are more easily adapted to different farm contexts. Incentives and charges change the rate of diffusion by increasing or decreasing, respectively, the relative advantage offered by an innovation, given that the innovation offers a relative advantage independently of the incentive or charge. Where incentives or charges are of a sufficient magnitude to create or eliminate relative advantage then the incentive or charge themselves become part of the set of choice criteria. In such circumstances the incentive or charge is sufficiently large to redefine the farm context for the innovation and thereby change the population of potential adopters. Hence, care must be taken in regard to setting incentives and charges to ensure the desired change in the behaviour of producers is obtained.

The third implication is that the findings point to the potential for producers to respond in unexpected ways to policy initiatives. As discussed earlier, agricultural innovations may be adopted by producers to realise benefits other than those for which the innovations were designed. The characteristics of producers and farming systems are such that variety will emerge in the uses to which agricultural innovations may be put (Kaine and Higson 2006). This raises the possibility that policies may be implemented to accelerate the diffusion of an innovation on the grounds that adoption will generate desirable public benefits, but the innovation may be implemented in ways that are not consistent with achieving those public benefits (Kaine and Johnson 2004).

The consequence is that producers adopt and implement an innovation in ways that do not contribute as strongly to the outcome sought by the policy maker as might have been anticipated. The result is a gap between the desired policy outcome and the outcome that is actually achieved. For example, incentives have been offered for construction of water storages on farms as a means of ensuring irrigation water is contained in a closed system on farms, thereby increasing irrigation efficiency and reducing accessions to water tables. The use of storages for this purpose requires that the storages be empty at the commencement of irrigations. However, producers in
some farm contexts have constructed the storages in order to better control the timing of irrigations. The use of storages requires the storages be full at the commencement of irrigations, thereby negating the purpose of the incentives (Kaine and Bewsell 2000a; Kaine and Bewsell 2004a).

These implications suggests that policy makers require a comprehensive understanding of the farm contexts for agricultural innovations if they are to accurately anticipate and influence the behaviour of producers in regard to the adoption of agricultural innovations.

6.4 Limitations and learning experiences

The validity of the approach described in this thesis to identifying the population of potential adopters of agricultural innovations depends in some degree on the familiarity of producers with the innovations of interest. The longer an innovation has been readily available the more likely it is that producers will have identified the elements in their farming systems that will influence the benefits to be had from adopting the innovation. Hence, the longer an innovation has been readily available the more likely producers will have identified and be able to articulate the farm context for the innovation, the benefits to be had from the innovation, and the choice criteria they employed to evaluate the innovation.

Where innovations are only recent, or are yet to be released, the population of potential adopters might be inferred to some degree either by using relevant theories to characterise the probable farm contexts for the innovation (Kaine, Lees and Sandall 1994b; Kaine et al 1998; Kaine et al. 2001; Kaine et al. 2003a; Kaine et al. 2003b; Kaine et al. 2004a), or by identifying the farm contexts for the technologies and practices that the innovation will supersede and questioning producers about desirable improvements in the features of those technologies and practices (Hill et al. 2007; Kaine et al. 2003c).

The identification of the population of potential adopters of agricultural innovations through the identification of farm contexts has the potential to contribute valuable information with regard to the design of research and extension programs. With regard to research into innovations, knowledge of farm contexts may be used in setting directions with regard to the desirable characteristics of innovations.
However, there are limits to the value of this information. Knowledge of the farm context does not in itself assist the manager of a research program to identify the features of an innovation that will deliver the desired characteristics. With regard to extension, knowledge of farm contexts may be used in formulating messages that signal the relevance of an innovation and extension activities. However, knowledge of the farm context does not in itself assist the manager of an extension program to identify the informational needs of producers or the types of extension activities that will satisfy those needs.

Another limitation is that the case studies were not drawn from a program of studies designed to methodically test the assumptions on which the thesis is based. Consequently, the case studies do not provide an integrated and complete chain of empirical evidence supporting them. For example, a case study integrating the identification of the population of potential adopters of an innovation and the farm contexts for that innovation, with an investigation of the diffusion of the innovation through the population of potential adopters, has not been undertaken. Relatedly, the method is yet to be applied to the adoption of innovations such as seed stock, in particular, in dryland cropping industries.

A further limitation is that, to date, a scale for measuring producers’ involvement with agricultural innovations has not been developed. While the evidence presented here is consistent with the proposition that the adoption of agricultural innovations is highly involving for producers, the development and application of a scale would be valuable for two reasons. First, such a scale would complete the chain of evidence in support of the theory and methods advanced in this thesis. Second, such a scale would allow differences in the sources of producers’ involvement in the adoption of agricultural innovations to be identified and explored. These differences may have implications for the design of agricultural research and extension programs.

6.5 Potential for future research

There are a number of possibilities for future research. To begin with, one possibility that would contribute to testing the theory and methods in this thesis is developing a scale for measuring the involvement of producers in the adoption of agricultural innovations, and the sources of that involvement. Another is a study integrating the
identification of the population of potential adopters of an innovation, and the farm contexts for that innovation, with an investigation of the diffusion of the innovation through the population of potential adopters.

From a methodological perspective one possibility for future research is the use of spatial modelling techniques to quantify the population of potential adopters of an innovation and their location in the landscape where the relevant dimensions of farm context such as biophysical variables are contained in spatial databases. Another is the use of causal mapping techniques during interviews with producers to describe farm contexts.

The definition and identification of the population of potential adopters of agricultural innovations in this thesis is founded on farming systems theory. There are parallels here with the use of systems theory in the organisational behaviour literature to describe and classify innovations into types. Each type of innovation is predicted to have different organisational consequences in terms of resource deployment and skills acquisition (Henderson and Clark 1990; Gatignon et al 2002). The integration of farming systems theory with that literature offers the promise of providing managers of extension programs with insights into the needs of producers in regard to information and skills acquisition.

The theory and methods presented in this thesis offer avenues for further research in three broad areas of research. The first is the integration of these with the theory and practice of extension evaluation. Such integration offers the promise that the evaluation of extension could encompass measures such as the rate of diffusion and penetration of awareness and knowledge of innovations among the relevant population of potential adopters.

The theory and methods presented here may also have the potential to offer insights into the purchase of consumable agricultural inputs such as animal health products, nutrition products, and chemicals for controlling plant and animal pests by producers (Kaine et al 2003c; Hill et al 2007; Kaine and Bewsell 2003; Bewsell and Kaine 2004; Kaine and Bewsell 2004b; Kaine and Bewsell 2005b).

Finally, to the degree that the behaviour of producers as managers of agricultural enterprises is governed by their farm systems then efforts to influence the behaviour of producers through policy initiatives must account for the nature of farm systems. In
principle, producers’ responses to policy initiatives will vary depending on their farm system and the consequences of the initiative for those systems. In other words, just as there is a population of potential adopters of an agricultural innovation that may be partitioned into benefit segments based on differences in farm contexts, so might there be a population of potential respondents to a policy initiative that may be partitioned into response segments based on relevant differences in their farm systems. The potential for the elements in the farm systems of producers to govern their behaviour in circumstances other than the adoption of innovations, such as in regard to the regulation of agricultural activities, has only begun to be explored (Murdoch et al. 2006; Murdoch et al. 2007).
References


Ajzen, I. 1971, 'Attitudinal vs. normative messages: an investigation of the differential effects of persuasive communications on behavior,' *Sociometry*, vol. 34, no. 2, pp. 263-280.


Ambrosio, C. and C. Linehan 2004, 'Adoption of Variable Rate and Site Specific Technologies of Nitrogen Application in the Victorian Grains Industry,' Department of Primary Industries, Tatura, Victoria, p. 17.


Andrew, J., Breckwoldt R., Crombie A., Aslin H., Kelly D. and T. Holmes 2005, 'Fostering Involvement — How to Improve Participation in Learning,' Rural Industries Research and Development Corporation, Canberra, no. RIRDC Publication No. 05/105


Antil, J. H. 1988, 'New product or service adoption: when does it happen?,' *Journal of Consumer Marketing*, vol. 5, no. 2, pp. 5-16.


AWI 2006, 'Australian Wool Production Forecast Report,' Australian Wool Innovation, Melbourne,


Bewsell, D. 2005, 'Adoption of Once-A-Day Milking,' AgResearch, Hamilton, New Zealand,

Bewsell, D. and M. Brown 2006, 'FeedMaster Farmer Survey Report,' AgResearch, Hamilton, New Zealand,


Bewsell, D. and G. Kaine 2001, 'Soil Monitoring, Irrigation Scheduling and Vegetable Production (First Report),' School of Marketing and Management, University of New England, Armidale,

Bewsell, D. and G. Kaine 2002, 'Soil Monitoring, Irrigation Scheduling and Vegetable Production (Second Report),' School of Marketing and Management, University of New England, Armidale,

Bewsell, D. and G. Kaine 2003, 'The Adoption of Sustainable Practices in the Wine Grape Industry,' AgResearch, Hamilton, New Zealand,


Burrows, D., Boland A. and S. Putland 2003, 'Recommendations for an Improved Regional WUE Extension Program,' Cooperative Research Centre for Viticulture, Urrbrae, South Australia,


Byerlee, D. 1987, 'From adaptive research to farmer recommendations and extension advice,' Agricultural Administration and Extension, vol. 27, pp. 231-244.

Byerlee, D., Harrington L. and D. L. Winkelmann 1982, 'Farming systems research: issues in research strategy and technology design,' American Journal of Agricultural Economics, vol. 64, no. 5, pp. 897-904.


Carruthers, G. 2007, 'Using the EMS process as an integrative farm management tool,' *Australian Journal of Experimental Agriculture*, vol. 47, pp. 312-324.


Casey, A. 1997, 'Merino Flock selection - Getting the Most From Measured and Visual Assessment,' NSW Agriculture, Orange, NSW,

Casey, A. A., Coelli K. A. and S. Semple 1998, 'Merino Bloodline Performance,' NSW Agriculture, Orange, NSW,


CGIAR 1978, 'Farming Systems Research at the International Agricultural Research Centers,' CGIAR, Washington,


Collinson, M. 2001, 'Institution and professional obstacles to a more effective research process for smallholder agriculture,' *Agricultural Systems*, vol. 69, pp. 27-36.


Dinar, A. and D. Yaron 1992, 'Adoption and abandonment of irrigation technologies,' *Agricultural Economics*, vol. 6, no. 4, pp. 315-332.


Dorward, P. T., Shepherd D. D and W. L. Wolmer 1997, 'Developing farm management type methods for participatory needs assessment,' *Agricultural Systems*, vol. 55, no. 2, pp. 239-256.


Fulton, A., Fulton D., Tabart T., Ball P., Champion S., Weatherly J. and D. Heinjus 2003, 'Agricultural Extension, Learning and Change,' Rural Industries Research and Development Corporation, Canberra.


Grieshop, J. I. 1988, 'Adoption and Diffusion of Intergrated Pest Management Innovations in Agriculture,' Bulletin of the ESA.


Hattam, C. 2006, 'Adopting organic agriculture: an investigation using the theory of planned behaviour', paper presented to *International Association of*


Hill, M., Linehan C. and H. Murdoch 2004, 'Efficient Irrigation Technologies to Match Soils and Dairy Farming Systems,' Department of Primary Industries, Tatura, Victoria,


Joshi, K. D., Musa A. M., Johansen C, Gyawali S., Harris D. and J. R. Witcombe 2007, 'Highly client-oriented breeding, using local preferences and selection,
produces widely adapted rice varieties,' *Field Crops Research*, vol. 100, pp. 107-116.


Kaine, G. and D. Bewsell 2003, 'Adoption of Integrated Fruit Production: A Qualitative Study,' AgResearch, Hamilton, New Zealand,

Kaine, G. and D. Bewsell 2005b, 'Adoption of Integrated Fruit Production: A Quantitative Study,' AgResearch, Hamilton, New Zealand,

Kaine, G. and D. Bewsell 2002b, 'Are market research and extension complementary?' in 18th Annual Conference of the Association of International Agriculture and Extension Education, May, Durban, South Africa.


Kaine, G. and D. Bewsell 2000a, 'Irrigation Systems, Irrigation Management and Dairy Farming (First Report),' School of Marketing and Management, University of New England, Armidale,
Kaine, G. and D. Bewsell 2004a, 'Irrigation Systems, Irrigation Management and Dairy Farming (Second Report),' School of Marketing and Management, University of New England, Armidale,

Kaine, G. and D. Bewsell 2001a, 'Managing Irrigation and Fertiliser in Dairy Farming (First Report),' School of Marketing and Management, University of New England, Armidale,

Kaine, G. and D. Bewsell 2001b, 'Managing Irrigation and Fertiliser in Dairy Farming (Second Report),' School of Marketing and Management, University of New England, Armidale,

Kaine, G. and D. Bewsell 2002c, 'Managing Irrigation and Fertiliser in Dairy Farming (Third Report),' School of Marketing and Management, University of New England, Armidale,

Kaine, G. and D. Bewsell 2000b, 'Managing Irrigation for Grapevines (First Report),' Cooperative Research Centre for Viticulture, Urrbrae, South Australia,

Kaine, G. and D. Bewsell 2002d, 'Managing Irrigation for Grapevines (Second Report),' Cooperative Research Centre for Viticulture, Urrbrae, South Australia,

Kaine, G. and D. Bewsell 2002e, 'Managing Irrigation for Grapevines (Third Report),' Cooperative Research Centre for Viticulture, Urrbrae, South Australia,


Kaine, G. and D. Bewsell 1999, 'Soil Monitoring, Irrigation Scheduling and Fruit Production (Part One),' School of Marketing and Management, University of New England, Armidale,


Kaine, G. and D. Bewsell 2002a, 'Soil Monitoring, Irrigation Scheduling and Fruit Production (Part Two),' School of Marketing and Management, University of New England, Armidale,


Kaine, G., McDemott A., Bewsell D., Sheath G. and B. Binnie 2004b, 'Strategic needs of sheep and beef farmers with respect to strengthening the growth and development of their farm businesses,' AgResearch, Hamilton, New Zealand.

Kaine, G. and E. Niall 1999, 'Market Segmentation and Wet Soils Management,' School of Marketing and Management, University of New England, Armidale,

Kaine, G. and E. Niall 2001b, 'Sheep Breeding: Complex Decision-Making and Brand Loyalty,' School of Marketing and Management, University of New England, Armidale,


Kaine, G., Sandall J. and D. Bewsell 2001, 'Personality, Strategy and Innovation in Agriculture', School of Marketing and Management, University of New England, Armidale,


Kaine, G., Tarbotton I. S. and D. Bewsell 2003c, 'Factors Influencing Choice of Health Products for Livestock,' AgResearch, Hamilton, New Zealand,


Kitzinger, J. 1994, 'The methodology of focus groups: the importance of interaction between research participants,' *Sociology of Health and Illness*, vol. 16, no. 1, pp. 104-121.


Macadam, R. D. 2000, 'From pushing production inputs to empowering the community: a case study in the transformation of an extension agency,' *Australian Journal of Experimental Agriculture*, vol. 40, no. 4, pp. 585-594.


Mittal, B. 1989, 'Measuring purchase-decision involvement,' *Psychology and Marketing*, vol. 6, no. 2, pp. 147-162.


Morse-McNabb, E., McAllister A., Kaine G., Linehan C. and B. Rowbottom 2008, 'Spatial Market Segmentation and Healthy Productive Landscapes Framework,' Department of Primary Industries, Tatura, Victoria,


Murdoch, H., Lourey R., Kaine G. and C. Linehan 2007, 'Understanding Behavioural Responses to Biosecurity Interventions ', Practice Change Research, Department of Primary Industries, Tatura, Victoria,


Napier, T. L., Camboni S. M. and C. S. Thraen 1985, 'Factors associated with the importance placed on environmental concern in the adoption of farm technologies and techniques', paper presented to *Southern Association of Agricultural Scientists*, February, Biloxi, Mississippi, Ohio State University, Columbus.


Norman, D. W. 2002, 'The farming systems approach: a historical perspective', paper presented to *Invited for presentation at the 17th Symposium of the*
International Farming Systems Association, November 17th-20th, Lake Buena Vista, Florida.


OECD 2001, 'Adoption of Technologies for Sustainable Farming Systems - Wageningen Workshop Proceedings', Wageningen, p. 149, OECD.

Ollendick, T. H. and M. Hersen 1979, 'Social skills training for juvenile delinquents,' Behaviour Research and Therapy, vol. 17, no. 6, pp. 547-554.


Pannell, D. J. 1999a, 'On the estimation of on-farm benefits of agricultural research,' *Agricultural Systems*, vol. 61, no. 2, pp. 123-134.


Prasad, G. V. and B. S. Siddaramaiah 1999, 'Agro-economic, socio-psychological and extension communication variables discriminating the high and low adoption


Reeve, I. and A. W. Black 1998, 'Improving Farmers Management Practices Through Learning and Group Participation,' Rural Industries Research and Development Corporation, Canberra,


Riley, J. and W. J. Fielding 2001, 'An illustrated review of some farmer participatory research techniques,' *Journal of Agricultural, Biological, and Environmental Statistics*, vol. 6, no. 1, pp. 5-18.

Roberts, G. 1997, 'The Power of One Ram: An Easy guide to Progeny Testing,' Department of Natural Resources and Environment, Melbourne, Victoria,


Röling, N. 1985, 'Extension science: increasingly preoccupied with knowledge systems,' _Sociologia Ruralis_, vol. 25, no. 3-4, pp. 269-290.


Röling, N. 2001, _Extension in Europe and the Third World: Comparisons and Implications_, University of Guelph, Department of Extension Studies.


Smith, K. 2000, 'Innovation as a systemic phenomenon: rethinking the role of policy,' *Enterprise & Innovation Management* vol. 1, no. 1, pp. 73-702.


Sumberg, J. 2005, 'Constraints to the adoption of agricultural innovations. Is it time for a re-think?,' *Outlook on Agriculture*, vol. 34, no. 1, pp. 7-10.


Sumberg, J., Okali C. and D. Reece 2003, 'Agricultural research in the face of diversity, local knowledge and the participation imperative: theoretical considerations,' *Agricultural Systems*, vol. 76, pp. 739-753.


Vanclay, F., Howden P., Mesiti L. and S. Glyde 2006, 'The social and intellectual construction of farming styles: testing Dutch ideas in Australian agriculture,' *Sociologia Ruralis*, vol. 46, no. 1, pp. 61-82.


Victorian Dairy Industry Authority 1999, 'Facts and Figures,' Victorian Dairy Industry Authority,
Wadsworth, J. 1995, 'Adoption of innovations by Costa Rican livestock producers under different levels of extension intensity: predicted versus observed behaviour,' *Agricultural Systems*, vol. 49, pp. 69-100.


Windsor, D. 2003, 'Genetics for sheep breeders,' *Farmnote*, Department of Agriculture, Western Australia, Bunbury, vol. 4/2003,


Zinnah, M. M., Compton J. L. and A. A. Adesina 1993, 'Research-extension-farmer linkages within the context of the generation, transfer and adoption of improved mangrove swamp rice technology in West Africa,' *Quarterly Journal of International Agriculture*, vol. 32, no. 2, pp. 201-214.