Are farmers empowered? The role of empowerment in farmer decision making about weed and invertebrate management.

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Thomas Jason Major
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Abstract

This research investigates how Australian broadacre farmers make decisions about weed and invertebrate management in the context of two science-based agronomic strategies, Integrated Weed Management (IWM) and Integrated Pest Management (IPM).

A principle purpose of IWM and IPM is to slow the incidence of and better manage chemical resistance. Research indicates that chemical resistance in weeds and invertebrate pests in broadacre farming continues to escalate. This has the grains industry concerned about the potential effects of resistance on farm productivity, resilience and sustainability, and they perceive that broadacre farmers are not adopting IWM and IPM effectively or in sufficient numbers to avert the identified problems of resistance. This concern about low farmer adoption of IWM and IPM formed the basis of the research problem and prompted the initial broad question that underpinned this research, why are farmers not adopting these strategies?

This research is informed by constructivist grounded theory and used an iterative research process that combined in-depth interviews, observation and document analysis to extract rich data. What began to emerge from the data and focus the research direction was farmer agency and control that appeared to affect the dynamics of their knowledge networks, how they constructed knowledge and ultimately made decisions. Agency and control emerged as defining components of empowerment. The research question of this thesis therefore became, how does empowerment affect farmer decision making about weeds and invertebrate pest management?

Most previous research analysed for this thesis cited as an objective a need to empower farmers, often through acceleration of technology or knowledge transfer. There appeared to be no attempt to understand whether farmers are already empowered or if they seek to be empowered. Indeed, farmers are not empowered in all situations, but this research found that in the context of complex problems such as weed and invertebrate management farmers are typically empowered. Their empowered status affects the dynamics of their power-knowledge relationships; how they interpret information, risk and uncertainty; and how they learn, construct knowledge and make decisions. Farmer behaviours emerged that supported and facilitated their empowerment, and these too became concepts that are examined in this thesis. They are social capital (networking and trust); farmers' long and short-term thinking; and farmers' on-farm trialling.

This research helps fill a knowledge gap about knowledge construction and decision making in complex contexts, especially at the social and cultural level. The findings will inform the engagement process between extension and farmers, not only on weed and invertebrate management, but similar complex agronomic problems.

Extension initiatives therefore will need to consider the potential for the empowered farmer as it affects the engagement process and the nature and dynamics of the relationship constructed with farmers. Extension will need to invest in social capital and build long-term knowledge networks built on trust that enable dialogue, analysis and reflection. Open discussion of uncertainties and the implications should be part of any dialogue involving complex concepts, but apply particularly for the farmers in this study.

Keywords: empowerment, power, agriculture, decision making, technology transfer, adoption, trust, IPM, IWM
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**Glossary of terms**

**Agro:** a colloquial term for agronomist.

**Beneficials:** invertebrates that are predators of pest invertebrates. They are considered beneficial to have in a farm system as they help control pest populations.

**Broadacre farming:** farms engaged in the production of cereals, oilseeds and legumes, or grazing of livestock on large areas of land.

**Broad spectrum and selective insecticides:**
- **broad spectrum:** A chemical that controls or is toxic to a wide range of pests. A broad-spectrum insecticide does not discriminate between pests and beneficial species. This type of insecticide may be used when several different pests are a problem (Australian Pesticides and Veterinary Medicines Authority, n.d.-a).
- **selective:** A term mainly applied to herbicides and insecticides that indicates it is capable of killing some kinds of plants or insects and not injuring others (APVMA, n.d.-b).

**Cotyledon:** the first leaf or one of the first pair or whorl of leaves developed by the embryo of a seed plant, which in crop plants such as canola is highly susceptible to damage from invertebrates. Damage to cotyledons can kill the young plant.

**Empire building:** this is a code that describes a farmer's objective to increase the size of their farm by purchasing more land. There are a number of reasons for this that include economies of scale or to ensure there is adequate land to allow the farmers' next generation (sons and daughters) to farm alongside themselves.

**Legacy:** this code describes a farmer's objective to ensure they have a more productive, resilient and sustainable farm business to pass onto the next generation. It is a subjective concept, but can be achieved for example, by increasing the farm size, building soil fertility, or improving the environmental qualities of the farm (tree planting, fencing off sensitive areas).

**Acronyms**

AHRI: Australian Herbicide Resistance Initiative

APEN: The Australasia Pacific Extension Network

BCG: Birchip Cropping Group

CESAR: The Centre for Environmental Stress and Adaptation Research

CSIRO: Commonwealth Scientific and Industrial Research Organisation

GRDC: Grains Research and Development Corporation

HR: Herbicide Resistance
IPM: Integrated Pest Management
IR: Insecticide Resistance
IWM: Integrated Weed Management
SFS: Southern Farming Systems
1. Introduction

Overview of research argument

This research investigates how Australian broadacre farmers make decisions about weed and invertebrate management in the context of two science-based agronomic strategies, Integrated Weed Management (IWM) and Integrated Pest Management (IPM).

The research straddles the disciplines of science communication, extension theory and rural sociology. It covers science communication and extension theory because the research examines how farmers interpret the science that underpins IPM and IWM, and how this affects their decision making. This provides insight into how extension can communicate with farmers about these concepts. It covers rural sociology because of how it builds on our understanding of the socio-cultural processes of farming.

A key purpose of IWM and IPM is to slow down the incidence of and better manage chemical resistance. Resistance occurs when the weed or invertebrate evolves resistance to the chemical used to control them, rendering an important management tool ineffective.

There is research that acknowledges that farmers will adopt innovations at different rates and for some farmers it is a rational choice not to adopt. However, the rising incidence and concern about chemical resistance in invertebrates and weeds has motivated agricultural research and industry groups to urge farmers to adopt a greater number of IWM and IPM tactics. As I examine later in this chapter, these groups typically say that farmers' rate of adoption so far is too slow or sufficiently effective to avoid the untimely loss of important herbicides and insecticides.

This perceived ineffective adoption of IWM and IPM forms the basis of the research problem and guided the initial research direction for this thesis. It became apparent that when farmers make such important decisions about whether to adopt that farmer empowerment has a role in how they construct knowledge and make decisions. In the context of complex problems such as weed and invertebrate management, however, there is minimal understanding of the process of farmer decision making, especially at the social and cultural level. My research aim became a need to understand the effect of
empowerment on farmers' knowledge construction and decision making. My research question became, how does empowerment affect farmers' decision making about weeds and invertebrate pest management? To answer this research question it was necessary to understand farmer relationships, how farmers interpret the IWM and IPM-based science, and farmers' interpretation of the relevant risk and uncertainty, which includes understanding their values and worldviews. Insights from these questions are intended to improve the engagement process between science, industry, extension and farmers.

This chapter builds the narrative for my research in which empowerment forms the central argument of the thesis. I describe first the agronomic problem and the broad research problem that guided the initial exploratory research that led to more focused questions and further rich data. From this data emerged the significance and role of empowerment and my research aim and question.

1.1 The agronomic problem

Chemicals are an important tool to manage weeds and invertebrate pests, but the weeds and invertebrates are quickly developing chemical resistance. There is concern that if resistance continues to evolve and spread, and farmers continue to predominantly use chemical-based management, important chemistry will become ineffective before alternative chemicals can be developed. Should this occur, the consequence is increased management costs and lower farm resilience and sustainability. For some farmers the consequence may be an unviable farm business.

IWM and IPM are science-based approaches to the long-term, sustainable management of weeds and invertebrate pests. They are based on the integration of chemical and cultural (non-chemical) tactics. For weeds, cultural methods include cultivation, crop rotation, and capturing weed seed at harvest. IPM is based on the use of naturally occurring beneficial organisms (mostly invertebrates) to control the pest invertebrates.

1 Unless specified otherwise, industry in this thesis refers to the agricultural industry, which includes private companies, rural supply stores and organisations such as the Grains Research and Development Corporation (GRDC) that considers itself a research organisation responsible for planning, investing in and overseeing research, development and extension (RD&E) to deliver improvements in production, sustainability and profitability across the Australian grains industry. I define extension in more detail in Chapter 2, but in this thesis I refer to extension as a role (noun) that is performed by anyone engaged with farmers to elicit change. Thus a scientist, industry representative, district agronomist or the farmer’s personal agronomist may consider extension as part or all of their job description as each are in a position to engage with the farmer to affect change.
The use of broad spectrum insecticide is recommended as a last resort only (Grains Research and Development Corporation, 2009; Nash & Hoffmann, 2012).

IWM is a concept driven and promoted by the GRDC and its research affiliates such as the Australian Herbicide Resistance Initiative (AHRI) and the CSIRO (Commonwealth Scientific and Industrial Research Organisation). They promote IWM as essential to manage herbicide resistance (HR) and the weed seed bank (viable weed seed in the soil that continues to germinate in subsequent years). Although weeds are estimated to cost Australian grain growers (revenue loss plus expenditure) $3.3 billion a year, or $146 per hectare (Llewellyn et al., 2016), it is the increasing prevalence of HR and the decreasing number of effective herbicides to manage it that concerns the GRDC and others conducting weed management research (Storrie, 2014). At the moment, HR is estimated to cost grain growers $187 million each year in additional herbicide treatment. This is in addition to the cost of IWM practices, which is estimated at $475 million a year (Llewellyn et al., 2016).

To manage HR and the weed seed bank in the long-term, the GRDC and associated research groups urge farmers to implement IWM tactics for all weed control operations. Failure to adopt IWM leads to herbicide resistance (Preston, 2010; Storrie, 2014). None of the literature I examined is explicit about the number of farmers required to adopt IWM to effectively manage HR from a landscape perspective, and the acknowledged reality is that many farmers, through rational choice, will delay or avoid adoption (Pannell et al., 2006; Rogers, 2003; Vanclay & Lawrence, 1994).

The GRDC and research groups have a similar concern about insecticide resistance (IR) and urge farmers to also adopt IPM (GRDC, 2012; Horne & Page, 2008c; Nash & Hoffmann, 2012; National Invertebrate Pest Initiative, 2014a). Similar to IWM, the literature lacks an explicit desired proportion of farmers required to adopt IPM to manage the resistance problem on a landscape scale. With invertebrate management, there are also concerns about insecticide residue in the environment and food, and human health and safety to motivate adoption of IPM (Horne & Page, 2008a). Although the above concerns are cited as reasons for farmers to implement IPM, I did not find any empirical evidence in the literature examining whether broadacre farmers also share these concerns about insecticide use and IR.
1.2 The research problem

IWM is considered an effective strategy to control weeds and better manage the risk of herbicide resistance (Casimero et al., 2006; Chikowo, Faloya, Petit, & Munier-Jolain, 2009; van der Meulen, Reeve, & Sindel, 2007). As noted, there is no adoption rate target for IWM and IPM, but the number of farmers adopting the strategies is monitored and there remains concern that implementation of IWM and IPM remains too low to manage chemical resistance and, in the case of IWM, the weed seed bank (Nash & Hoffmann, 2012; Parsa et al., 2014; van der Meulen et al., 2007). This section outlines the data that underpins the research problem.

Some perspective on what is still considered inadequate adoption is provided in a 2012 GRDC grower survey. This telephone survey found that 72% of Australian farmers were aware of IWM. This is up from 68% in 2010 (Watson & Watson, 2012). In an attempt to establish the level of IWM adoption, the survey asked farmers the following question:

Integrated weed management means combining a range of different techniques to overcome a weed threat to a crop. Based on this definition, are you currently adopting IWM? (Watson & Watson, 2012, p.114)

In response, 76% of Australian farmers (up from 57% in 2010) said they had adopted IWM (Watson & Watson, 2012). Thus awareness and adoption of IWM is improving, but concern about adoption remains. What the survey failed to reveal, however, is what IWM techniques are used and how many, and how extensively they are used. Nor do we garner any understanding of how a farmer interprets IWM beyond the definition in the survey question. For instance, multiple techniques for the farmer may involve two or three herbicide-based tactics. Many IWM tactics have what GRDC considers a low farmer uptake, though this varies with the farming region. For example, in Australia a growing number of farmers are experimenting with manuring systems as a weed management tool (Roper, Milroy, & Poole, 2012), but only 28% of growers in Australia's southern region, which includes Victoria, use this tactic and only on 14% of the cropping land (Llewellyn et al., 2016). Further, data on how effective this tactic is remains sparse and poorly recorded (Roper et al., 2012). Nationally, 30% of growers are using Narrow Windrow Burning to manage weed seed post harvest, a tactic where chaff is placed in windrows at harvest and later burnt (Llewellyn et al., 2016). Again this
research was part of a survey to understand the effect weeds have on broadacre agriculture. The motivation for farmers' use of certain tactics is unknown as is their interpretation of the knowledge underpinning them. This applies especially to HR, which Ervin & Jussaume (2014) argue cannot be mitigated without addressing the human dimensions, including the social, economic, political, and cultural aspect, aspects they say have received minimal analysis. It is these human dimensions that this thesis will examine.

Australian broadacre farmers are less aware of IPM than IWM and have lower levels of adoption. Only 56% of Australian broadacre farmers said they had adopted IPM (Watson & Watson, 2012), though the accuracy of this could be questioned because of subjective terminology, and the numerous definitions and debate over what is "true" IPM (Horne & Page, 2008a; Parsa et al., 2014).

IPM is an established concept in horticulture (flowers, fruit, vegetables), but it is a new concept to broadacre farming where its adoption level is considerably lower (Horne, Page, & Nicholson, 2008; Nash & Hoffmann, 2012; Parsa et al., 2014). Despite this, Nash and Hoffman (2012) argue that IPM can provide low cost control of invertebrate pests in broadacre agriculture.

Thus IWM and IPM are considered effective, yet broadacre farmers are not adopting them in the way desired. This is the basis my research problem and one that generates a number of initial research questions. One of the key questions is, why are farmers failing to adopt IWM and IPM in the way the GRDC and associated research organisations desire? This question guided my initial exploratory research to better understand the broad problem. I interviewed scientists, agronomists and farmers, and searched the academic and farmer-targeted literature to develop a set of questions that I examine in the following sections.

Two elements of the broad research problem and the initial questions directed my research and produced the data that helped refine and underpin my final research aim and question. The first element was the concept of adoption and what motivated farmers to adopt innovations. The second was the role of extension. Although the role of extension has changed over the years, extension is a recognised influence on farmer awareness, understanding and decision making about adoption of innovations.
1.3 Evolving adoption models and the problem with adoption

The GRDC and associated research groups consider farmer adoption of IWM and IPM as a key research objective. Thus the concept of adoption, its implications and relevance need to be examined to understand and provide context to the research.

There is a long history of research exploring factors that affect farmers' adoption of technologies. One of the first models to examine adoption was diffusion theory (see Rogers, 1983). It conceptualises the process of how technologies diffuse through systems (Rogers, 2003). It has evolved since it was first published in 1962, but the basic premise is that progressive or "innovator" farmers will adopt an innovation followed by a process of diffusion through to all farmers in the social system. The transfer of knowledge is supposed to flow from the laboratory to the farmer, usually via an extension officer or farm consultant. Extension's role, in this instance, is to enhance this transfer and diffusion (Dunn, Gray, & Phillips, 2000). One noted change in diffusion theory is the recognition that an innovation does not necessarily have to be diffused and adopted. Rogers (2003) recognised there are circumstances where individuals, for their own benefit, should not adopt an innovation.

There is genuine merit in certain aspects of the diffusion theory because it is established that some farmers (as all people) are more willing to adopt technologies than others (Abadi Ghadim, Pannell, & Burton, 2005). There are also certain attributes of innovations, such as the ability to trial it on-farm, that are known to affect the rate of adoption, or how quickly it diffuses through the system (Llewellyn, 2007; Pannell et al., 2006; Rogers, 2003).

By the 1970s, diffusion theory began to be challenged (Barr & Cary, 2000; Cary, Webb, & Barr, 2001; Guerin & Guerin, 1994). In the early 1980s various farmer participation models emerged as an alternative to diffusion theory. They were based on the need to "listen and learn from the people" and to make farmers active participants in research (Wood et al., 2014). As farming became more system orientated and complex, a key criticism of diffusion theory and even of some of the participation models, such as Farmer First (see chapters 2 and 8), was that they did not account for the social, political and cultural context in which agricultural knowledge is generated (Thompson & Scoones, 1994; Vanclay & Lawrence, 1994). If we are to engage farmers in effective
dialogue about research and innovation, Thompson and Scoones (1994) argue that methodologies need to recognise this complex nature of knowledge generation and transmission.

Indeed, the GRDC acknowledge this in their 2014 Research Development and Extension (RD&E) strategy:

> [Delivery of RD&E] has changed[from a linear hierarchy of public sector scientist–district agronomist–extension officer–grower] into a complex matrix, still involving public sector entities, but increasingly also a mixture of private sector relationships through grower groups, consultants and agribusiness. (GRDC, 2014, p.57)

> The process is non-linear and involves a complex set of relationships and information flows provided by public, private and community organisations. (GRDC, 2014, p.58)

Regardless of the approach and the person or organisation behind it, one apparent objective of extension is to get farmers to adopt an innovation. This emphasis on adoption is an acknowledged priority in the GRDC 2014 RD&E strategy, which frames it around the need to "accelerate or enhance" adoption of technologies and for extension "to deliver" these technologies to the target audience (GRDC, 2014).

Some research has now begun to question the conceptualisation of adoption and its use as a quantitative measure of a technology's success, which usually manifests itself in the form of how many farmers are aware of the technology and how many have adopted or intend to adopt it. Dunn, Gray, and Phillips (2000) consider this a narrow conceptualisation of the so-called problem of adoption.

> This narrowness is manifest in a failure to consider the potential significance of cultural factors which lie beyond the activities of land management in the practice of adoption of conservation farming in western societies. (p.32)

Following his experience with Indonesian farmers' adoption of IPM, Bartlett (2008) suggests that a more meaningful way to understand what is happening in this context is to examine farmer behaviours. Instead of measuring the rate of adoption, Bartlett (2008) measured self-determination among the farmers, or *agency*. Such behaviours included the number that conducted their own field trials and removal of village credit packages for insecticides. Neither of these behaviours are adoptions of IPM practices *per se*, but
behaviours that involve self-determination; they are indicative that the concept of IPM is being considered and worked through by farmers; and they are indicative of some level of farmer empowerment (Bartlett 2008). The behaviours, in effect, describe a learning journey, but a journey, as I describe in chapter 9, without a defined end. Instead of adoption targets, it is this journey that Price, Nicholson, and McGuckian (2009) argue that research and extension should put more emphasis on understanding.

It should be noted, however, that as much of Bartlett’s (2008) research is with agricultural systems in developing nations it is prudent to expect differences that, in some circumstances, would make comparison difficult with broadacre agricultural systems in a developed country such as Australia.

The research described above helped guide the direction of my research that generated data from which emerged the significance and role of farmer empowerment. The initial rich data on farmer empowerment enabled me to better understand my research problem and define my research aim and question, which is discussed next.

1.4 Research aim, question

Exploratory research around the question of adoption produced further questions, such as what is the significance of farmers' relationships with groups conducting research and extension, especially relationships with their agronomist, and what role do these relationships have in farmer decision making? The data that emerged from research into these questions enabled me to narrow my research focus and refine my research aim and question.

My research is informed by a modified constructivist grounded theory approach. I interviewed broadacre farmers, and relevant agronomists and research scientists in three different cropping regions of Victoria. What emerged from the above exploratory questions was the concept of farmer empowerment, though there was a lack of clarity about its role and significance in farmers’ decision making about adoption of IWM and IPM. Further research made it apparent that empowerment had an important effect on how farmers constructed knowledge and made decisions in complex contexts. Relationships too were crucial for this knowledge construction and decision making to occur. The aim of my research evolved then to be a need to understand the effect of empowerment on a farmer's knowledge construction and decision making. This
prompted the research question, how does empowerment affect farmer decision making about weeds and invertebrate pest management?

1.5 Empowerment, relationships and decision making

This section provides a brief overview of empowerment and its link to farmers' knowledge relationships and decision making, and the minimal understanding of this at the social and cultural level.

Empowerment involves power, knowledge and relationships (Bartlett, 2008; Bourdieu, 1986; Gerth & Wright Mills, 2009). Farmers confront varied knowledge about IWM and IPM that they interpret and use to help to construct their own knowledge. As part of the process they assess and manage risk and uncertainty.

The consideration of empowerment in agricultural extension and the relationship with farmers is relatively new (Bartlett, 2008). Certainly, a search of the literature found few references specifically investigating empowerment and farmers. The introduction in the mid-1980s of the Farmer First participation model, however, (see chapters 2 and 9) implied empowerment's relevance with its requirement that farmers help define and solve their own problems (see Dunn, Gray, & Phillips, 2000; Nettle, Waters, Kenny, & Love, 2012; Thompson & Scoones, 1994).

Although there is no settled definition of empowerment and it is discussed using competing philosophies (see Kabeer, 2001), if we are to facilitate farmer learning or adoption of more sustainable agricultural practices, then Roling & van de Fliert (1994) argue that farmers' empowerment is necessary. Most definitions describe an empowered person as someone with the capacity to change and ability to define their own problems and opportunities. I include the concept of agency defined by behaviours, analysis and reflection, and control where the empowered person exhibits the ability to choose and define their own objectives.

A farmers' agency and control are intimately linked to their knowledge relations. Empowerment affects the dynamics of these relationships, and in turn farmer decision making (see Bartlett, 2008; Kabeer, 2001; Thompson & Scoones, 1994). The principal relationships for farmers are social and cultural connections at the farm and community level (Darnhofer, Fairweather, & Moller, 2010). In other words, farmers do not operate
or make decisions in isolation (Vanclay, 2004). Decision making is a social process, shaped by group social structures that include other farmers (Vanclay, 2004, Ervin and Jussaume, 2014), and at times, whole communities and their social relationships (Dunn et al., 2000). Extension, especially through farmers' agronomists, is an important farmer relationship and often a strong influence on farmer decision making (see Ingram, 2008). Thompson (2009) argues that greater attention should be given to eliciting the cognitive and socio-cultural influences of agricultural extension on farmer decision-making.

Fleming, Wilson, and Measham (2014) consider relationships are a foundation of any participatory research process, yet note that even the most pervasive and basic models of social and adult learning do not include them. Further, the theory underpinning these relations are, according to Kelly (2011), poorly understood and neglected by research. This insight underpins my focus on the socio-cultural aspects of farmer relationships and why it is an important question for me to explore in my research.

Research has typically found important the concepts of farmer empowerment, relationships, knowledge construction and decision making about the adoption of complex innovations. In the case of empowerment, however, they have been isolated studies and in different contexts from my research (Bartlett, 2008; Kabeer, 2001; Nettle et al., 2015). These studies do provide valuable insight into my research question about empowerment, but they are not specific to IWM and IPM. Research more directly relevant to my research question rarely provided an in-depth examination of the farmer motivations or reasons for their decision making (see Ingram, 2008). For instance, Ervin and Jussaume (2014) argue the herbicide resistance problem will not be solved without considering the human dimensions, such as the social, economic, political, and cultural aspects, but they note the question remains, which of these human dimensions have the greatest influence and how do they motivate and affect knowledge construction and decision making about HR?

As I began to understand the concept of empowerment in more depth, I developed sub-questions that this thesis explores and answers, and which help achieve the research aim. They included the following:

- What are the dynamics of farmer relationships and networks and how do they affect their knowledge construction and decision making?
- How do farmers interpret the science and the farmer-targeted messages from extension about IWM and IPM? How does the farmer's interpretation compare to that of science and extension?
- How does farmers' interpretation of the science and messages affect their behaviour?
- How do the concepts of complexity, risk and uncertainty associated with IWM and IPM affect farmer knowledge construction and decision making?
- What role do heuristics such as values, worldviews and intuition play in decision making?

What also emerged from the early data was that farmers' and agronomists' motivations and perceptions that influence their decision making about weeds are distinctly different from those that influence their decisions about invertebrate management. This prompted a further question: what is responsible for this difference? The data relevant to this question mean IPM gets its own story.

None of the above questions were directly asked in interviews with research participants. They emerged during the iterative research process and then acted as a map to guide my conversation in subsequent interviews. They also focused my literature search.

There is a recognised value in understanding empowerment's effect on farmers' relationships, knowledge construction and decision making, and it is the minimal knowledge we have of what happens in these contexts, especially at the social and cultural level, that helped coalesce my research aim and question. It is intended that this research will provide, at the social and cultural level, insights into the nature of farmer empowerment and its effect on relationships, knowledge construction and decision making. These insights are intended then to improve the engagement process between science, extension and farmers on not only IWM and IPM, but similar complex concepts or technologies.

My research focus is on the farmer-agronomist and farmer-farmer relationships as it is the effect of these relationships on farmers' knowledge construction and decision making that I am interested in. Having said that, although farmers will be beneficiaries
of this research, the principle audience for my research are people with an extension role.

### 1.6 Overview of thesis

Having introduced the research problem, aim and question, chapter 2 introduces us to farmers themselves. The role of chapter 2 is provide the context to my research problem, aim and question. I examine the literature and reveal what we know about farmers: who they are, what motivates them and what we know about their decision making, especially decisions about weed and invertebrate management. I give an overview of how farmers make decisions in the context of their farm as a complex system, and in the presence of risk and uncertainty. The chapter provides a basic introduction to empowerment, and its connection to farmer relationships, social capital and adoption. Adoption is explored in the context of farmer experimentation and trials, a process that is poorly understood at the farm level, and not well reflected in policy approaches to agricultural innovation. An examination of the more theoretical concepts underpinning the data is presented in chapter 8.

Chapter 3 provides greater detail on IWM and IPM. I also examine factors such as chemical resistance and regulatory changes that are thought to motivate farmers to consider IWM and IPM.

Chapter 4 outlines and justifies my research design and how my method is informed by constructivist grounded theory. I reveal the existing philosophies that support this and reveal my own philosophical position and how it influences each aspect of my research.

Chapters 5 and 6 are data analysis chapters and expand on the narrative around the core theme of empowerment. In chapter 5, I argue that when it comes to agronomic and many farm management decisions the typically empowered status of farmers in my research is a powerful motivator and facilitator of their knowledge construction and decision making. Chapter 6 examines the supporting concepts (foundations) that facilitate empowerment.

Chapter 7 is also a data analysis chapter that examines the narrative for IPM. It also explores the differences in how IWM and IPM are perceived, differences that have implications for understanding farmer decision making about these strategies.
Chapter 8 examines the theories that underpin the core concepts that emerged in my data. I expand on or contribute to these theories.

Chapter 9 brings together the separate data analysis sections (chapters 5-7) into an overall discussion that answers my research question and examines the implications of this for my research problem of why farmers are not adopting IWM and IPM. I make recommendations that should be considered for any future engagement with farmers that is applicable to not only weed and invertebrate management but any complex concept that affects farmers' agronomic management. I discuss also the limitations of my research.
2. Who are farmers?

Overview

The research aim of this thesis is to understand the effect empowerment has on farmers' knowledge construction and decision making. My research question is, how does empowerment affect farmer decision making about weeds and invertebrate pest management? The purpose of this chapter is to provide context to the research aim, questions and data analysis through an insight into who farmers are, their motivations, values, worldviews and attitudes.

This chapter gives an overview of the literature that discuss the concepts of empowerment and power, and their relation to knowledge construction. It examines the role and significance of power-knowledge relations between farmers and agronomists, what we know about how farmers perceive and assess risk, and what influences their knowledge construction and decision making in the complex environment that is their farm. Again, these concepts emerged from the early data, which then helped guide the direction of my research through its iterative process.

The following section examines literature that provides insight into who farmers are, why they farm and how they are embedded in the socio-cultural matrix that is farming.

2.1 So, who are farmers?

Depending on what you need to know, we either know a lot or not much about farmers (Crase & Maybery, 2004). One consensus among researchers is that farmers are not homogenous and are therefore difficult to categorise (Cary, Webb & Barr, 2002; Race & Curtis, 1997; Vanclay, 2004). They are young, old, male, female, they differ in their ethnicity, sexuality, religion. They may be large or small operators; they have high and low equity. There are innovators, traditionalists, or pro-chemical versus pro-organic. Farmers also have different attitudes to income needs, risk perception, dynastic expectations and cultural expectations of farming (Cary, Webb & Barr, 2002). Women or spouses not actively engaged as farmers, but playing a support role as part of a family farm operation, are an integral part of the farm, and becoming more so. Farms themselves can be complex partnerships involving many people beyond what happens in the paddock (Vanclay, 2004).
Vanclay (2004) describes farming as a socio-cultural practice that is "governed, informed and regulated by social processes...and acquires a meaning far deeper than almost any other occupational identity" (p. 213). Acknowledging this complexity and diversity has implications for how science and extension personnel engage with farmers (Vanclay, Mesiti, & Howden, 1998; Vanclay, 2004). These cultural influences and social processes, and how they affect engagement with farmers about IWM and IPM also became important factors that helped answer my research question.

This farmer diversity and the varied physical and cultural contexts a farmer operates in are integral to and part of what makes a farm system complex. The first half of this next section defines a complex system and the implications of managing such a system. Risk, uncertainty and ambiguity are part of complex systems (Renn, 2003, 2005). In broadacre farming, weeds and invertebrates are also part of such systems, and farmers need to construct knowledge and make decisions in this environment. In the second half of this next section, I define risk, uncertainty and ambiguity and examine how it affects farmer decision making.

### 2.2 Risk and uncertainty in a complex system

**It's complex.**

A farm is a complex system requiring complex decisions (Pannell, Malcolm, & Kingwell, 2000). The farmer is immersed in this environment, so some understanding of it is required.

Although no single set of principles is going to apply to all complex systems (Mitchell, 2009), the following principles suggested by Snowden and Boone (2007) seem to be widely accepted, and are the most applicable to the data in this thesis (see also Darnhofer et al., 2010; Mitchell, 2009):

- It is a system with large numbers of interacting elements.
- The system is dynamic, ever changing and often unpredictable such that solutions cannot be imposed, rather they emerge from the circumstances.
- Understanding of problems comes only with hindsight, but does not lead to foresight because conditions and systems constantly change.
For a farm, this requires understanding there is no stable state or final equilibrium. Change is continuous, therefore farmers must acknowledge a certain state of perpetual ignorance (Darnhofer, 2014). For a farmer trying to make an informed decision in this context, a right answer will exist, it just cannot be known or the issue understood except in retrospect. Complex contexts place you in the realm of "unknown unknowns" (Snowden & Boone, 2007).

To manage this, a farmer can observe, wait and assess emerging patterns before making a decision, but it is still a complex system, thus outcomes can remain unpredictable. Farmers have always made decisions in this environment and extension needs to recognise this and that any decisions a farmer makes are optimal for them at that time, given limited information available and unpredictable outcomes. It may ultimately be the wrong decision with hindsight, but it will be the right or optimal decision at the time it was made (McGuckian, 2006; Snowden & Boone, 2007).

To facilitate complex decision making, farmers (or anyone) will typically seek multiple opinions, information sources and clues to guide such decisions and present new possibilities. Potential decisions are shared with trusted sources and usually involve validation with these sources (Snowden, 2003). Complex decisions can be improved by farmers discussing options, working through and testing ideas out in social settings (McGuckian, 2006).

Despite the need for validation from peers, there is evidence that when farmers make complex decisions, many will often rely less on rational choice and scientific facts and more on information filtered through value-laden perceptions and mental models. In other words, heuristics (Darnhofer et al., 2010; Menapace & Colson, 2012; Murray-Prior & Wright, 2001). For example, research for the Grain and Graze program revealed farmers struggled to articulate answers to questions about financial management because of the complex decision-making process. Their answer to how they determine the most profitable enterprise was, "we do the sums". Attempts to articulate further on this introduced uncertainty. Often it came down to simply the commodity price at the time, despite their being a large number of other variables, including non-financial variables, to consider (McGuckian, 2006). According to McGuckian (2006), farmers think these variables make decisions too complex. Variables such as labour management, environmental effects, or the effect on recreation time or family mean
there is no value in spending time doing a complex analysis. Hence heuristics or rules of thumb predominate (McGuckian, 2006).

This reliance on heuristics in such environments implies that complex contexts lack an option and we are fated to fall back on values and mental models rather than rational, analytical thought. But heuristics are not necessarily used in isolation from reason. It is clear we use the two systems as a joint operation, where heuristics and reason interact with one another to identify and prioritise experiences and influence how we value and interpret risk (Epstein, 1994; Finucane & Holup, 2006). A heuristic important in farmer decision making is intuition or gut feel, which can also function in tandem with reason (Kahneman, 2003).

**Intuition, gut feel.**

To distinguish intuition from reason, Kahneman (2003) summarises the following characteristics for each: intuition is fast, automatic, effortless, associative and emotive. Reason is distinguished by being slower, serial, effortful and controlled. Or more simply, there are two different ways of knowing: one associated with feeling and experience; the other with intellect (Epstein, 1994). The two systems, however, are not polar opposites that never interact. They work together to inform decisions (Dane & Pratt, 2007). McCown (2012) talks about a continuum with analysis on one end and intuition on the other, but in the uncertain environment of Australian dryland agriculture, farmers will tend to combine analysis and intuition with greater reliance on one or the other depending on the decision making context and the individual farmer's interpretation of the information (McCown, 2012).

For example, Nuthall (2012) says many New Zealand sheep farmers fall short of optimum livestock output given the pasture production they have. Computer-based decision support systems are available, yet few farmers make use of them (Nuthall, 2012). For farmers that did use the decision support systems, Nuthall notes they seldom blindly accept decisions from the system. For all farmers in Nuthall's research, intuition is an important influence with each farmer developing their own unique, intuitive based decision-support system. But farmers use reason or logic also to think through their actions and make decisions they are comfortable with (McCown, Carberry, Dalgliesh, Foale, & Hochman, 2012; Nuthall, 2012). According to Finucane and Holup (2006),
understanding both thinking processes and how they integrate to influence judgment and decision-making is key to understanding risk.

However, Nuthall (2012), says research into developing and assessing intuition in agricultural management is yet to occur in a formal way, but he contends that researchers need to find ways to facilitate and improve farmers’ intuition. One idea he proposes is to encourage farmers to share and critically review their decisions and experience through mentor groups involving trusted farmers (Nuthall, 2012).

As noted already, a consequence of managing a complex system such as a farm is the need to manage risk and uncertainty (see Kane, King, & Brien, 2009; Marra, Pannell, & Abadi Ghadim, 2003; Pannell et al., 2000). Along with ambiguity, risk and uncertainty emerged as important concepts in my data and are integral to my research aim and question. To continue building a picture of farmers, I provide a brief overview of these concepts and how farmers perceive and respond to them.

**Risk, uncertainty, ambiguity.**

There is comprehensive literature on risk, uncertainty and ambiguity. With risk and uncertainty, some such as Pannell et al. (2000) use the two concepts interchangeably, others speak of the two as one inseparable element, risk uncertainty (see Frewer, Miles, & Marsh, 2002). Riesch (2012) defines risk as a measure of uncertainty, though similar to much of the literature, Riesch describes risk and uncertainty as distinct concepts, and based on this and my data they are treated as such here.

**Defining risk.**

Although there are many approaches to risk (see Zinn, 2008a), the following is a workable definition of risk for this research:

[R]isk [is] a measure of uncertainty of an event happening times the severity of the outcome. (Riesch, 2012, p.92)

Despite the varied approaches to risk, to provide appropriate context for my data it is sufficient to understand there are two basic approaches. One is the concept of risk as an objective entity that can be calculated and quantified. Risks are real events or dangers and not confounded by social factors (Zinn, 2008b). For example, the risk of dying from bovine spongiform encephalitis (BSE) can be calculated based on the known level of
contamination and the numbers of people who contracted the disease and died (Renn, 2005). The second is risk as an expression of culture and something socially constructed by humans (Kasperson, Renn, Slovic, Brown, Emel, & Goble, 2005). Values, knowledge, rationality, power and emotion become important factors (Zinn, 2008b). In the case of BSE, values and emotion were apparent in the treatment of the BSE risk when the public expressed greater outrage at the fact herbivorous cows were fed meat than the mortality rate of humans (Renn, 2005). It could be argued that Riesch's above definition of risk stems from the technical, objective approach as it suggests the ability to measure something (uncertainty and degree of severity of outcome). But as Riesch (2012) acknowledges, uncertainty and degree of severity of outcome are difficult to measure and define and both these elements are considered from the technical and socio-cultural approaches to risk (see Beck, 1992; Riesch, 2012; Wynne, 1992b).

**Risk and farmers.**

Risk is implicated in farmer adoption of new technologies (Marra et al., 2003). Carruthers and Vanclay (2012) claim that where the risks and uncertainties associated with a new technology are perceived as too high, then adoption is minimal. But risk is subjective (Marra et al., 2003) thus a farmers' risk perception and attitude toward risk have an important influence on adoption (Abadi Ghadim et al., 2005).

For example, a farmer in a drought-prone area or one where drought has recently occurred will have a different context for the risk and thus perceive it different to a farmer from a climate that rarely suffers from drought. For one farmer it may be personal; for the other it might be an agricultural or food security issue in general (see Kuehne, Bjornlund, & Loch, 2010; Milne, Stenekes, & Russell, 2008).

Abadi Ghadim et al.'s study with Western Australian farmers found risk is an important influence on adoption of chickpeas. The more risk averse farmers were less likely to introduce chickpeas into their rotation. The risks perceived were largely economic and whether the benefits of crop diversification (weed/disease control, spreading economic risk) outweighed the economic risks of trying a new crop, for example diversion of seeding machinery to setting up a chickpea trial and the question of whether chickpeas will have a better profit margin than the traditional crop (Abadi Ghadim et al., 2005).
Dealing with uncertainty.

Similar to risk, uncertainty too is classified in many ways and, as noted above, approached from different perspectives—philosophical, social, scientific—(see Riesch, 2012). A consequence is that the actual dynamics that determine how uncertainty statements will be interpreted and affect behaviour are not yet understood (Breakwell, 2007).

A simple definition that I argue reflects the uncertainties in farming is as follows: "Uncertainty is the intangible measure of what we do not know" (Cleden, 2009, p.5).

Extending this definition, Cleden (2009) defines two forms of uncertainty: the uncertainties that exist, but have yet to be analysed (inherent uncertainty), and the uncertainty that remains after analysis and the risks identified (latent uncertainty). Inherent uncertainty can exist because of ignorance or lack of knowledge (Riesch, 2012). Latent uncertainties are the unknowable uncertainties, which includes those that exist because of variability in nature, including human nature (Riesch, 2012; Snowden & Boone, 2007).

For example, a farmer planning his or her crop rotation is aware of the risk of frost and can manage it as far as knowledge allows, for instance by choosing frost resistant cultivars and staggering sowing time. Frost in this sense is an inherent uncertainty. But farmers cannot predict the timing or severity of frosts that might affect yield during critical growth periods and potentially destroy a crop regardless of the above management efforts. This is a latent uncertainty. Latent uncertainty can also involve the stochastic (random) relationship between, for example, beneficial and pest invertebrates, or between the pest population and other unknown environmental factors. Other researchers (Renn, 2003; Riesch, 2012; Wynne, 1992b) have created more defined dimensions to these two broad categories. These are described in more detail in chapter 8.

Uncertainty arises from complex situations and is therefore integral to a farm system. One certainty is that the more complex a problem or context the more latent uncertainty will exist. (Cleden, 2009). This is reflected in McCown, Brennan, and Parton's (2006) argument that what makes management of a farm system difficult is the uncertainty rather than the complexity of the system.
Nevertheless, (Wynne, 1992a) argues that farmers are typically comfortable managing in the context of uncertainty. In his work with Cumbrian sheep farmers, Wynne found farmers were familiar with uncertainty and comfortable with adaptation to factors beyond their control (Wynne, 1992a). Wynne's research also highlights how experts such as scientists can interpret the risks and uncertainty different from farmers. This is the concept of ambiguity, which is discussed next.

**Ambiguity.**

Ambiguity occurs when a scientific statement is interpreted differently by different groups (Renn, 2005). For example, scientific experts and the public can differ in their interpretation of risk with the result that neither side understands the perspective of the other (Renn, 2003). This is especially apparent where risk becomes subjective or transformed into cultural-symbolic risks (Zinn, 2008c). Although likely generalising, Wynne (1992a) emphasises this in his argument where he says that it is not that non-scientists do not understand the science, they simply do not recognise it, or identify with it, morally speaking and any risk interpreted by science comes with an imposed meaning that may not be shared by others. Science or experts will present risk problems as knowledge problems. For example, they will seek to quantify the concentration and exposure level of a specific pollutant that is harmful to the environment or human health (Renn, 2003). In contrast, non-scientists might frame risk, for example, as ethical risks. That is, as a society what level of risk are we prepared to accept with that pollutant (Zinn, 2008a). They are different questions that generate different answers and understanding about the same thing.

Or as Beck (1992) contends:

> What becomes clear in risk discussions are the fissures and gaps between scientific and social rationality in dealing with the hazardous potential of civilisation. The two sides talk past each other. Social movements raise questions that are not answered by the risk technicians at all, and the technicians answer questions which miss the point of what was really asked and what feeds public anxiety. (p. 30)

This provides some impetus for discussion about how science and risk can include value systems (Scheufele, 2013). For example, Lash and Wynne (quoted in Beck, 1992, p.5) describe the incident of farm workers in the UK who claimed herbicides caused unacceptable health effects. The British government's Pesticides Advisory Committee
examined the scientific literature and concluded that there was no risk. Further evidence from the farm workers produced the additional response from authorities that there was no risk so long as the herbicide was used under the correct conditions. The farm workers’ response to this was that using these chemicals under these conditions was impractical and untenable given the constraints and uncertainties associated with the farm system. This included dealing with natural and unpredictable variation in the weather that affected timing of spray application, and ability to access the correct spray equipment. Not only did the scientific perspective not consider the cultural aspects of a farm system, Lash and Wynne contend this idealised model of risk which focused on laboratory knowledge reflected a naive model of society (Beck, 1992).

Eastwood and Kenny (2009) reveal similar competing and disparate motivations in their research project to encourage dairy farmers to adopt a new satellite-based technology. The technology provides objective grazing management data to improve farmer decision-making. The data allows a farmer to determine a paddock’s average biomass and farm average growth rate for perennial ryegrass dairy pastures. Researchers found that farmers trialling the technology quickly replaced it with rule-of-thumb or heuristic-based assessment methods once they were confident that what they observed with their own eye was comparable with the satellite data. The research also highlighted a tension between the worldviews of the farmer and scientists. Farmers rationally placed simplicity and time efficiency above what they considered minor improvements in measurement accuracy from the satellite data. In contrast, the scientific worldview placed value on pasture measurement that is accurate, objective, and repeatable. Without consideration or acknowledgement of such tensions, misalignment of new technologies with farmer needs will limit their commercial application (Eastwood & Kenny, 2009).

So far I have established that farmers are diverse and make decisions within a complex system that is their farm. Risk and uncertainty in these contexts influence decision making directly, but different farmer values, worldviews and attitudes affect interpretations of these concepts. This builds a picture of who farmers are that is an important context to understand my research data and this thesis’ aim, which is to understand the effect empowerment has on how farmers construct knowledge and make decisions. An overview of the theories underpinning empowerment, power and knowledge is explored in the next section.
2.3 Understanding empowerment, power and knowledge

Empowerment, power and knowledge are intimately linked. You cannot talk about one concept without reference to at least one of the other two. Empowerment is also the core theme that emerged from the data and underpins my research question, so in this section I explore how empowerment and power are defined.

There is some debate in the interpretation of theories underpinning empowerment and power. Because of its significance to the analysis of the data I provide an overview of this debate here, and I examine it in more detail in chapter 8. At the end of this section I examine the role and significance of power-knowledge relations between farmers and their agronomists.

Defining empowerment.

The World Bank describes empowerment around the concept of choice and capacity to change.

Empowerment is the process of enhancing the capacity of individuals or groups to make choices and to transform those choices into desired actions and outcomes. In essence empowerment speaks to self determined change. (World Bank, 2016)

Roberts and Coutts (2007) describe an empowered farmer as one who, within their own farm system, will define their own problems and opportunities, and seek ways to solve or take advantage of them. Pratto (2016) defines empowerment as simply an ability to fulfil one's goals. Defining and interpreting empowerment, however, comes with competing philosophies and discourses. Bartlett (2008) describes two distinct discourses for empowerment: one centres on empowerment's instrumental benefits (instrumental discourse), the other on the intrinsic value of empowerment (intrinsic discourse).

The instrumental discourse places empowerment in a context where it is a means to achieve goals set by groups such as government or research institutes, whom Bartlett (2008) refers to as the "political and technical elite". A key purpose of such projects is to empower farmers. Any control a farmer has is predictable and non-threatening to others (Bartlett, 2008). For example, Bartlett argues that many development projects have defined and specific objectives such as food security or to conserve natural
resources. These are quantifiable outputs that are used as measures of success, but make rural people the object of production targets or adoption rates (Bartlett, 2008).

In contrast, intrinsic empowerment involves a permanent change in how people (farmers) live their lives. It is what Bartlett considers true empowerment, and something he describes as a "transformation". Bartlett's transformation involves three elements: means, process and ends. Means includes farmers' rights, access to and availability of resources (physical and social), capabilities and opportunities. Process is seen in terms of making choices that involve ability to analyse, make decisions and act, all of which must be self-directed to be considered empowerment. Bartlett's third element, ends, is people taking control of their lives (Bartlett, 2008). Thus with instrumental empowerment farmers are given a greater role, which Bartlett refers to as participation. With intrinsic empowerment farmers take control (Bartlett, 2008).

Kabeer (2001) shares a philosophy similar to the intrinsic discourse, but describes empowerment in terms of changes in ability to exercise choice, which is made up of the dimensions, resources, agency and achievements, or outcomes of those choices. Kabeer description of resources is similar to Bartlett (2008). Kabeer's concept of agency is similar to Bartlett's process. Both consider agency involves reflection, analysis and the ability to act. Kabeer describes agency as the meaning and purpose behind that action (Kabeer, 2001. See also Pratto, 2016). Bartlett (2008) describes it as "the construction of that person and their world" (p.528).

Agency also underpins Bartlett's concern about the instrumental discourse as he perceives it constrains a person's agency. Although the discourse provides for choice, it does so within defined boundaries such as regulations, or objectives defined by others. For example, farmers are encouraged to make their own agronomic decisions, yet simultaneously put under pressure to adopt or reject certain associated technologies or practices. Bartlett (2008) perceives this localises and limits agency to narrow technical and social parameters. Empowerment, Bartlett says, comes when agency is generalised and relationships change, and the consequences of such changes become unpredictable. Agency, as the key to true empowerment, is a consequence of something that people, including farmers, do for themselves rather than anything that science, policy or extension can do for them. Empowerment requires people setting their own goals,
managing their own activities and evaluating the outcomes for themselves (Bartlett, 2008).

Thus agency is integral to empowerment, yet according to Pratto (2016) you can have agency and be disempowered. Defining goals and being in a position to achieve them is part of being empowered, though a person's environment and personal capacity can change through time and affect their ability to achieve these goals (Pratto, 2016). Pratto assumes everyone has agency, but empowerment can vary with time.

Agency—the ability to act—is not the same as power. One can act (or have agency) without being able to fulfil one’s goals—to be empowered—because of deficiencies in one’s context, capacities, or their relation. One’s degree of empowerment is variable across agents, time, and location. One’s degree of agency is universal, singular, and constant. (Pratto 2016, p. 11)

Note that Pratto's definition of empowerment (a state of being able to achieve one's objectives), closely mirrors Weber's conceptualisation of power outlined below. Pratto makes a subtle distinction between empowerment and power, defining power as what a person wants to do, though constrained by a combination of the capacity of the person and what is afforded by the physical and social environment they inhabit (for example, access to technology, regulations, finance, and social norms) (Pratto, 2016).

Although not explicitly mentioning empowerment or agency, Barr and Cary (2000) reflect this reality in their observation that farmers, conscious of their own objectives and position as social agents within their community, will still operate as individual agents within their own farm system and these broader constraints of Australian agriculture. Barr and Cary are describing choice and self-direction, or agency, but agency that operates within the regulatory, political and economic constraints of Australian agriculture and social constraints of local communities. Nevertheless, agency is a crucial element of empowerment, and I use it, among other elements, to define empowerment (see chapter 5).

As noted already, farmers' decision making is social and bound up in relationships, something evident in my early data also. The nature of relationships and the intimate link to power, empowerment and decision making is explored next.
**Power-knowledge.**

Regardless of how it is conceptualised, empowerment has an intimate relationship with power and knowledge. This is reflected in the following quotes.

In his definition of power, Weber, connects power with empowerment through his description of people realising their "will". He describes also an individual or group's ability to achieve their own goals. This is agency.

> Power [Macht] is the probability that one actor within a social relationship will be in a position to carry out his own will despite resistance, regardless of the basis on which this probability rests. (Uphoff, 1989, p. 299)

Foucault, in Foucault and Gordon (1980), connects power and knowledge construction. Foucault alludes to empowerment through his description of means to observe and assess (agency) and control (ends).

> [Power] is the production of effective instruments for the formation and accumulation of knowledge—methods of observation, techniques of registration, procedures for investigation and research, apparatuses of control. (p. 102)

Simon and Oakes (2006) imply that a person or group can wield control and constrain agency and therefore the potential for empowerment. "[Power is] coordination and management of productive human agency" (p. 114).

Fazey et al. (2012) connect all three concepts in their description of Knowledge Exchange.

> Power as a distribution of knowledge...highlights Knowledge Exchange (KE) as a process of empowerment or disempowerment, where sharing and exchanging knowledge is inseparable from the dynamics of power. (p. 28)

Power is conceptualised in different ways. For the purposes of this chapter and to provide context to the data analysis it is sufficient to acknowledge two broad conceptualisations of power. The first emerges from Weber's above definition of power and authority (Weber, 1947) where power is either authoritative (exercised with consent from those subject to it) or coercive (conflict-based and exercised through force) (Simon & Oakes, 2006; Uphoff, 1989). In both contexts, power is a property of a social
relationship where one party has the chance to dictate or control the agency of another (Pratto, 2016; Raven, 1992; Simon & Oakes, 2006). Power itself, however, remains abstract in the sense that it only exists via the means or resources at a person or group's disposal. These resources include coercion, legitimacy (authority, respect), expertise and knowledge (see Heizmann & Olsson, 2015; Raven, 1992; Uphoff, 1989). It is these resources that are deemed to allow someone to "be in a position to carry out his [or her] own will" (Weber, 1947). Bruckmeier and Tovey (2008) describe something similar when they describe their "elitist model" of knowledge management practice that relies on the scientific or expert knowledge devaluing or suppressing local knowledge and experience. They imply that power is wielded as a tool to control.

The second conceptualisation of power is based on Foucault's understanding that power is exercised through and intimately linked with relationships and knowledge (Foucault & Gordon, 1980). Power is not conceived as a resource to control or dominate. It does not emanate from an authority. Power exists and functions through relations that results in the construction of knowledge (Heiskala, 2001; Schirato, Danaher, & Webb, 2012).

While I do not dismiss the importance of other concepts of power, in the context of my research, Foucault's conceptualisation is highly applicable to help explain farmers' knowledge construction and decision making. I elaborate on how I define and apply this conceptualisation of power to my data in chapter 5 and I provide a more in-depth examination of the two conceptualisations in chapter 8.

Regardless, both Weber and Foucault's conceptualisations of power are built around and rely on relationships. Power is produced or co-produced through varied and negotiated interpretations of meaning that occur through social interactions (Heizmann & Olsson, 2015). In agriculture also, power relations are an acknowledged part of extension and farmer-agronomist relations (Gray, Dunn, & Phillips, 1997; Ingram, 2008).

It is through these relations that innovation and knowledge are created (Darnhofer et al., 2010). Indeed, as Foucault argues in Foucault and Gordon (1980), power exists only when exercised in relationships, relationships that cannot exist without the relevant production of knowledge.
[Power] is the production of effective instruments for the formation and accumulation of knowledge...All this means that power, when it is exercised through these subtle mechanisms, cannot but evolve, organise and put into circulation a knowledge, or rather an apparatus of knowledge. (Foucault and Gordon, 1980, p. 102)

As noted, the power-knowledge relations that exist between farmers, agronomists and other extension services are important for farmers' knowledge construction. But the nature of extension is changing, thus the dynamics of farmer relations with extension and how knowledge is constructed is changing. The next section provides insight into what we know about farmer relationships in the context of these changes.

2.4 Extension and the farmer-agronomist relationship

This section will briefly define extension and examine the changing nature of extension, a change that has affected the nature of the farmer-agronomist relationship, and therefore how farmers construct knowledge.

The following definitions from The Australasia Pacific Extension Network (APEN) and the GRDC provide elements that appear to have consensus among other definitions in the extension literature, with the key element being extension's role as a process to facilitate change.

Extension is about working with people in a community to facilitate change in an environment that has social, economic and technical complexity. This is achieved by helping people gain the knowledge and confidence so they want to change and providing support to ensure it is implemented effectively. (APEN, 2014)

Extension is a field of communication, information exchange and promotion of learning to build capability and change practice. Extension includes the development of practice change methods required to achieve high levels of adoption of research outcomes and new technologies. It is recognised that these tools and delivery mechanisms will by nature be diverse and vary according to the intended outcome sought, the target segment of the industry and the local situation. (GRDC, 2014, p.ix)

Changing extension.

In Australia, all state government departments responsible for agriculture have moved from a focus on "public good" research and service characteristics towards various models of what Marsh and Pannell (1998) term a "market driven" or "private good"
philosophy of service provision. This has led to a restructuring that means the nature of the services they provide are outsourced or privatised (Marsh & Pannell, 1998). This is reflected in the new philosophy that has shifted from a worldview that focused on the top down transfer of technical data to one incorporating the socio-economic aspects of agriculture (Vanclay, 2004; Hunt, Birch, Coutts, & Vanclay, 2012). Further, farmers increasingly have access to the same information and networks that scientists and extension do, and formal scientific research no longer has a monopoly over solutions to problems (McKenzie, 2013).

This restructure of the process of extension that began in the late 1970s (Hunt et al., 2012) saw research institutions begin to embrace various participatory extension models and techniques (see Black, 2000). The concept of participation models is based on greater farmer equity in research and development. However, it is a concept open to interpretation. For instance, Thompson and Scoones (1994) and Black (2000) have reviewed the Farmer First paradigm, one of the first models to challenge the linear or top down process of technology transfer. Farmer First reshaped the research process with a concept to make local people active research partners (Wood et al., 2014). Farmer First now broadly encapsulates multiple participation concepts that have evolved to suit specific farming contexts (Dunn et al., 2000). Despite this, Thompson and Scoones (1994) consider the notion of participation as espoused by many Farmer First advocates as superficial because it fails to consider the complex political and sociological settings where farmers interact with extension. See chapter 8 for further discussion on Farmer First and participation models.

Another development in extension has been the appearance of farmer-driven extension organisations, or farm systems groups. Two examples based in Victoria are Southern Farming Systems and the Birchip Cropping Group. Farmer groups have varied histories, but many were catalysed through the initiation of the Australian Government's Landcare program that began in 1990 (Gianatti & Carmody, 2007). The groups tend to be community-based with a focus on production at a farm, local and regional level (Gianatti & Carmody, 2007). Despite varied structures, such groups share committed ownership from their members, the ability to identify and prioritise local constraints to farm business, and they can readily engage community interest in local agricultural problems. The GRDC considers such traits make these groups excellent vehicles for enhancing the adoption of new practices (GRDC, 2014). There is concern though about
a decline in smaller farming groups and growers not accessing their extension services such as crop walks and agronomy discussions (Rice, 2015). Rice considers this affects adoption of Research and Development (R&D) and feedback between growers and research scientists. There is no project work being done to identify methods to solve this issue (Rice, 2015). One salient point in the perceived purpose of these farmers’ groups is to accelerate farmer adoption of R&D, which in turn implies that farmers should adopt innovative practices and that not doing so is detrimental to their farm productivity and viability.

Regardless, these groups have facilitated an increase in farmer participation in research and extension through working directly with scientific institutions and individuals from public and private sectors, often with funding from R&D corporations or corporate sponsors (Marsh & Pannell, 1998). In some instances, farmer groups invite researchers or research institutions to become participants in their research. Llewellyn (2007) describes the actions of such farmer groups as a demonstration of social capital, capacity building and empowerment, and though the majority of farmers are not active participants in these groups they are the key recipients of the research.

**GRDC’s Regional Cropping Solutions Networks.**

In their 2014 RD&E strategy, the GRDC states one of their priorities is to engage more effectively with farmers and ensure farmers and other stakeholders help determine the GRDC’s research and investment priorities (GRDC 2014). One way the GRDC is engaging more intimately with farmers and farming groups is through their Regional Cropping Solutions Networks (RCSN), an initiative that enables regional and on-ground links between farmers, farming groups, agribusiness and researchers. It remains unclear, however, how this greater farmer participation manifests itself. For instance, how do the actors in the interconnected relationships perceive their role? Is it authoritative; are those in the RCSN there to consult, educate farmers, deliver knowledge and innovation; what discourses are apparent? How do these factors affect the perception of power, and knowledge construction and decision making?

Effective extension requires an effective relationship and empowerment and power cannot exist without some form of relationship (Foucault & Gordon, 1980; Heizmann & Olsson, 2015; Thompson & Scoones, 1994). This applies equally to the participatory models, of which Farmer First is but one. Fleming et al. (2014) argue that without
explicit consideration of the relationship dynamics in participatory theory and practice, even celebrated participatory methods can fail. One of the more significant relationships for many broadacre farmers is the one with their agronomist.

The farmer and the agronomist.

Extension facilitates farmer interaction with multiple people, but principal among these is their agronomist (Ingram, 2008; McGuckian, 2006). Agronomists are sought for their expertise in agronomy, but they are also mentors, sounding boards and confidants (McGuckian, 2006), and they are one of the more significant actors in the agricultural knowledge system (Ingram, 2008). Ingram (2008) illustrates this in her research that examines how knowledge about sustainable farm management is exchanged between agronomists and farmers, an exchange characterised by an interaction of knowledge and power. She distinguished two main types of knowledge exchange encounters: expert-based and facilitative.

Expert encounters occur on a broad spectrum. At one end agronomists behave as the proactive and dominant experts. In this conceptualisation farmers are reactive. They rely on agronomists and develop a high dependence on their expertise and advice. At the other end, the farmer is proactive and powerful. It is the farmer who dictates to the agronomist the nature of advice required. In this instance, agronomists tend to be unwilling to risk advice on untested practices for fear of losing a client. In between these extremes occurs greater interaction. Farmers respond to advice and use it in varied and distinctive ways, often influenced by the social dynamics of the farmer-agronomist relationship. However, Ingram considers all expert encounters exist in a climate of power imbalance and distrust.

In contrast, facilitative encounters exhibit a more equitable exchange of knowledge between farmers and agronomists. In this space there is dialogue, and consultation rather than instruction. Such relationships need time to develop and are underpinned by trust, credibility and empathy (Ingram, 2008). As alluded to, networking (knowledge relations) and trust are essential elements for knowledge construction, which are key components also of social capital. The role of social capital in farmer decision making is explored next.
2.5 Social capital

Social capital is implicated as having a key role in our understanding of farmers and their decision making, including that relevant to innovation and adoption (Ervin & Jussaume, 2014).

Social capital is considered a general concept with many variables, which makes a precise definition hard to pin down (Paxton, 1999; Portes, 1998). Most definitions of social capital, though seem to contain the following elements:

Community processes: Social capital involves networks, norms, reciprocity and social trust that make up and define community processes (Alston, 2002; Stanley, Clouston, and Baker (n.d.). Opinion leaders and other influential community members have an important influence on land users in their adoption decisions. They can uphold or create new norms in a community that influence the behaviour of other land users (Guerin, 1999).

Securing benefits: Social capital includes the ability of people to secure benefits through involvement in social networks and similar social structures (Alston, 2002; Stanley, Clouston, and Baker (n.d.). Such benefits can include lowering the cost of a community working together, facilitating cooperation and providing people with the confidence to invest in collective activities (Pretty & Smith, 2004).

Relationships: It is the relationships that underpin the above elements and are key to what defines social capital. This is best captured in one of the more precise definitions of social capital by Bourdieu (1986) and it is the definition used as the basis for my data analysis:

Social capital is the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalised relationships of mutual acquaintance and recognition—or in other words, to membership in a group. (p. 248)

Bourdieu contends that it is the social relations themselves that allow individuals access to desired resources (securing benefits) (Bourdieu, 1986). Further, these relationships will be specifically sought (Smith, Anderson, & Moore, 2012) and involve positive feelings of reciprocity and trust (Paxton, 1999).

To emphasise and expand on this, in collaborative research between farmers and scientists designed to produce new knowledge about herb-based pastures, (Wood et al.,
sought to understand how farmers participate with scientists and extend this participation by sharing knowledge with other people. Although the initial purpose of the contact concerned the farm business, Wood et al. found the relationships between farmers and others with whom they sought to share knowledge were strengthened through informal and social interaction, especially the long-term relationships, which became multi-dimensional and personal. Those whom farmers sought to share knowledge with included seed merchants, vets and other farmers.

Long-term relationships inevitably become highly personal. Rather than being narrowly defined by any formal role, they thicken with social interaction and sentiment. Contacts are thus expected to speak well beyond the bounds of any specialised competency. The value that farmers place on richly interpersonal contact means that their most valued relationships are multi-dimensional and their knowledge networks are highly informal. (Wood et al., 2014, p.7)

Gray, Phillips and Dunn (2000) add another dimension to farmer relationships. They imply that farmers' relationships within their community are important for the interpretation and meaning of ideas and innovation, but more importantly they help maintain the cultural traditions that these interpretations and meanings are filtered through.

The social networks which could be seen as potential conduits for innovative ideas become something much more: they are relationships in which ideas and conditions are interpreted, and meanings are transmitted through cultural tradition. (Gray, Phillips & Dunn, 2000, p. 42)

Networking and trust are the two elements of social capital that emerged in my data as a significant influence on farmer decision making and I examine them in the next section.

Networking and trust.

Although trust is conceptualised in many ways (Breakwell, 2007; Renn, 2003), the trust relevant to my data is best understood in the context of the following three forms of social trust outlined by Breakwell (2007):

- Public trust: the amalgamated feelings of trust towards all societal institutions and leaders such as governments and the United Nations (UN).
- Institutional trust: the general feeling of trust about a specific organisation or social group, for example environmental groups or scientific research institutions.
• Specific trust: confidence in a specific institution dealing with a specific problem at a single time. For example, for specific problems such as land clearing you might trust one environmental group or research institute over another. In other words, you do not necessarily trust all environmental or science research institutes, just specific ones, and possibly only for certain problems.

Social trust is where individuals perceive they lack adequate knowledge and will assess the competence of others to assess the hazards and its risks for them (Henry & Dietz, 2011). Conversely, where a person deems their knowledge is adequate, they will make their own judgement of the risks and benefits. Reliance on the opinion of others becomes unnecessary (Henry & Dietz, 2011; Siegrist & Cvetkovich, 2000). Some research argues that we now rely more than ever on the credibility and sincerity of those from whom we receive information. Institutional risk management has become a substitute for personal control (Beck, 1992; Breakwell, 2007; Renn, 2008).

This reliance emphasises the importance of networks or relationships. Trust is integral to the strength of social ties and the relationships within them, which for farmers can influence their capacity to adapt (Milne, Stenekes, & Russell, 2008; Smith et al., 2012). For instance, strong social links and trust are thought to have influenced Queensland graziers' adaptive capacity to deal with climate risk. They were recorded as being low adopters of probabilistic seasonal climate forecasts, a potentially useful technology for reducing the uncertainty associated with the future climate. Marshall, Gordon, and Ash (2010) found that graziers' level of networking was highly correlated with their likelihood to adopt the forecasting technology. This, they suggest, may be because graziers with increased stocks of social capital typically have reciprocal networks and increased social trust. Farmers with these strong formal and informal networks are also more likely to have the opportunity to learn about innovations and to possess adaptive behaviours (Howden et al., 2007; Nelson, Adger, & Brown, 2007).

Research by Wood et al. (2014) emphasises this, but they discovered these informal networks do not necessarily radiate out from the origin of the scientific research. Wood et al.'s study on collaborative research between farmers and scientists suggests farmers exchange new scientific knowledge within long-term relationships in which the farmers are the principal facilitators. They found that knowledge exchange of their herb-pasture
experiment did not radiate out from the scientists as the central point; it occurred through self-organising and distributed farmer networks (Wood et al., 2014).

McGuckian (2006) too places importance on farmer networks. He found that for Australian farmers a shared context between the information source and the farmer is critical (see also Snowden, 2003). Validation of the information tends to occur once it is taken to a trusted sounding board (the social relationships) for confirmation (McGuckian, 2006). This process increases the probability of finding a solution that avoids repeating mistakes and also opens up new possibilities (Snowden, 2003). As alluded to, other farmers are one of these trusted sounding boards. Wood et al. (2014) consider farmer reasoning operates openly in the form of repeated and public sharing of empirical observations. A lot of this is between farmers themselves (Wood et al. 2014).

Thus a farmer acquires and builds up social capital through investment in relationships and the consequent connection of the networks. These relationships gain farmers access to the resources (social, cultural, economic, physical) that aid knowledge construction (Portes, 1998). To emphasise this, Wynne (1992a), in his analysis of the reactions of UK Cumbrian hill farmers to the Chernobyl crisis, puts greater weight on social relationships, networks and identities derived from trust rather than trust itself when it comes to explanatory concepts for understanding public responses to scientific knowledge and advice. Wynne's interviews with the farmers revealed the complex and multi-dimensional social basis of trust and credibility as a central factor in the meaning farmers placed on scientific advice they received. In the development of trust, farmers monitor and construct evidence from wide ranges of behaviour of the expert institutions, including historic behaviour. In other words, the beliefs farmers construct, including their perception of the credibility and trustworthiness of different scientific and other social actors, are functions of the social networks with which they identify (Wynne, 1992a).

As alluded to in some of the literature reviewed so far, there is considerable focus on understanding why farmers do or do not adopt innovations. Given the research question for this thesis, the issue of adoption, or technology transfer, is considered next.
2.6 Adoption theories

Theories and models.

In chapter 1, I mention diffusion theory, one of the original models to explain the adoption process (see Rogers, 1983). Although I note certain merits of the theory there is also criticism, the key criticism being that the theory ignores the social, political and cultural context in which agricultural knowledge is generated (Dunn et al., 2000).

Further, the diffusion model is becoming incompatible with more recent approaches to farming, for instance, the management of whole systems—farm and catchment area—or adoption of conservation technologies. All these approaches require new ways of thinking (Vanclay & Lawrence, 1994). Dunn et al. (2000) argue that concepts or practices that generate questions and problems regarding long-term sustainability and economic viability, which I argue that IWM and IPM do, are too complex and too socially involved to be solved by paradigms such as diffusion theory.

Some of this change in thinking has happened because of shifts in how we conceive innovation. In the context of technology transfer or diffusion models, innovations were technical devices or principles, for instance a new seed variety, or chemical. This has shifted to thinking about innovation as a process involving factors such as social relationships, cultural constraints, laws and regulations. Once considered external influences to adoption, they are now considered integral to the process (Leeuwis & Aarts, 2011).

The remainder of this section examines the relevant literature exploring factors thought to affect farmers' perceptions of technologies or ideas and what constrains or enables adoption. I also examine what underpins farmers' need to conduct on-farm trials as an apparent step in decisions about adoption.

Preventing, enabling adoption.

In this thesis, I question the focus on the concept of adoption itself and its use as a quantitative measure of a technology's success. Nevertheless, factors do affect how farmers perceive an innovation and whether or not it is 'adopted'. Some of these factors are apparent in my data and thus it is pertinent to examine the relevant literature here.
A key frustration for researchers and extension agents with agricultural innovation is slower than expected adoption levels (Rogers, 2003). Consequently, there is considerable effort to understand what drives adoption of innovations among farmers (Llewellyn, 2007; Rogers, 2003).

This is where elements of diffusion theory are useful. Rogers (2003) lists five attributes of innovations that he perceives affect the rate of adoption and help to understand how people value or assess an innovation. The five attributes are the complexity of the technology, or whether people can comprehend it; whether the outcomes of an adoption are observable; the ability to first trial the technology; the perceived relative advantages of the technology and how it compares to what it supersedes; and compatibility of the innovations with a person’s values, experiences and needs, which includes compatibility with the values and norms of the social system (Rogers, 2003). See Guerin and Guerin (1994) for a further review of these attributes. Guerin and Guerin (1994) also consider a farmer's level of motivation and perception of risk affect adoption.

Auges and Zouvelekas (2006) too find risk has a prominent role in farmers' adoption of more efficient irrigation technology. In this case risk is associated with risk to production from aridity and the physical traits of the farm such as soil type that might exacerbate this, especially in extreme climatic conditions. Human capital in the form of better education, extension services and access to information were also thought to improve the likelihood farmers would adopt this technology (Auges & Zouvelekas, 2006; Llewellyn, 2007).

Llewellyn, Pannell, Lindner, & Powles, (2005) also consider education is influential in adoption. They found farmers with higher levels of education were more likely to adopt IWM practices or technologies. For instance, those with a university degree were 45% more likely to adopt IWM than those without a degree (Llewellyn, Lindner, Pannell, & Powles, 2007).

Exploring more abstract perspectives, Coughenour (2003) describes the influence of farmers' social relationships and networks on their adoption behaviour. Using no-till cropping as their case study, Coughenour advances the argument that actor-network theory (ANT), an analytical perspective that focuses on actor(s)-networks as the central problem in social phenomena, is more appropriate to explain adoption of certain
Agricultural innovations. Coughenour notes that farmers' relationships with their environment and human actors are usually considered as causal sources, resources, or constraints to adoption, a perspective he considers as partial and limited. Conservation and no-till farming instead occur as a consequence of new ways of developing social networks that join farmland, farmers, extension, scientists, farm supply agents and others in a way that accords the same problematic status to all actors. This includes humans and bio-physical entities. Indeed, as Leeuwis and Aarts (2011) argue, innovation is a conflictive process and dependent on dynamics in networks. This conceptualisation highlights the linear transfer model as largely one-dimensional and unsuited to the complex and dynamic process involving knowledge construction in networks (Leeuwis & Aarts, 2011).

An important component of farmers' knowledge construction is on-farm trialling. Risk and uncertainty are key motivators. Because it involves knowledge construction, relationships are also integral to the behaviour. The concept of on-farm trials is examined in more detail next.

**Farmer-led trials and the learning journey.**

This section examines on-farm trialling as an enabling factor to help farmer decision making. Trialling is a key step in a farmer's learning process and to reduce uncertainty (Abadi Ghadim et al., 2005; Cary, Webb & Barr, 2002). But despite acknowledgement that farmers have been innovating for a long time, the process at the farm level is poorly understood, and not well reflected in policy approaches to agricultural innovation (McKenzie, 2013). What do we not know then about the motivations and implications for farmer-driven innovation?

What the research so far mentioned in this chapter examines, to a large extent, is the technology or innovation itself (see Auges & Zouvelekas, 2006; Guerin & Guerin, 1994; Llewellyn et al., 2005; Pannell et al., 2006). The question asked is what aspects of the innovation constrain or enable its adoption? In contrast, McKenzie (2013) argues for a shift in focus from the barriers to adoption to the socio-cultural processes farmers operate in and that affect decision making about an innovation. For example, the dynamics of knowledge supply and demand, interactive networks, and opportunity creation among farmers.
I argue that one of these socio-cultural processes is a farmer's learning journey and how it is facilitated through varied forms of on-farm innovation. Adoption, in this conceptualisation, is secondary to the learning journey. In reference to IPM, Röling and van de Fliert (1994) put it thus:

If, as IPM's experience suggests, acceptance of more sustainable practices is not so much a question of adopting an innovation, but of a 'paradigm shift' requiring a learning process, then we need a much greater understanding of the learning path, the changing perception of risk and insecurity during that path. (p.106)

In research with no-till farmers again, Coughenour (2003) talks about such farmers being embedded within no-till cropping networks and engaged in a never-ending process of social construction of new techniques that require their shared cultural knowledge where innovation and adoption is often about incremental problem solving, making continual nuanced adjustments or improvements. It is an on-going process rather than a one-off event that focuses on a single point of adoption, something that can be overlooked by extension (Coughenour, 2003; Pannell et al., 2006).

Bartlett (2008) also talks about a farmer's learning journey but implies a more constructivist approach to facilitating it. Farmers' knowledge, he argues, is constructed as a consequence of critical thinking, on-farm trialling and communication within their social networks. For example, at the point of interaction between knowledge and behaviour, agency can be stimulated through experiential learning, and by encouraging and supporting a process of observation and experimentation. Farmers construct their own knowledge and make their own decisions about behaviour (Bartlett, 2008).

Röling and van der Fliert (1994) put a similar emphasis on agency and farmers' power-knowledge relations suggesting a need to value farmers' "cognitive autonomy" and their acquired skill in farming as a craft. The consequence of these attributes facilitates collective experimentation and development of innovative processes, and the co-construction of solutions (Röling & van der Fliert, 1994). In other words, extension should support and facilitate a farmers' own expertise.

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2 Constructivism is a broad philosophy that describes how we think and learn. Rather than knowledge being a set of objective facts (objectivism), constructivism values how we construct knowledge. Constructivists contend that what we know is a function of previous experiences, values, beliefs that we use to interpret an event, or "reality" (Ertmer and Newby 2013, Jonassen 1991). See Chapter 9 for further discussion.
A final factor to consider is the motivation of profit or cost, which is more complex than profit for profit's sake. It was not a focus for this research, but it is important to consider how profit and economic aspects of farming compare to other farmer priorities and concerns that are a focus of this research.

2.7 Profit. It's all relative and it's not all about money

Profitable and sustainable farming practices are not necessarily indicative of good farming (Dunn et al., 2000). Nevertheless, it is unlikely that adoption can be properly explained unless factors influencing perceived profitability are recognised (Llewellyn, 2007). For example, Byron, Curtis, & Mackay (2006) found farmers in NSW's Lachlan Catchment were reluctant to adopt many of the current recommended practices or enterprises where they were either unprofitable, unsustainable, or both.

Even if profit is a key objective, the motivation for it is often a means to protect values such as freedom and the independence linked to farming lifestyles. Frost (2000) showed that farmers linked business expansion (and therefore financial capacity) with the qualities of freedom and independence. Byron et al. (2006) found that farmers were less likely to implement even an environmentally and economically sound practice if it put at risk their desired lifestyle.

The issue debated in the literature is how much influence profit and other social and ethical factors have and in what context. Social and ethical factors themselves can influence the role of profit in decision making. For instance, what is an acceptable profit for a farmer (Barr & Cary, 2000), and what is a productive or sustainable farm, are concepts subject to individual farmer values and worldviews (Richards, & Lawrence, 2005).

Most of this chapter has focused on understanding farmers and what affects their knowledge construction and decision making. This is important context to my research aim and question. As the specific aim of this research is to understand the role of empowerment in farmer decision making about IPM and IWM, it is important to also understand the science that underpins IWM and IPM. The next chapter examines how science defines IWM and IPM and the definitions used for this thesis. It also examines what motivates farmers to consider IWM and IPM.
3. Understanding IWM and IPM

Overview

This research asks the question, how does empowerment affect farmer decision making about weeds and invertebrate pest management? IWM and IPM are two weed and pest management strategies that are the focus of this research, hence it is important to understand what they are. In chapter 1, I gave a brief overview of this and the perceived problems with their adoption. This chapter provides greater detail about IWM and IPM strategies and examines the motivations, such as chemical resistance, that are thought to affect farmer decision making about them.

3.1 IWM

What is IWM?

IWM is a weed management strategy that contains a diverse range of biological, cultural and mechanical tools and technologies, and selective use of herbicides to control weeds. Used together they apply minimal selective pressure for HR (Llewellyn, Lindner, Pannell, & Powles, 2004). In Australia, a key proponent of IWM is WeedSmart, an industry-led initiative to enhance on-farm weed management practices and promote the long-term sustainable use of herbicide (weedsmart.org.au). It is managed by the Australian Herbicide Resistance Initiative (AHRI) at the University of Western Australia.

WeedSmart developed an IWM-based 10-point plan that contains strategies and technologies to help farmers combat weeds and herbicide resistance (WeedSmart, 2014). The parts of the plan most relevant to my research are as follows:

- Capture weed seeds at harvest. Techniques and technologies to achieve this include chaff carts that capture the chaff and weed seed from the header, which is then dumped in a pile for burning or for stock to eat.
- Rotate crops and herbicide modes of action (MOA).
- Where herbicide failures occur, do not let the weeds set seed. Strategies include cutting for hay or silage, fallowing or brown manuring the paddock.
• Use the double knock effect. This is the use of two herbicides with different MOAs and applied sequentially. The second treatment will kill survivors from initial treatment that may be resistant to the initial herbicide.

• Employ crop competition techniques. For example, narrow row spacing, high seeding rates and sowing crop in an east-west orientation to increase shading of weeds.

Llewellyn et al. (2004) adds the following IWM-based weed management practices:

• Autumn tickle: the use of light scarification/cultivation to stimulate weed germination. This allows for a higher proportion of weeds to be killed non-selectively before sowing.

• Croptopping: the application of a non-selective herbicide to mature or near-mature crops, to reduce viable seed set in weed species.

• Cultivation: the use of cultivation to kill germinated weeds.

• Delayed sowing: deliberate delay of crop sowing for two weeks or more to allow for additional weeds to be non-selectively killed pre-sowing.

• Narrow windrow burning (NWB): a practice where crops are harvested low to the ground, to maximise the amount of crop residue and weed material that passes through the harvester. Rather than being spread over the paddock, the crop residue and weed seed is placed in rows that enables greater fire temperature that will kill weed seed when burnt.

• Timely intense livestock grazing of paddocks not sown to crop can reduce weed seed set and weed seed return to the seed bank.

• Fallow: the maintenance of land free of living plants using herbicide or cultivation, usually for a period in summer–autumn before crop sowing.

• Manuring: the pre-maturity sacrifice of a crop using herbicide (brown manuring) or mechanical means (green manuring) to prevent weed seed set and return organic matter to the soil.

• Mechanical pasture top: seed set in pasture can be prevented or reduced by slashing the pasture before weed maturity.

• Pasture phase (treated): the use of a pasture phase of two years or more treated as above to reduce the weed seed bank before a cropping phase (p. 1001).
HR status.

HR is becoming more widespread. For example, surveys of farmers by Watson & Watson (2012) found 93% of respondents reported a weed problem mostly because of herbicide resistance. Of these, 29% think herbicide resistance is an increasing problem. Similarly, the 2013 Kondinin Group National Agricultural Survey (NAS) found more than 70% of farmers surveyed reported HR (White, 2014). In Western Australia, multiple chemical resistance is now the norm for the state’s two worst cropping weeds: annual ryegrass and wild radish. Only two percent of annual ryegrass populations remain fully susceptible to herbicide control, with all others resistant to one or more groups of herbicide (Owen, Preston, & Walker, 2013).

IWM motivation.

Llewellyn et al. (2004) provide insight into what IWM strategies farmers might use and why. Llewellyn et al. surveyed Western Australian grain growers to understand their IWM practices and IWM’s perceived value for weed management. They found that adopters and non-adopters of IWM strategies were equally informed about weeds and HR, and the efficacy of IWM tactics. This indicates that knowledge is not a factor in adoption. Growers who experienced resistance problems, however, used significantly more IWM tactics than growers without resistance on their farms. The study also found that those farmers without resistance who employed IWM tactics did so not for general weed control, but because they form an integral component of the preferred farming system and provide benefits other than weed control such as hay and pasture phases. Farmers with resistance tended to adopt IWM strategies that had the primary function of weed control and few other benefits. These included crop topping, catching of chaff and burning windrows.

HR is also threatening the use and effectiveness of no-till agriculture (D’Emden, Llewellyn, & Burton, 2008). No tillage is important for soil conservation and prevention of soil erosion, but without tillage the strategy is reliant on herbicides as its main weed management tool. Weed management problems, such as HR, are leading many growers to reduce their use of no-till (D’Emden & Llewellyn, 2006). This further emphasises that farmers are more likely to employ IWM tactics only after the resistance appears on their property. This notion is counter to attempts by weed scientists and extension agents to have farmers initiate pre-emptive adoption of IWM to delay the development of herbicide resistance (Llewellyn, Lindner, Pannell, & Powles, 2004).
Uncertainties about HR and IWM can also influence whether farmers will implement alternative weed management tactics. Farmers can have uncertainty about the seriousness of herbicide resistance, or the value of IWM to manage resistance (Llewellyn, Lindner, Pannell, & Powles, 2007). There is also farmer uncertainty about the potential for new herbicides to come into the market. For example, research with Western Australian cereal growers found those who were more certain that replacement herbicides for ryegrass control would be available were less likely to adopt IWM. What influences this technological optimism is poorly understood (Llewellyn et al., 2004; Llewellyn et al., 2007). Conversely, farmers uncertain of when a new herbicide will become available are more likely to adopt IWM tactics (Llewellyn et al., 2005).

3.2 IPM

What is IPM?

The definitions of IPM are numerous but are based on the need to integrate multiple control methods and minimise chemical use ( Parsa et al., 2014). Horne and Page (2008) argue that certain versions of IPM still rely too much on chemical, or what they term integrated pesticide management, rather than on what they consider is true IPM. This subjective terminology also leads to incomparable and distorted evaluations of IPM’s efficacy (Horne and Page, 2008). The definition used and treated as ‘true’ IPM in this research is that defined by the GRDC (2009) and the key principles of IPM defined by Horne and Page (2008).

IPM is defined therefore as an invertebrate management strategy to manage pest invertebrates. It employs three control options: biological, cultural and chemical. The emphasis is on the first two, with chemical control used as a support tool only (Horne and Page 2008).

The biological option is the use of naturally occurring beneficial pathogens (virus, bacteria), parasites (other insects and nematodes) or predators (invertebrates and vertebrates) to control invertebrate pests. Cultural control is alternative farming methods such as genetically modified (GM) crops that are engineered to produce specific insecticidal proteins (Bt crops), or ecological engineering of the landscape to increase biodiversity and provide habitat for the beneficial invertebrates. These two options are
the mainstay of IPM. Use of chemicals, especially those classed as broad spectrum, is the last resort (GRDC, 2012; Horne & Page, 2008a).

**Weighing up IPM and conventional management.**

Insecticides became an accepted part of conventional agriculture in the 1950s, an approach incompatible with IPM. Despite IPM's reported ability to improve a farm's economic, environmental and social outcomes, broad spectrum insecticides form the basis of pest control for most broadacre farming in Australia (Horne & Page, 2008a). Chemical control is simple, cheap and effective and requires minimal knowledge of the pest species, but it has increased selection pressure for insecticide resistance (IR) (Horne & Page, 2008a). Additional concerns about the chemical-based strategy include chemical residues in food, environmental health and human safety, effects on non-target species and chemical drift to neighbouring farms (GRDC, 2009; Horne & Page, 2008a).

Unlike the simple chemical-based strategy, IPM does require an understanding of pest and beneficial invertebrates, and careful and consistent monitoring of their populations. This includes developing the following skills: the ability to accurately identify invertebrate pests and beneficials, an understanding of pest and beneficial life cycles, how populations are affected by climate and other environmental factors such as the presence of host plants, and how specific predators interact with prey to control them and under what condition this can occur (GRDC, 2009; Horne & Page, 2008a).

**Use of selective chemicals.**

Where farmers must resort to chemicals as a control measure, the preference is to use chemicals that are selective for the pest and, when used appropriately, will have minimal effect on the beneficial invertebrates.

A key regulatory change has assisted this 'slow' shift to more targeted chemicals. In response to societal requirements, the Australian Pesticide and Veterinary Medicines Authority has deregistered many of the persistent chemicals (organochlorine and organophosphates), thus triggering the shift toward acutely toxic, but more selective insecticides (Nash & Hoffmann, 2012). Nash and Hoffmann (2012), however, caution that any shift to selective insecticides needs careful consideration as new problems may be created, such as the resurgence of secondary pests.
Thresholds.

Before invertebrate control decisions are made it is necessary to know the numbers of pest and beneficial invertebrates in your paddock. This includes their life stage and whether the populations are increasing or decreasing with time. When a farmer or agronomist estimates the pest population will cause economic damage that is greater than the cost of control, or thebeneficials will be unable to control the pests without unacceptable economic loss then they may decide to intervene with chemical control. To help farmers work this out, thresholds have been developed. The two key types relied on in broadacre are economic and nominal thresholds.

Economic thresholds are one of the cornerstones of IPM. Just because a pest is present in a crop does not mean that control is required. There is usually a level of pest damage that is uneconomic to prevent. Economic thresholds help to rationalise the use of pesticides and are one of the keys to profitable pest management. The National Invertebrate Pest Initiative (NIPI) defines an economic threshold as the pest population likely to cause damage equal in value to the cost of control. Spraying is only recommended when the pest invertebrate numbers will cause crop damage of a value that will exceed the cost of control (NIPI, 2014).

Despite the cornerstone status of economic thresholds, the majority of thresholds for insects in broadacre farming are nominal thresholds. A nominal threshold is where research has yet to experimentally establish a reliable relationship between pest density and yield loss. A nominal threshold is instead a subjective estimate based on experience of farmers, agronomists and researchers (NIPI, 2014b).

IPM motivations.

Because the presence of HR is a motivation for change in weed management, one might predict that IR would act as a similar motivation for invertebrate management. Although focusing on cotton production, Deguine, Ferron, and Russell (2008) indeed place increasing public and scientific concern about the threat of IR as one of the key motivators for change away from the conventional chemical strategy to alternative chemical control strategies such as the use of economic thresholds and, in parallel, IPM.

Although the introduction of economic thresholds is intended to exploit the use of beneficial invertebrates, Deguine et al. (2008) argue that the thresholds are instead
simply risk evaluations used to justify chemical applications and reinforce cotton growers' recourse to synthetic insecticides rather than exploring the potential for tactics indicative of IPM principles. Given this scenario with cotton growers, chemical control in Australian broadacre crops is predicted to remain an important and dominant component of pest invertebrate control (Gentz, Murdoch, & King, 2010; Zalucki, Adamson, & Furlong, 2009).

Other potential motivations may operate in broadacre crops. For example, farmers consider canola a high risk crop because, among other things such as significant input costs, it is highly susceptible to cotyledon damage (Gu, Edwards, Hardy, & Fitt, 2008). This risk leads to growers using prophylactic broad spectrum insecticide protection before and at establishment of canola seedlings (Micic et al., 2008). Such tactics are not considered IPM as defined in my research.

As noted, IPM is still novel among broadacre farmers. Kogan (1998) uses an adoption continuum that illustrates different stages of adoption of IPM, or farmers' integration of IPM tactics into their systems (see Figure 1). He describes three levels of IPM integration. Level 1 represents the minimum set of tactics required to reach Kogan's "IPM threshold". Nash and Hoffman (2012) suggest some Australian broadacre farmers occasionally stray into Level 1, but this is largely because of frugal financial management. Thus, most Australian farmers are more often than not positioned somewhere below Level 1.
Figure 1 Modified from Kogan (1998), p. 262: Adoption curve presenting the various stages of adoption of IPM.

Notes: Kogan’s adoption curve outlines the different levels of adoption from conventional pest control to level 3 IPM. Kogan considers there is a minimum set of tactical components combined within a basic strategy that defines the “IPM threshold” (Kogan, 1998, p.262)

My research method to explore and understand empowerment and farmer decision making is an approach informed by a modified constructivist grounded theory. The next chapter outlines and justifies my research design, method and provides insight into the philosophy that underpin this.
4. Method

Overview

This chapter outlines and justifies my research design, method and provides insight into the philosophy that underpins this. My research method is informed by modified constructivist grounded theory. I use it to explore farmer decision making relevant to weed and invertebrate pest management. I first cover my journey to define my research questions and the examination and understanding of my own philosophical position and how it influences each aspect of my research. I discuss the grounded theory method and different epistemologies behind the different forms. I examine my choice to use a modified constructivist grounded theory and how it was suitable to explore and understand my research problem. Finally, I provide an outline of the research process including sample selection, data collection and analysis.

4.1 Introduction to my research journey

What is my understanding of reality? How does this influence my choice of research method and how I interpret the data, and indeed even help define my research question? Exploring and understanding my personal ontology and epistemology was important to consolidate my decisions that determined my approach to the research and provided answers to these and related questions. The following describes my journey to find the answers and become comfortable with my research method.

We all see the world differently. Consequently, we ask questions and try to answer them in ways that reflect these differences. This worldview influences our assumptions about the nature of reality (ontology) and our relationship with that knowledge, what we perceive can be known and how we determine its validity (epistemology).

To understand my broad research problem of why farmers were not effectively adopting IWM and IPM, I had to first take a personal journey to understand my own ontological and epistemological perspective and how this influenced each aspect of my research, from the choice of research method (modified constructivist grounded theory), to the analysis and my interpretation of the data, even how I defined my research question (see Annells, 1996). That is, while there exist many approaches or models developed to understand decision making under uncertainty or to elucidate farmers' risk perception
(see 4.3), my own ontological and epistemological position influenced my choice of method. Given a different research problem and context that required an understanding of farmer decision making and risk, I may have chosen an alternative method or methods.

I discovered the way I perceived reality placed me closer to a constructivist ontology, which I explain in more detail later in this chapter. For my research method I chose a modified form of constructivist grounded theory, which considers the subjective observer. Indeed, the method's philosophy is underpinned by the perception that our values are inherent in our research and provide a lens for understanding and shaping our analysis, and should be made explicit. There is no neutral observer (Charmaz, 2014; Goodrick, 2013). Part of my ongoing reflection and understanding about my philosophical position therefore included questioning how my perspective could bias my research. Although clarity on my philosophical position emerged early in the interview stage of research, once I understood this and the factors underpinning this, I became comfortable with the philosophical lens through which I viewed and interpreted what was happening in the context of my research.

This reflection occurred alongside different methods of data collection to provide varied perspectives and theories, and to cross-check data and my interpretations (see Guba, 1981). I used interview, observation and analysis of varied literature to triangulate my data. This was not to establish convergence of a single or predominant social phenomenon. Indeed, from these multiple data sources emerged a number of contradictions and inconsistencies. This not only provided a richer picture of farmer decision making in complex contexts, but the iterative nature of grounded theory enabled me to explore these conflicting data sources to understand these social phenomena in greater depth (see Mathison, 1988). Follow up interviews of participants were important in this context. These interviews also helped clarify any potential misinterpretations from the original interview.

The following sections provide insight into my views and values that influenced the different aspects of my research including my research question and decision to use modified constructivist grounded theory. I also describe briefly the philosophical background to grounded theory and the constructivism paradigm.
My philosophical influences.

Glaser and Strauss (1967) note that qualitative research is reliant on those who conduct it. Researchers are not passive receptacles into which data are poured. In other words, we cannot dismiss the influence of our values or what we bring in to the study by claiming scientific neutrality and authority (Charmaz, 2006).

Some of my philosophical stance can be understood from what influenced the initial focus of my research. These came from a number of sources and include my personal interest in agriculture, sustainability and science from growing up on a farm and studying and working in the field of biological science. This experience helped form strong values on the environment and sustainability. I had also previously worked with farmers and rural audiences trying to understand how they interpret controversial science such as genetically modified crops. Although evidence from my engagement with farmers is largely anecdotal, I formed impressions of farmers' attitudes and values toward science and technology. Doubtless this affected my perceptions of the farmers interviewed for this thesis. My research topic, however, was something I initially had minimal knowledge of and for which I had no prior assumptions about. Any personal bias is likely to have had greatest influence in the interview questions asked and the direction I steered the conversation. My interpretations of data will also be influenced by my ontological leaning and worldviews generally. This does not mean my interpretation is biased or wrong. The subjective constructivist researcher sees their research, and its interpretation, as constructed rather than discovered. It means that our values shape our analysis and the facts we identify. Thus we have differing concepts of reality (Goodrick, 2013). But this means also that we must examine and understand how these preconceptions influence our construction of what is happening (Charmaz, 2014). I examined how my previous engagement with farmers and my own experience on a farm influenced my concept of farmers, especially regarding sustainable agriculture; how farmers considered science and technology; their competing priorities, and how all these factors might influence their decision making.

Although not strictly a philosophical influence, the GRDC's interest in understanding why farmers were not, according to them, effectively adopting IWM and IPM narrowed the research focus, though it still only identified a perceived problem. In this early phase
of research, my research question was yet to emerge, and it did not for some time. That part of the journey toward my research question is explained next.

**Finding my research question.**

In most studies, the research question determines the direction of the research. In grounded theory, the research question emerges from the iterative research process itself (Birks & Mills, 2011; Charmaz, 2014). But as Seldén (2005) argues, concepts and theory do not so much emerge from the data; rather they emerge from the researcher who subjectively identifies and interprets them from the data. So too it is the researcher that identifies the research question from their interpretation of the data and what they consider important.

To begin to explore the research problem and hence define my question, I began with the broad question, What is happening here? To find this out, I read the farmer-targeted literature such as fact sheets and the GRDC IWM manual, I sat in and observed farmer and agronomist-targeted professional development programs run by GRDC, SFS and BCG. From this, it became apparent that farmers faced two key agronomic problems: nitrogen use efficiency (NUE) and weeds, with the latter problem focused on the need to employ IWM to better manage herbicide resistance.

With this knowledge I developed four broad, open-ended questions based on the grounded theory concept that minimal and open questions allow the participant to tell their story (Charmaz, 2014). In this case, I wanted to understand more about what motivated people to be farmers, how farmers thought about weeds and nitrogen use, and how these factors affected decision making. They were exploratory questions only to get a broad overview of what was happening. The four questions were as follows:

- Can you tell me about your farm?
- What does it mean to you to be a farmer? (I usually had to elaborate and ask, what value does being a farmer mean to you?)
- Can you tell me about your weeds (and how you manage them)?
- Can you tell me about how you use nitrogen?

I arranged three pilot interviews with farmers to test the validity of the interview process and whether the above four questions could give me insight into and enable me to
understand farmers’ perceptions about weeds and nitrogen use. I later did follow up interviews with two of these farmers that became part of my research data.

I judged that the interview technique and the questions did enable me to get insight into the social and cultural contexts that farmers operate in and how it influences their decision making about weeds and nitrogen use. But it was evident that the concerns about nitrogen, for instance nutrient runoff into waterways, that are apparent in some agricultural regions of the world, including Australia, are not applicable to the mid-low rainfall cropping zones in south-east Australia. There is some scientific concern in the high rain fall zone of western Victoria, but it is insignificant compared to other parts of the world where nitrogen use is considerably higher. This was confirmed with some further analysis of the literature and a conversation with a relevant scientist.

What the pilot interviews instead made apparent was farmer concern about managing pest invertebrates. There is a similar push from science and organisations such as the GRDC for farmers to adopt IPM as a way to manage invertebrates more sustainably. Farmers talked about managing invertebrates and the use of insecticides in a number of contexts, for example how their perception of insecticide use differs from their agronomist’s, and their fear of crop loss caused by invertebrates. This became more apparent following initial interviews with agronomists. Again I asked, what is happening here? It led me to dropping nitrogen as a focus and instead exploring farmer decision making about IPM and IWM.

I now had a broad research problem and a way to explore it, but I still had no research question. With a problem and method I could begin the iterative process of gathering data. It was about midway through the interviews, as the analysis and coding began to reveal concepts of importance, that my research question began to emerge to eventually become, how does empowerment affect farmer decision making about weeds and invertebrate pest management? The following sub-question concerning IPM emerged also: What underpins the different farmer perceptions and motivations in their management of weeds compared to invertebrate pests?

I have outlined what influenced my philosophical stance and the path toward my research question. To provide context to this, I need to outline my personal ontological and epistemological position. I explain this next.
My ontology, epistemology.

My alignment with constructivism and choice of a modified constructivist grounded theory need to be understood in the context of the philosophy underpinning grounded theory.

Grounded theory emerged from a successful collaboration between Barney G. Glaser and Anselm L. Strauss and resulted in the publication in 1967 of *The Discovery of Grounded Theory: Strategies for Qualitative Research*. The book and the concept of grounded theory outlined systematic strategies for qualitative research that had the potential to generate abstract theories of social processes (Charmaz, 2014).

Charmaz (2014) describes two main forms of grounded theory that align with the ontological and epistemological stances of social research. One is objectivism, the other constructivism. Charmaz does identify a third form, she calls post-positivism, that lies between the two (Charmaz, 2014).

I discuss the following philosophical concepts further in chapter 8, but broadly objectivism and constructivism are distinguished by the following perspectives: objectivism perceives that there are truths out there that can be obtained from rigorous research, or that data represents objective facts (Charmaz, 2014). The researcher is objective and thus is detached or distant from research participants. Researchers need to excise values from the research process (Charmaz, 2014). Glaser and Strauss (1967) position themselves most closely to what is considered objectivist grounded theory, although in later years Strauss shifted toward a more constructivist form (see Corbin & Strauss, 2008).

Arising as an alternative to objectivism was constructivist grounded theory. Charmaz was pivotal in defining constructivism, which aims to understand complex human phenomena (Charmaz, 2014). The researcher engages in an enquiry process that creates knowledge and truth through interpreted constructions that are dependent on the social or cultural context where it is experienced (Annells, 1996). According to Patton (2002), the world of human perception is not real in an absolute sense, but is "made up" and shaped by cultural and linguistic constructs. Rather than seeking a singular truth, the
constructivist researcher seeks to generate multiple interpretations through collaboration with participants (Charmaz, 2014; Patton, 2002).

Sitting under these broad influential forms are varied paradigms of enquiry. These act as a lens through which we view the world. There is a line of research exploring these paradigms of enquiry (see Annells, 1996; Charmaz, 2006; Goodrick, 2013). Annells, however, narrows it down to four key paradigms that sit on a continuum. At one end is Positivism; at the other is Critical Theory (which incorporates Post-structuralism). In between are Post-positivism, and Constructivism. Goodrick (2013) and Charmaz (2014) add Pragmatism to that list which sits closer to Critical Theory (see Figure 2).

**Figure 2 Paradigms of enquiry. Adapted from Goodrick (2013)**

A researcher's epistemological and ontological perspective will determine their paradigm (Goodrick, 2013). For example, positivists will follow the scientific method and assume an external reality and an unbiased observer, they discover abstract generalities, explain empirical phenomena, and they separate facts from values. The positivists sit more comfortably with the objectivist ontology. Constructivists start with the assumption that social reality is multiple, dynamic, and constructed. Thus, the researcher's position, privileges, perspective and interactions need to be considered as an inherent part of the research reality (Charmaz, 2014).

This thesis is informed by constructivist grounded theory described by Charmaz (2014). In the context of my research, I was uncomfortable with the objectivist approach, despite a scientific background where objectivity is paramount. I struggled with the concept of separating myself from the experience of the farmer or other participants. Some of the background literature on farmers and my own perceptions indicated also that farmers use their experience and the socio-cultural contexts they operate in as influences that help them construct knowledge, a notion that reinforced my difficulty to
separate myself from the farmer's experience. This became more apparent as the interviews progressed and is a further reason why understanding my own philosophical position took time to clarify itself.

This outlines my personal ontology and epistemological perspective and why my research was informed by the constructivist perspective, but it only partly explains why modified grounded theory was an appropriate method for this research problem. The next section explores the reasons for this.

**4.2 Why modified grounded theory?**

Of the varied social research methods suitable to investigate my research question, I outline below why modified grounded theory was an appropriate method for this research.

In the early phase of research it quickly became apparent that I was dealing with complex farm systems, complex problems with inherent risk and uncertainty, and complex socio-cultural contexts. The literature underpinned this. For instance, Vanclay (2004) emphasised that farming is a socio-cultural practice governed and informed by social processes. Further, Pannell and Zilberman (2000) and Abadi Ghadim et al. (2005) emphasised risk, uncertainty and complexity as factors that affect adoption of agricultural innovations. Much of the literature on risk and uncertainty is quantitative and focused on economic factors. Although these methods provide valuable insight into how farmers perceive risk, quantitative methods alone are inadequate to elucidate the complexity of risk perception (Renn, 2008; van Winsen et al., 2013).

I argue that there is a knowledge gap, one that requires a qualitative approach to understand and give a different perspective on the risks, uncertainties and social processes that influence farmer decision making about IWM and IPM. Grounded theory is one method appropriate to understand such complex social phenomena (Charmaz, 2006). The method can capture social dynamics to better understand an interviewee as a complex, changeable, socially embedded actor, making decisions on less than perfect information, and in an uncertain and shifting environment (Glaser & Strauss, 1967). It can reveal interviewees' views, feelings, intentions, and actions within the different contexts of their environment. The method lets you examine the 'why?' as well the what and how (Charmaz, 2006, 2014).
Thus the modified grounded theory I adapted allowed me to contextualise and understand the nuances of the social processes that facilitate farmer decision making. Grounded theorists, however, use data to construct inductive concepts with the goal to construct theory. In the realm of grounded theory research there is some ambiguity and debate over what constitutes a theory, which has led to arguments over whether grounded theorists have actually constructed theory and instead produced a study that is descriptive rather than theoretical (Charmaz, 2014; Salsali, Esmaeili, & Valiee, 2016). If a theory is produced, what form of theory? The definitions and type of theory can differ depending on your epistemological position such as positivist or interpretivist, or which form of grounded theory you are pursuing (Charmaz, 2014).

My broad aim was to understand the role of empowerment in farmer decision making about weeds and invertebrate management, and its implications for the engagement process between farmers and extension. Modified grounded theory was a good tool to achieve this. Concepts were treated analytically, but not used to construct a theory. Regardless my approach does aim to follow the constructivist grounded theory principle as it avoids advocating a single, true answer and opens up my findings for wider interpretation.

The use of any form of grounded theory appears uncommon in understanding technology transfer, extension and socio-cultural contexts of farmer decision making, but there are some examples and they influenced my decisions about method. A brief discussion on these is next.

4.3 Grounded theory in extension and technology transfer literature

There are good qualitative studies that explore what is happening in the process of adoption or technology transfer in agriculture and industry generally. The research specific to management of weeds and pests, however, is largely quantitative. For instance, it measures rates of adoption (de Buck, van Rijn, Roling, & Wossink, 2001), the variables involved in adoption (Llewellyn et al., 2007), and identifies factors that act as a barrier or facilitate adoption (D’Emden et al., 2008; Llewellyn et al., 2007; Parsa et al., 2014). Although, these quantitative methods provide valuable knowledge about adoption that give an insight into the what and how, there is minimal insight into the why that comes from examination of the complex human phenomena of farmer decision making about weeds and invertebrate management. The constructivist approach in this
research provided this perspective. For instance, I needed to know how farmers interpreted data, advice and information about IWM and IPM, what meaning did they place on it and how did it influence their decision making? How did they construct their knowledge about these management strategies? Initial research indicated that certain risk concepts relevant to weeds and invertebrate pests were also potentially important to explore. These included how farmers perceived risk and what understanding and meaning they had of the uncertainties, and how these affected decision making. Thus I needed a qualitative tool that could explore the human interaction with knowledge and the social process affecting that. This is a different approach from what has been taken to understand my research problem so far.

Research papers by Farmar-Bowers and Lane (2009) and van Winsen et al. (2013) helped confirm that grounded theory was an appropriate tool to achieve this. Farmar-Bowers and Lane (2009) used grounded theory to explain farmer decision-making about maintaining biodiversity on their farms. van Winsen, et al. (2013) used grounded theory to understand farmers' perception of risk. To further elucidate and strengthen their grounded theory analysis, van Winsen et al. used a form of cognitive mapping. They used interview data to construct cognitive maps to explicate and clarify the complex interrelations between diverse risk events perceived by farmers. This emphasises that alongside the quantitative methods, there exists varied qualitative research methods to generate a richer understanding of farmer decision making and risk perception. However, as noted, it was my personal ontological and epistemological position that helped form my research question, so too it influenced my selection of modified constructivist grounded theory as an appropriate research method.

I used a modified grounded theory approach to conceptualise farmer decision making about weed and invertebrate pest management and provide a more nuanced insight into the process of adoption of IWM and IPM.

The above outlines my journey to understand and define my research problem and question, and select an appropriate research method. The next step was to do the research. The process I undertook and the justification for each step are outlined in the next sections.
4.4 Research process

In adherence to the principles of constructivist grounded theory described by Charmaz (2006, 2014) my research was an iterative process continually switching between data collection, analysis and consultation of the literature to understand and clarify concepts emerging from the data. This meant continually questioning the data and my interpretation of it. It also meant taking care that my understanding or interpretation was supported by the data and not driven by the literature alone. The literature was used to compare with the data and help guide the research direction; it helped frame what I looked for, but not necessarily the answers that were found.

I used a combination of in-depth interview, observation and document analysis. The interviews involved conversations with five types of research participant:

- Broadacre farmers (male and female) that were either continual croppers (no livestock) or mixed livestock and cropping
- Scientists conducting research in areas specific to my research problem
- Agronomists that were either sales agronomists (often referred to as resellers), or independent. Sales agronomist worked for a local agricultural supply store that sold chemical, fertiliser and other farm supplies. Often the agronomy service was free if the farmer bought chemical or other inputs from the store, though some stores offered varied fee-for-service options. Independent agronomists operated independently of any store or connection to industry. They were full fee-for service.
- Research Agronomists whose predominant role is managing research projects and trials for farmer groups such as SFS and BCG. Some of these also operated as independent agronomy consultants.
- Farmers' partners. Partners were interviewed because the literature and personal experience emphasise partners not actively engaged as farmers, but acting more in a support role have a significant role on the farm that includes management decisions. I define farmers' partners further in chapter 5.

The following sections outline the various steps of my research process:

- ethics
- sampling strategy
- data collection
• the in-depth interview
• observation
• documents analysis
• data analysis
  * initial coding
  * focused coding
  * conceptualisation: concept coding
• memo writing
• theoretical sampling, data saturation

4.5 Ethics

Each component of the research process was approved through the ANU Human Research Ethics Committee. See Appendices A-C.

4.6 Sampling strategy

I used a combination of ways to gather a sample of farmers and agronomists to interview. I already knew some broadacre farmers and I asked them if they could ask any farmers they knew if they would be happy to participate in my research. I got them to ask their agronomist the same question. The farmers and agronomists interviewed through my initial contacts were asked the same question. Through this snowball strategy I reached a number of farmers and agronomists spread over three Victorian broadacre farming regions: Western Districts, Northern Wimmera and East Mallee. See Figure 3 below. The three different regions improved the credibility of the data through what Shenton (2004) calls site triangulation, which reduces the effects of any regional factors.

A second strategy I used was attending farmer professional development workshops run by the GRDC, BCG and SFS. At these events I was able to present an overview of my research and having made available a short survey, I asked farmers and agronomists at the event to complete the survey. The survey also asked whether they would be happy to participate in my research. Using the snowball strategy again, any farmers or agronomists that agreed to participate in an interview were asked if they were able to ask other farmers and agronomists they knew if they would be happy to participate in my research.
A third strategy involved placing the same short survey on Survey Monkey. I wrote a brief story about my research and asked readers to complete the survey. They could tick a box and supply contact details if they were also willing to be interviewed in a face-to-face interview. See Appendix A for the survey. The story and notification about the survey was sent out with different farmer group newsletters.

The scientists and research agronomists were selected based on the relevance of their research. Some of these I met at farmer and agronomist professional development workshops. As part of any conversation with them, I asked if they would be happy to be interviewed for my research. Others such as the research agronomists at SFS were approached through the organisation's CEO to ensure the CEO was happy with his/her staff participating in my research. I asked the CEO to nominate and then approach relevant staff. The SFS CEO let me know who was willing to participate and I then contacted them directly.

Farmers' partners in my research were all wives of male farmers. To gather data on farmers' partners, I attended a BCG Women's farming group meeting functioning under the banner of their Growth, Adoption, Productivity and Profitability (GAPP) project. I attended as an observer and engaged in discussion on topics raised during the meeting. I chatted to them as a group during the breaks and after the meeting. There were seven women at the meeting. One was a graduate agronomist. The other six could be described as farmers' wives (partners). I separately interviewed in more depth two of the women who attended the meeting. This was done by phone after the meeting, at times convenient to them.

All interviewees received a participant information sheet outlining the purpose of the research and my ethical obligations that included details about ensuring their privacy. They also signed a consent form agreeing to be interviewed and for the conversation to be recorded. See Appendix B and C.

In total I interviewed eight research agronomists, nine scientists, 11 agronomists (three independents, eight sales), one GRDC representative with expertise relevant to my research, one group of six farmers' wives, two individual farmers' wives, and 26 farmers. Two farmers were outside the three nominated cropping regions (Northern Wimmera, Western Districts and East Mallee). One was from the northern cropping
zone of Western Australia who received my survey through his networks and agreed to be interviewed. The second from southern NSW was introduced to me through one of the agronomists I interviewed. See Appendix D for full description of identification coding for each interviewee.

Figure 3 Map of the state of Victoria showing the three cropping districts where participant farmers and agronomists reside.

4.7 Data collection

My first step was to talk to the relevant scientists researching weeds and invertebrates, and research agronomists attached to farmer groups. These were spaced apart as each interview was transcribed and coded to see what ideas or concepts were emerging. Where a greater understanding of any concept was needed, I sought the relevant literature. This enabled more focused questions in the interviews that followed with farmers.

I read broadly the academic literature to get an insight into farmers, their motivations and to get some understanding of how they manage agronomic problems, such as salinity, chemical resistance and climate change. This process also helped identify knowledge gaps. I also attended farmer- and agronomist-targeted professional development workshops and seminars as an observer. I continued to attend these throughout the data collection and analysis phase. These initial events, interviews and reading gave me an understanding of the agronomic problems farmers faced. This was sufficient data to start interviewing farmers and agronomists, though here strict adherence to grounded theory method proved difficult.
The iterative process of grounded theory means that in principle once an interview is completed it is coded and ideas extracted that are further understood by searching the literature. As occurred with the initial interviews with scientists and research agronomists, that knowledge is then used to focus the research direction or follow up potential new directions. My constraint was the distance I had to travel to interview farmers and agronomists. This meant I had to arrange to interview them in small batches of 3-5 at a time over 1-3 days. There was no time to transcribe and code each interview before the next. There was, however, a chance for reflection between these interviews that meant I did ask new questions or seek greater detail on specific points made by the previous farmer or agronomist. Transcribing, coding and any analysis of literature occurred after returning home from each batch of interviews.

Audio of all interviews was recorded, except one where the equipment failed. All interviews were transcribed, a process that began my immersion into the data. It also allowed reflection on the interview experience and what was discussed. Where possible all interviews were done face-to-face. This was the case for all farmers except for the farmers in WA and southern NSW who were interviewed by Skype. Those interviewed face-to-face were interviewed at a location of their choice, which was always their farm and normally around the kitchen table over a cup of tea. In about one-third of farmer interviews other family members were present, usually the wife of the primary interviewee. In two of the interviews the husband and wife were interviewed together as they both worked full-time on the farm as farmers. The farmer's home helped create a less formal environment for the interview and ensured the interview quickly became a conversation. Each interview lasted between 1.5 and 2 hours, except for Farmer 18 who I caught between appointments. His interview lasted about one hour only.

All agronomists and research agronomists were also interviewed face-to-face, usually in their office. These interviews ran for a similar time to farmers. Most of the scientists were based interstate so they were interviewed over Skype. These interviews tended to be shorter, lasting about one hour.

There were 17 participants interviewed twice and some contacted a third time through email with one or two short questions. Any follow up interview was used to explore new avenues or to get a greater understanding on emerging concepts. I also used these interviews to clarify any ambiguities or confusion in the original interview. This
avoided potential misinterpretation about what was said and was an important part of the data validation. Most follow up interviews were done by phone, but still recorded.

Throughout the whole data collection process I collected and analysed farmer-targeted documents such as fact sheets, reports and training manuals relevant to my research. I coded the contents looking for key messages, their objectives and how they were framed. This data was continually compared with the interview and observation data.

The three methods of data collection are discussed in more detail next. The interview was the principal method of data collection.

4.8 The in-depth interview

The in-depth interview is one way to understand the meaning and significance people give to their actions (Jones, 2004). A constructivist interview attends to the interviewer-participant relationship as well as the content of the interview. The interview is where the interviewer begins to understand the experience of the participant, noting silences as well as what is said to build the picture of what is happening (Charmaz, 2014). Audio recording of the interview allowed me to recall the important nuances such as tone and humour. I captured the situational details that note taking would have missed. The face-to-face aspect let me experience things such as emotions during silences. The location, usually the farmer's kitchen, gave me further context to experiences of the farmer, for example, in a couple of houses we discussed photos on their wall of recent floods, or aerial shots of their property.

One constant issue with the interview where questions can be spontaneous and dependent on the conversation, is the challenge of asking important and specific questions without forcing responses (Charmaz, 2014). There were instances where I asked questions that produced a forced answer. I realised this either as I asked the question, or later during transcription. If I became aware this occurred in the interview I would try and ask the question again later in a different way. If I noted it during analysis, unless the answer was elaborated on and discussed in more depth, the data had to be ignored.
Observation and document analysis had a less significant role than the interview, but they provided important context to my interpretation of the data and in some cases helped validate it. They are discussed briefly next.

4.9 Observation

I observed a variety of events targeted at farmers and agronomists that could be loosely considered professional development. They ranged from formal conferences with seminars and speakers, to informal crop walks organised by the local farmer groups where farmers would visit trial crop sites and discuss what they saw with the farmer group representatives and coordinators of the trial. I also participated in two webinars on weed management run by AHRI. For each observational event, I noted the objective of the event and took notes on who attended and the conversations I listened to or participated in. These were coded similar to interview data.

4.10 Document analysis

Documents can provide key data (Charmaz, 2014; Glaser & Strauss, 1967). I analysed a number of farmer-targeted documents that included fact sheets, information manuals on IWM and reports. The authors of these documents were the GRDC, AHRI, CESAR and the farmer groups such as SFS and BCG. I also analysed media articles from the agricultural media, for example The Weekly Times and The Land.

I examined these documents to find answers to all or some of the following questions, depending on the document, to add context to their content: Where does the data in them come from, who are the authors and what is their objective for the document, and who is the intended audience? For each document, I examined the messages it conveyed and how they were framed, and how this compared with what emerged from the interview and observational data. I also asked the intended audiences (farmers and agronomists) how they interpreted the messages in the documents, at least the documents and messages they were aware of.

Although the process of data analysis described below appears as an uninterrupted process, as noted already, it occurs in conjunction with data collection and review of literature.
4.11 Data analysis

As I am guided by constructivist grounded theory, my analysis of the data involved three main phases: initial coding, focused coding and what Charmaz (2014) calls theoretical coding. I refer to this latter phase as concept coding, but the purpose and principles are the same, and it is where the more abstract concepts emerge from the analysis of the focused codes. Coding is where I started to make analytical sense of participants' stories, the observations and content of any documents. The three phases are discussed below.

A constant throughout all three analysis phases is close interaction with or immersion in my data. This involved comparing data with data and codes with codes. It revealed similarities and differences within and between participant data and codes. I constantly compared data and initial coding throughout a single transcript and with other transcripts. I did this across all three coding phases. This constant comparison is part of the grounded theory method described by Glaser and Strauss (1967) and forms the basis of any version of grounded theory. From the process emerged new analytic questions, new research directions to pursue and it later allowed the conceptualisation of my data.

NVivo was used to manage transcripts and the focused coding and concepts. The software was used as a searchable database rather than an analytical tool. All analysis was done manually.

**Initial coding.**

As soon as possible after each initial interview I wrote a short memo describing the property, the interview location, my thoughts on the engagement and what it achieved, and a description of those I interviewed. This often helped me engage with the initial coding later on.

In the initial coding of participant interviews the transcripts were broken into fragments that could have been single words, whole lines or ideas, depending on their analytic importance.

Initial coding, through the use of gerunds, describes actions and reveals meaning where it is evident. I would analyse a word, then a line or sentence, then the idea or thought
evident in the transcript. I would then go back and ask the question, what is happening here? Sometimes the initial code would apply to the word. More often it would apply to the sentence or thought/idea. At this stage, each code was flexible and refined as comparison across data and codes progressed.

Following direction from Charmaz (2014), throughout the process of initial coding I sought analytic ideas to pursue, some of which went onto to become concepts. Others went no further than the initial coding but I coded everything in an attempt to remain open to any direction the research might lead. Table 1 shows an example of how I did initial coding for an interview.

Table 1 A Portion of Farmer 20's Transcript and its Initial Coding

<table>
<thead>
<tr>
<th>Coding - Initial</th>
<th>Transcript Farmer 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part of long family history on property</td>
<td>F-20: I am 7th generation on this place, right here in this house</td>
</tr>
<tr>
<td>Being the 7th generation farmer on theproperty</td>
<td>We used to be mainly sheep about 3500-4000 sheep.</td>
</tr>
<tr>
<td>Living in same house that grandparents lived in</td>
<td>Dad was always into cropping...dad and I always really disliked sheep.</td>
</tr>
<tr>
<td>Liking cropping, disliking sheep</td>
<td>We started cropping in Pa's generation, then got bigger and bigger</td>
</tr>
<tr>
<td>Building cropping business from Grandfather's time</td>
<td>We only run Merino wethers - buy young wethers in, keep them for wool until they</td>
</tr>
<tr>
<td>Running Merino wethers for wool</td>
<td>are 4-5 years old, then off to the abattoirs</td>
</tr>
<tr>
<td>Continuously cropping for 35 years</td>
<td>ME: Given the family history on this place tell me a bit about what this place means</td>
</tr>
<tr>
<td>Living for farming</td>
<td>for you?</td>
</tr>
<tr>
<td>Growing up with farming</td>
<td>F-20: We have been continuously cropping now since 1979. it is what I have grown</td>
</tr>
<tr>
<td>Having strong attachment to home farm</td>
<td>up with and what I know, what I live for</td>
</tr>
<tr>
<td>Enjoying being a farmer, enjoying the outdoors</td>
<td>ME: describe what it means to be a farmer - the significance of being a farmer?</td>
</tr>
<tr>
<td>Enjoying maths</td>
<td>F-20: Just being outside...I dislike bookwork, though I do like maths, I like</td>
</tr>
<tr>
<td>Enjoying challenge and working out problems</td>
<td>sitting down and working a problem out</td>
</tr>
</tbody>
</table>

Notes: Note the use of gerunds to emphasise actions and reveal meaning.

Once initial coding of an interview or batch of interviews was complete I moved onto the second phase, focused coding.
Focused coding.

Using constant comparison of data, this is where I began the process of filtering the initial codes to find those making analytical sense. It is where I began to conceptualise the data; it is the phase that revealed new and more defined directions for my research. New directions and more focused questions were explored in subsequent interviews and the process of transcribing initial and focused coding repeated. Throughout this process there was a need to go to the literature to increase my depth of knowledge. While this provided important contextual knowledge, it also established where a sound knowledge already existed, or if there were knowledge gaps worth investigating.

More than one focused code could be generated from an initial code depending on the potential for multiple interpretations of an action. For example, the initial code, 'Enjoying being a farmer, enjoying the work' generated the focused codes, 'Freedom' and 'Vocation-cultural'. See Table 2.

Constant comparison meant focused codes were continually refined throughout the analysis process.

Table 2 A Portion of Farmer 20's Transcript and its Initial and Focused Coding

<table>
<thead>
<tr>
<th>Coding - Initial and [Focused] codes</th>
<th>Transcript Farmer 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part of long family history on property</td>
<td>F-20: I am 7th generation on this place, right here in this house...</td>
</tr>
<tr>
<td>Living in same house that grandparents lived in</td>
<td>ME: Given the family history on this place tell me a bit about what this place means for you?</td>
</tr>
<tr>
<td>[Land attachment]</td>
<td></td>
</tr>
<tr>
<td>Continuous cropping for 35 years</td>
<td>F-20: We have been continuously cropping now since 1979, it is what I have grown up with and what I know, what I live for</td>
</tr>
<tr>
<td>Living for farming</td>
<td></td>
</tr>
<tr>
<td>Growing up with farming</td>
<td></td>
</tr>
<tr>
<td>Having strong attachment to home farm</td>
<td></td>
</tr>
<tr>
<td>[Vocation-cultural] [Land attachment]</td>
<td></td>
</tr>
<tr>
<td>Enjoying being a farmer. Enjoying the work [Freedom] [Vocation-cultural]</td>
<td></td>
</tr>
<tr>
<td>Enjoying maths</td>
<td></td>
</tr>
<tr>
<td>Notes: Focused code are those in [bold]</td>
<td></td>
</tr>
</tbody>
</table>
**Conceptualisation: Concept Coding.**

Charmaz (2014) calls this phase, Theoretical Coding, and defines its purpose as an aid to theorising the data and focused codes. The codes help tell a coherent analytic story and conceptualise the relationship between the focused codes, but they do not replace the focused codes (Charmaz, 2014).

I am using modified grounded theory. I have not set out to construct a theory, but I am using the principles of grounded theory to understand my research problem and find answers to my research question. Because of this I refer to this analysis phase as Concept Coding and I used it to find and understand the relationships between the focused codes, and establish important concepts that underpinned my understanding of the research problem. It was in this phase that importance of farmer empowerment and its relationship to farmer knowledge construction and decision making began to become apparent. Consequently, it was early in this phase of my research that I formulated my research question.

My concepts and their relationships emerged from an immersion in the data and with the focused codes. It also required considerable reflection on what was already understood about these concepts in the literature. For instance farmer empowerment first emerged as a focused code, but its significance was unclear and farmers and agronomists presented conflicting messages about its role. At this stage, my research raised questions such as, were farmers in need of empowerment or were they empowered and, if so, which farmers and in what circumstances? I went to the literature to understand the philosophical context of empowerment, what understanding was there of this notion, especially in regard to farmers, extension and technology transfer. I sought insight into the relationship, if any, between empowerment and other codes such as networking, the various forms of trust, or legacy and empire building. I asked further questions such as, what did these relationships mean for the farmer and their decision making, and their interpretation of scientific data or advice? There was significant reading of the literature, further interviews and immersion in the transcripts, and reflection during this phase. Empowerment and its significance eventually emerged as a concept that became central to the argument of this thesis.
Further to the coding was the concept of memo writing that was a continual, but important process that allowed me to play with data, clarify and define concepts, and help show me which concepts to eliminate or elevate in importance.

4.12 Memo writing

Memo writing is an integral part of grounded theory. Memos are informal, analytic notes that describe thoughts about your codes and data and might be considered a fourth analytic phase (Charmaz, 2014). I started writing memos when the more prominent focused codes became apparent. I used them to explicate these codes and compare them between other data and codes and later concepts. It is where I asked questions of the data and identified analysis gaps. I used them to analyse and track the evolution of the codes and concepts, how they refined and defined themselves. They were a continual work in progress. In addition to my diary, they became a record of my research.

Table 3 contains selected portions of a memo I wrote for gut feel and its role in farmer decision making. It includes my thoughts on its definition based on how farmers and the literature perceive it, my understanding of how farmers use or rely on gut feel, the problems I struggled with and the questions I needed to explore to try and understand them, and how gut feel might relate to other codes. Initially, gut feel emerged as a significant code and a potential concept, but in the process of conceptualisation (concept coding), it simply became a one of many heuristics supporting the core concepts.

Table 3 A selected section from the Gut Feel Memo

<table>
<thead>
<tr>
<th>Memo: Gut feel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Define gut feel:</td>
</tr>
<tr>
<td>&quot;It is experience,&quot; (F-4 Peter Martin).</td>
</tr>
<tr>
<td>A concept I have termed as the, &quot;you just know&quot; and is largely developed from experiences. Gut feel builds self-belief. The more experience one has in a situation the stronger the gut feel and greater self-belief/confidence one has in their gut feel.</td>
</tr>
<tr>
<td>Or as F-9 says, &quot;When you have your discussions (with agronomist) and you are working out your rotations you have your own gut feel about ..I suppose your gut feel is your experience and retained knowledge over the years,</td>
</tr>
<tr>
<td><strong>Gut feel, tacit knowledge, intuition</strong></td>
</tr>
<tr>
<td>From Brockmann and Simmonds (1997): Tacit knowledge is defined as work-related practical knowhow that is learned informally on the job; it is manifest by people knowing more than they can tell. It is sometimes associated with intuition, which is defined as choice made without formal analysis (Behling and Eckel, 1991).</td>
</tr>
</tbody>
</table>
There appears to be a battle between gut feel and analytic reasoning. This can be conscious or sub-conscious. Both have important roles in decision making but how much one dominates seems to depend on the circumstances which include the following:
- The farmer's experience of the issue, technology or situation
- How complex the issue is
- How immediate the problem is. Is it something that needs to be dealt with now or can the decision be made somewhere into the future?
- The risk attached to the problem. What is the risk? ie what is at stake here?

Gut feel has a role in every situation, I think, though it seems the more complex the problem, and the more that is at stake (ie the more money to be spent or greater the risk) the slower and more analytical the decision making becomes -unsure about this. Need to dig deeper?? In unfamiliar situations and where the risk is high, farmers may consciously try as much as possible to quantify their decision with data and reasoned analysis, thus leaving minimal space for gut feel, but only where that data or analysis exists or is accessible to the farmer, physically and psychologically.

Where reasoned, or quantified data is lacking or where risk is poorly communicated a farmer is left with gut feel (Research Agronomist).

Gut feel and on-farm trials - link between them
ME: So how do you weigh up whether his (agronomist) ideas are worth having a go at?
F-22(1): We have a go at it, and it ...at this stage most of his ideas are working.

With weeds and HR specifically, given HR's increasing prevalence and our understanding of it, does the complexity of the issue mean that farmers make less room for gut feel? There tends to be a lot of reliance on and trust in agro advice regarding chemical use and rotation.

### 4.13 Theoretical sampling, data saturation

I used the process of theoretical sampling to consolidate my concepts and their components. It meant examining what, at this stage, were tentative concepts, identifying the ambiguities, unknowns or assumptions and heading back to the field for further interviews. At this stage most of these were follow up interviews, though it included new interviews with two farmers and two agronomists as part of this process.

As a key process of grounded theory, the aim of this phase is to gather the required data to elaborate and refine my concepts and their properties (Charmaz, 2014; Glaser & Strauss, 1967). This was done until no new properties emerged from incoming data. When this occurred, the data was considered saturated (Charmaz, 2014; Corbin & Strauss, 2008). But as noted by Charmaz (2014) theoretical sampling in grounded theory is strategic and specific with the purpose of elaborating, refining and consolidating core concepts. I asked focused questions rather than the more broad open
questions of the initial interviews. New data was coded and comparative analysis done. I conducted theoretical sampling to develop the properties in each of my key concepts to ensure I understood their varied forms and their relationship with other properties and other concepts. It was also one of the ways for me to validate my interpretation of the data. Much of this occurred through a process of abductive reasoning (see Charmaz, 2014). This was the process I undertook to test my theories that I thought explained my observations and interpretation of them, and clarify anything I couldn't explain or articulate because of incomplete data. In conjunction with data from additional interviews, this again involved considerable re-examination of the existing data, including documents, and reflection to establish useful explanations of what was happening.

Thus theoretical sampling as I conducted it helped consolidate the properties of the core concepts and revealed and clarified the relationships between them and other concepts and their properties. It connected together the previously disparate parts of my research story that is my research question.

4.14 Introducing the analysis

As part of the theoretical sampling process I compared the core concepts and tested their relationships to each other. I modelled this visually through diagrams. Figure 4 below is the final model that outlines the key relationships between empowerment and its related concepts.

Empowerment emerged first as a focused code, but it took time for its role and significance to clarify. Some agronomists and the objectives cited in research data portrayed empowerment as something that farmers required, and that it was the job of research and extension to empower farmers. Although early data from some farmers implied that this may indeed be the case, it appeared to contradict what other farmers said. It was not until I focused in on this emerging concept and gathered more in-depth data from further interviews and a search of the literature that the significance of empowerment for farmers' knowledge construction and decision making became apparent.

The role of empowerment and power form the central argument of this thesis, a role that facilitates farmers' ability to construct knowledge, make informed decisions, and
interpret risk and uncertainty (chapter 5). Emerging from the data also were the following core concepts that supported and facilitated empowerment (chapter 6).

- Social capital (networking and trust)
- Let the innovators innovate (Farmer trialling and innovation)
- Long and short-term thinking. This examines the relative nature of long-term as a concept and how it affects farmers' strategies to manage weeds and invertebrates. I examine also the link between this core concept and the coded concepts, Attachment to land, Empire building and Legacy.

Within each concept, the influence of heuristics such as worldviews, values, attitude and gut feel was apparent and, to varying degrees, influenced knowledge construction.

**Figure 4 A model of farmers' decision making about IPM and IWM where the core theme is empowerment**

The following chapters, (5-7), are the data analysis. Empowerment is the core theme that is key to nearly all other findings in this research. The next chapter analyses the evidence for this.
5. The role of empowerment and power

Overview

People are not empowered in all situations, but a person may choose the circumstances where empowerment is important or necessary (Roberts & Coutts, 2007). I argue that when it comes to agronomic and many other farm management decisions all farmers participating in my research are empowered, though in different ways. That is, empowerment is defined by a number of elements. Unique to each farmer and context, one or more of these elements can operate with variable influence. Regardless, empowerment is a powerful motivator and facilitator of their knowledge construction and decision making. These actions do not happen in isolation. They occur within complex power-knowledge relations. The intimate link between power and knowledge mean any construction of farmer knowledge is reliant on farmer relationships and vice versa.

My research question is, how does empowerment affect farmer decision making about weed and invertebrate pest management? In this chapter, I first define empowerment and power. I then examine the evidence of farmer empowerment and its effect on power-knowledge relations, knowledge construction and decision making. To do this, I asked the following questions of the data: what is the nature and significance of these power-knowledge relations, how do they influence farmers' knowledge construction and decision making and consequently, their state of empowerment?

I analyse also the agronomists' and research agronomists' perspective on their relationships with farmers and the effect of these relationships on farmer empowerment and decision making. Farmers' partners, in this case their wives, are also considered as they appeared integral to many decisions on the farm. I make a distinction, which I describe in more detail later in this chapter, between these women ('Women on the farm') and female farmers. There were two female farmers in my research.

In presenting the analysis, I provide a cross section of farmer and agronomist attitudes and the differing contexts to which they apply. A broader picture of the role of empowerment and the power-knowledge relations in farmer decision making emerges in chapters 6 and 7.
5.1 Defining empowerment

Empowerment is an abstract concept that farmers in my research didn't mention explicitly, but they did talk about maintaining control and ownership of any decision, and carrying the burden of risk. They also discussed their process of analysis and reflection in any decisions making. These concepts, evident in the farmers' comments below, form the basis of how I define empowerment. They are also relevant to understanding power-knowledge relations discussed in the next section.

F-2: ...once you have that independent advice, the information is yours and you are more in control of your situation. You are not just at the bottom of the food chain waiting for all these so called experts to hand out info...
All the time we are faced with these complex decisions...At the end of the day it is the farmer who carries the risk.

F-9: You get a recommendation and you have got to have an understanding of it all and agree with the path you are going on.

F-23: So how do I do this (make good decisions), I mix with who I think are the best operators and I refine that in my own mind.

To define empowerment, I align the concepts of empowerment apparent in the farmers' comments with the relevant theory discussed in the literature. Bartlett (2008) describes three elements that underpin what he calls intrinsic or true empowerment (see chapter 2). I use two of these, 'Agency' and 'Ends'. Bartlett's third element, 'Means', includes a farmer's rights, access to and availability of resources (physical and social), capabilities and opportunities. Bartlett uses Means in the context of farmers in developing nations. Australian broadacre farmers, as part of a developed nation, cover diverse geographical regions. Some are considered remote, others such as some of Victoria's Western District farmers are less than an hour from the city of Geelong, with major health, education and port facilities. Thus while Means is still relevant in that not all farmers have equal rights or equal access to resources and opportunities, it is questionable how comparable the farmers in Bartlett's study would be with those in a developed nation such as Australia. For instance, I would argue that most Australian farmers (if not all) have better access to education, transport, technologies, and markets (as far as global markets, regulations and political agreements allow) than developing nation farmers. In this sense, Australian farmers have greater capacity for empowerment. What is more important in this research is how farmers access and use such resources and the motivations for doing so,
and this is where the elements of Agency and Ends become relevant. I use them as evidence of empowerment and describe them below.

Agency is the capacity to make choices, to analyse, make decisions and act, which must be all self-directed. It is also the meaning and purpose behind such actions (see Bartlett, 2008; Kabeer, 2001). I break it down to the following components:

- analysis, critique;
- reflection;
- self direction (self-defined objectives, action and evaluation).

Ends is people taking control of their lives. I use just the one identifying component below:

- control (self-defined choice, ownership of decision).

Nettle et al. (2015) complement these components in their research that examines how well research and extension engage with dairy farmers to support their empowerment and adaptability. They constructed a framework containing components that reflect farmers' empowerment and adaptability. Those relevant to empowerment include self efficacy, participation in and creating new networks, managing risk, and motivation for learning and adapting. Each of these components is reflected in those of Bartlett (2008) and Kabeer (2001) and in the foundations of empowerment analysed in chapter 6.

There are competing discourses among those trying to define empowerment (see Bartlett, 2008; Kabeer, 2001; Roling & van de Fliert, 1994). For instance, Bartlett's (2008) instrumental discourse is where farmers are given a greater role in research projects, but it occurs within project boundaries defined by others. This constrains Bartlett and Kabeer's concept of Agency and is not what Bartlett considers true empowerment. Because it has relevance to the evidence emerging in my data it is described here briefly.

The following components of the instrumental discourse are relevant to my data:

- boundaries are defined by science or 'experts' and outcomes are predictable;
- participation involves farmers given a role, but they lack control of the agenda and objectives. The objective is to empower farmers.
5.2 Understanding power

In my research, power-knowledge dynamics vary for each farmer relationship, but evident in all relationships that concern weed and invertebrate management is farmers' autonomy and attempts to construct knowledge. The dominant relationship for the farmer is with their agronomist, but those with other farmers, scientists, community members and family are also important. The following farmer comments all discuss their relationship with their agronomist. Evident are the concepts of autonomy and knowledge construction through farmers’ choice to seek an agronomist for advice, yet still have control over how that advice is interpreted and used to construct knowledge.

F-2: You respect that the agro comes in with more experience and knowledge than you, but at the end of the day the farmer makes the end decision and spends the dollars.

F-4: I do not query the cost of having a so called expert in their field to come and help me with my decisions, but to give me the info...It is always my decision in the end.

F-20: We have an agreement that he [agronomist] is here to help us not tell us what to do. We are still managing the farm.

F-1: I have a great relationship with my agronomist. He'll look after the chemical... I plan the rotation, what I want, where I want it...but if I get a new bloke in I will question his advice with greater scrutiny.

In chapter 2, I described two broad conceptualisations of power. One is a resource-based model where power is authoritative or coercive and exists via the means or resources that enable someone to meet their objective. The second, and the one that fits best with how I interpret my data, says that power exists through relationships. Knowledge and power are inextricably linked such that the relationship cannot exist without the relevant production of knowledge (Foucault & Gordon, 1980). Central to this concept of power is the ability to choose. This is autonomy.

I use the elements of autonomy and knowledge construction described below to interpret and explain the complex interactions of farmers' power-knowledge relations and their association with empowerment and farmer decision making.

- **Autonomy**: Farmers act as autonomous agents of power to construct knowledge. They display choice, discretion and critical thinking.
- **Knowledge construction**: This is where farmers filter and interpret competing knowledges. The knowledge may be co-constructed but it is largely constructed by farmers through the interconnected relations and farmers' varied and negotiated interpretations of meaning.

Despite my greater reliance on Foucault's conceptualisation of power to explain my data, some elements of Weber's resource-based model, where power is considered either authoritative or coercive, are also applicable. Authority must be legitimate, but while those with perceived authority may claim compliance from those subject to their authority, legitimacy is the acceptance of that claim (Uphoff 1989). Power itself is considered abstract. It cannot be possessed. What is possessed is the means or resources that those in authority use to achieve their objective (Simon and Oakes 2006). Two resources emerged as important in my data and provide context to my argument. They are Legitimacy and Expertise and are described briefly below (see Heizmann & Olsson, 2015; Raven, 1992). For a more detailed discussion see chapter 8.

- **Legitimacy**: where the role of the person affords them some authority or respect;
- **Expertise**: where the person possesses knowledge or skill considered valuable.

The rest of this chapter uses the above definitions of empowerment and power to analyse and interpret my interview data and begin to understand the role of empowerment in farmer decision making.

**5.3 Finding farmer empowerment**

Empowerment has an intimate link to power and knowledge as the state of empowerment itself influences the dynamics of power-knowledge relations and how the knowledge is constructed. Conversely, it is the knowledge constructed by the farmer in these relations that helps facilitate and maintain that state of empowerment. This section will explore the evidence for farmer empowerment and how power-knowledge relations underpin and facilitate that empowerment. This section also shows that the different elements that define empowerment are not all apparent or operating together in any one context. For example, a farmer may be empowered when he or she exhibits control, but analysis and reflection may not be evident, at least not overtly. The level of control may vary also, but there is still choice and ownership of decisions. Each context for each
farmer is unique. Appendix E provides a broader overview of the variety of farmer comments indicative of farmers' empowerment and the significance of power-knowledge relations.

The intimate link between power and empowerment meant that elements of both concepts can be reflected in a single participant comment. For example, Farmer 4 below exhibits agency when he seeks expert advice, yet does not passively accept it. It is actively analysed and reflected on. He exhibits autonomy and control when he says he needs to understand the agronomist's position and reason for his decision. It is Farmer 4 who decides how the agronomist's advice will be interpreted and used.

F-4: But I know my paddock and I can say yes, it will be this [issue]...The agro will suggest something and I will ask why am I doing that and not this...He [agronomist] is the expert, he has the training and the knowledge, but you need to know where he is coming from, what reasons he has for recommending a course of action. If a young agro still on a learning curve gave me the advice, I might question him more, or give him the benefit of the doubt just to see how his advice worked.

Because of the overlap of the defining elements of power and empowerment, I analyse farmer and agronomist comments under the following elements: Analysis, reflection; Self direction; Control; Autonomy, Knowledge construction; and Power and the agronomist. Most farmers interviewed were men. Two were women. Farmers' partners/wives ("Women on the farm") are also an integral part of the farm and form complex partnerships on and off the farm. This raises the question of who is empowered on the farm and where do farmers' wives/partners fit into the power-knowledge relations? For this reason their significance and state of empowerment is examined.

Analysis, reflection.

Empowerment means farmers ensure they are in a position to analyse and critique any advice or information they receive or seek. A number of farmers' comments, such as Farmer 2's above, suggest that to be otherwise makes you vulnerable and exploitable – disempowered. There were rare and isolated comments that portrayed farmers in my sample as passive recipients of information, that they afforded power to another party. This perception changes when the comments are put into the context of the entire conversation.
For instance, Farmer 12 is typical of how most farmers in my research sample approach farm chemical use. Knowledge about farm chemicals is an expertise they do not have the time or the inclination to keep up with. In isolation Farmer 12's comment, "the sprayer does not go into a paddock without talking to the agro" implies he devolves "expert" power to the agronomist. Yet Farmer 12 still has oversight that involves analysis and reflection. He needs to walk the paddocks with the agronomist, point out identified problems and discuss potential actions. He also evaluates the advice through benchmarking his property against others. Such evaluation is indicative of self-direction (agency).

F-12: The sprayer does not go into a paddock without talking to the agro[nomist] beforehand. This is just to get a handle on the rates, sprays, etc...the herbicides are more about him [agronomist]...Most times I will go around the paddocks with him to have a look and we'll talk about what has to be done. If there are any issues I will bring them up and he'll adjust herbicide recommendations accordingly...I guess if you are getting the results in the paddock; you are seeing what other people are doing and if you feel like you are up with them. I know a lot of the other clients he has and they are all good farmers.

Farmer 1 relies on his agronomist to manage the chemicals. Again there is apparent devolvement of power. When in context, though the power isn't so much afforded, it exists because of and through his relationship with the agronomist that involves trust (see chapter 6.1). There is still oversight (analysis, reflection) and control. It is not disempowerment.

F-1: I have a great relationship with my agronomist. He'll look after the chemical... I plan the rotation, what I want, where I want it and this will be for a lot of reasons... but if I get a new bloke in I will question his advice with greater scrutiny...He will need to justify his advice. I will do the same for the regular agronomist, but it is more because I want to learn more about all this.

When considered in the context of the whole interview, no farmer in my sample appeared to afford power in any way reflective of the resource-based model. The farmers in my sample actively seek expertise and information, but there is agency and autonomy. They analyse and reflect on advice and information to help construct knowledge. From the farmer's perspective, there is no apparent domination, no authority as portrayed in the resource-based power model.
This analysis and reflection happens with advice from independent or fee for service agronomists (Farmers 2 and 9), or from any considered expert (Farmer 23).

Farmer 2 chooses to use independent agronomist advice, and although highly valued, he will still critique this advice, which he then uses at his discretion (reflection, autonomy). Any decision he makes based on knowledge constructed from that and other advice is his own.

F-2: He [agronomist] has a feel for how I like to operate and what crops I like to grow...There is always that robust discussion and I respect his opinion...You always have to question it [agronomist's advice]. You respect that the agro comes in with more experience and knowledge than you, but at the end of the day the farmer makes the end decision and spends the dollars... That is the beauty of independent advice, you can use it at your discretion.

In his relationship with his agronomist, Farmer 2 makes apparent his self direction, control, autonomy and knowledge construction. He knows how he wants to manage his farm system; he displays choice and discretion about how and when to use advice or information, selecting the appropriate bits to help construct knowledge and make an informed decision, a decision he owns and takes responsibility for.

Further, nearly all farmers expressed the need to have an understanding of a situation, to have background knowledge on what is happening to put them in a better position to question, analyse and reflect on any advice. Farmer 9 is explicit in this need. There is no passive acceptance of advice from his agronomist; there is oversight involving critique and reflection and where necessary rejection of advice, traits that are also indicative of control and autonomy.

F-9: You get a recommendation and you have got to have an understanding of it all and agree with the path you are going on because if the agro[nomist] is recommending something and you are thinking no, no that is not right, you have to go and restart what you are looking at again.

Finally, analysis and reflection is not restricted to advice from the agronomist. There are competing knowledges from different relationships. Like all farmers in my research, Farmer 23 will seek out, analyse and reflect on selected advice from those with valued expertise or experience. He filters and weighs this advice up against other factors such
as values and gut feel. Again, there is no apparent evidence of domination or acceptance of a legitimate authority.

F-23: So how do I do this [make good decisions], I mix with good people, mix with who I think are the best operators and I refine that in my own mind.

**Self direction.**

A need to make a living and constraints such as debt will influence farmers' decision making (Brodt, Klonsky, & Tourte, 2006). Influential also for the farmers in my research are their self-defined objectives for the farm. Advice, once analysed and reflected upon, must be compatible with these objectives, for example see legacy and empire building, and valuing natural systems in chapter 6.2. This emphasises empowerment's effect beyond agronomic decisions and that certain agronomic decisions, especially those requiring long-term investment or planning, or where there is risk and uncertainty, need to be compatible with farmers' objectives for the family, farm system and farm business.

For example, Farmer 2's self-defined objectives, based around empire building and legacy, help guide his management decisions.

F-2: You are buying that land so that you or your family will farm it for another 20, 30 or 50 years.... If you look at the big picture side of it and you have livestock in the system and you try and keep things in balance and perspective and manage things a bit better for the long-term. And that is my way of looking at it rather than just trying to kick as many goals as we can.

By defining his objectives, he exhibits choice. To achieve these objectives requires ongoing evaluation of decisions and their implications, making adjustments where necessary. Such actions define agency. Farmer 2 is assessing the immediate risk on things such as the short-term profitability, but also the risk to his longer-term objectives. It requires analysis and constant evaluations to ensure any decisions align with his objectives. They are risks he manages and accepts the responsibility for (control).

F-2: But I like to farm the way I do...I have to be comfortable with what is going on in my farm. It is a choice and the way we choose to do stuff I guess...What is the long-term return for that? How much extra can I earn by investing that money? All the time we are faced with these complex decisions...At the end of the day it is the farmer who carries the risk.
Farmer 5 uses an independent agronomist and, with the exception of herbicide advice, is selective about how he uses his advice. His values and attitudes affect how he interprets such advice and what meaning it has for him (see Wynne, 1992a). His following two comments also illustrate how his values and attitudes help define his objectives for his farm system.

F-5: It is like all things, you get advice, but sometimes you have to nut it out and make adjustments to your own situation...you have got to make adjustments all the time anyway to suit your own needs.

Farmer 5 does not have strong emotional ties to the farm, despite the farm being in the family for a number of generations, but he does place a high value on the natural systems, and in most circumstances, refuses to use insecticide unless necessary, despite agronomist recommendations to the contrary.

F-5: [I] probably try and keep a bit of balance in life on the farm with the ecosystem. I have even thought about fencing off little areas and putting in millet and getting quail breeding and let them run through the crop because they are good bug eaters.

ResAg-8 has a perspective compatible with my interpretation of how farmers' self-defined objectives facilitate empowerment. ResAg-8 became disillusioned with programs funded by agricultural research organisations that had specific defined objectives and desired outcomes. According to him, they were too didactic in nature and less inclined to engage with farmers on what he considered important problems (see comment below). I have included ResAg-8's perspective of such programs here because it reflects the instrumental discourse described by Bartlett (2008) where project boundaries are defined by others, and the objective is to transfer knowledge and empower farmers. There is no attempt to establish a relationship as such, only a one-way transfer of knowledge. It reflects also the deficit model that has continually been revealed as inappropriate in complex contexts (see Potter & Oster, 2008; Wynne, 2006).

Although educational programs that deliver information with a desired outcome can serve an important purpose, ResAg-8 is explicit in his discomfort with their design and purpose. His preference for an engagement program is more aligned with letting farmers define the problem and create a discussion that can lead to any number of potential solutions. Roling and van de Fliert (1994) too talk about farmers being empowered when they rely on their own judgement and observation. They talk also about the need
for a paradigm shift that requires an understanding of farmers' learning paths and finding ways to facilitate these.

ResAg-8 also describes building a relationship with farmers where power and knowledge generate discourse (Foucault & Gordon, 1980; Schirato et al., 2012), one based on outcomes defined by all actors in the relationship. He does not appear to imply power exists as some form of authority (see Weber, 2009). ResAg-8's description of this form of relationship reflects Bartlett's intrinsic discourse where empowerment occurs when agency is generalised and relationships change, and the consequences of such changes become unpredictable (Bartlett, 2008). Because I argue that farmers are empowered and have autonomy, the intrinsic model is more compatible with the evidence emerging from my data.

ResAg-8: All those organisations want an outcome and the outcome is, I want you to learn how to condition score sheep [method to estimate animal's condition] for the money we will give you. And this is why I stopped doing Best Wool groups because it became far too focused on a learning objective rather than the innovation of ...[where] I have no idea of what we are going to end up talking about at the end of it.

**Control.**

"It is always my decision" (Farmer 4). Similar sentiments were reflected in many farmer comments where it was apparent they were in control of the advice they sought and from whom.

Control is also evident in the way farmers in this research used their agronomist's or similar expert advice to inform their decisions rather than accepting it as a form of decision made for them. Thus, through analysis and reflection on agronomists' and other competing knowledges farmers construct knowledge, then make and have ownership of any decision (control). Farmer 5 (below) seeks information, advice or opinion, but he has control over where that advice and information comes from. Advice is actively sought, rather than passively received. Farmers' interpretation of that information will determine its value and meaning, which he or she will use to help construct knowledge and make decisions compatible with their objectives. Such knowledge and any decision made on the basis of that knowledge is owned by the farmer.
F-5: So you get the best advice then you make a decision on that advice. You will select the bits that work for me and find ways around other things.

With a similar sentiment, Farmer 6 exhibits control through his acceptance of his agronomist's advice, but interpreting it according to his management objectives (choice) and need to own and be responsible for his decisions.

F-6: But that is something with an agronomist, we shouldn't rely on them. We are still managers and the agronomist gives you advice on your ideas or they can introduce new ideas, but they are not your manager...With all due respect to any agro[nomist] we are responsible for our stuff aren't we.

**Autonomy, knowledge construction.**

Farmers in my research sample show discretion in who they seek information from, they think critically about any information or advice and they show discretion in how they use it. They weigh this up against other competing knowledges and their own gut feel and values to inform their decision making.

The following farmers are indicative of all farmers in my research who exhibited autonomy, at least when discussing weed and invertebrate management. Their autonomy is expressed through their selection of expertise, the value they give it and its use to construct their own knowledge and inform their decisions.

Farmer 23, (mid-40s) is reflecting on when he first returned to the farm. He acknowledges his lack of skills in specific areas, and in this early learning phase he actively sought data through selected knowledge networks. He weighed up this varied advice against his existing knowledge. One of his key objectives is good decision making that he hopes will translate into a more profitable and robust business. He displays agency through his self-defined objectives, and his analysis of and reflection on the information he gathers. His empowerment affects and is defined through his power-knowledge relations.

F-23: So how do I do this [make good decisions], I mix with good people, mix with who I think are the best operators and I refine that in my own mind. How do I do that, one of them is getting involved in this benchmarking group, another was getting tied up with the field days...so I worked really hard on those networks.
Farmer 14 has been assessing the data and worth of soil moisture probes in his region and perceives they can help with his weed management by determining if soil moisture is sufficient for effective herbicide application. He has critiqued his agronomist's approach to weeds generally but is also seeking his opinion on the moisture probes and doing his own thinking on the problem. Thus he is acting as an autonomous agent, comparing competing knowledges, including his own, to help construct new knowledge and inform decision making.

F-14: The agro has to learn again. Instead of coming out here and trying to make us spend dollars...So we have to re-educate ourselves. That is why we need these [moisture] probes in the area to be working for us...But it is exciting; it is challenging and I am really opening my eyes up. You've got to do your own thinking.

The above analysis outlines the farmer perspective, but what about the agronomists? How do agronomists perceive their relationship with farmers and does this affect how they engage with them, and the advice they give?

**Power and the agronomist.**

There is some consistency in how agronomists in my research perceive their relationship with farmers. They all acknowledge themselves as a source of expertise and they provide advice based on that expertise. They also acknowledge that it is up to farmers how they use that advice. They are definitive about their role as advisor, not decision maker for the farmer.

Ag-S-11: My job is to give them [farmers] avenues. I cannot make the decision for them...you can advise them, but at the end of the day, the buck stops with the farmer.

ResAg-6: I have been working with farmers all my life and they need to own their final decision.

Ag-S-8 is more explicit than others.

Ag-S-8: I have guys [farmers] say to me, I do not worry about it, that is your job. Well no it is not...I am here to give you an opinion. I am not here to make your decisions for you.
They also acknowledge that each farmer is different, noting differences in risk perception, values and personalities. This affects the nature of their relationship and the advice given.

Ag-S-9: Each farmer approaches risk differently. I need to understand how risk averse a farmer is.

Ag-S-7: Every farmer is different so you have to establish a different relationship with each person depending on A: the size of their farm; B: their personality [and] the way they want to farm.

So far, this view aligns well with the farmers' position that the agronomist is there to provide advice, not tell them what to do. But Ag-S-8 in his comment above alludes to one of the contradictions apparent in agronomists' attitudes. Ag-S-8 refers to his perception that some farmers will defer the burden of decision making and any risk on to them.

Two agronomists implied that all farmers were like this. Ag-I-01 was the most forthright in this assumption reporting that farmers were effectively passive recipients of agronomists' advice, that farmers do not want to know or understand the problem, they just want the solution. Farmers from this perspective appear to subject themselves, their decision making, to an authoritative agronomist. From this perspective, these farmers are disempowered. This contradicts the evidence from farmers above.

Ag-I-01: They [farmers] want the agro to tell them what to do. They do not want to understand what is going on, they just want to know what do I use in this paddock right now. Even a lot of profitable, big farmers have said to me, and their agronomists/consultants have said to me, they do not want to know. They just want me to tell them what to do.

However, further to Ag-S-8's comment above, he and other agronomists I interviewed noted that farmers deferring risk and responsibility to the agronomist as Ag-I-01 describes applied to only some of their farmer clients. Ag-S-8's other clients were more like those he describes below, and which more closely reflect those participating in this research. I would argue also that Ag-S-8 seems to intuitively understand these particular clients are, at some level, empowered.

Ag-S-8: They [farmers] are the guys you like dealing with because they are taking on board what you say and balancing it against, as you say, their own
experiences and talking to others or reading. And that way, good decisions are made.

To unpack and understand this apparent contradiction in more depth required further interviews focusing on this issue. As Ag-S-8 suggests, it emerged that the farmers Ag-I-01 described indeed appear to be a small minority. For example, in the context of monitoring for invertebrate pests, Ag-S-9 notes similar deferment of responsibility and risk with his farmer clients, yet admitted they are a minority, a minority that still has important implications in implementing IPM tactics (see chapter 7).

Ag-S-9: But then the farmer was saying to me well you should have been out earlier looking [for invertebrate pests], which I found a bit offensive, to be honest...Most farmers wouldn't do that, but you get the occasional one.

There is further contradiction when agronomists talk about their relationship with farmers and the way advice is prepared and given to the farmer. Although agronomists say they are there to offer advice not make the decisions for farmers, the following agronomist comments suggests some consider their expertise gives them a form of authoritative power (see Gerth & Wright Mills, 2009). There is also evidence that they manage their relationship with farmers from the perspective of Bartlett's instrumental discourse. This was evident among sales, independent and research agronomists.

For instance, ResAg-6 is talking about weed management and HR and implies it is their role as experts to teach farmers about their system and thus empower them, which is indicative of the instrumental discourse. He further implies that farmers lack the ability to understand complex contexts such as their farm system, at least not without their help. This is something Wynne (2006) might dispute. Wynne claims authorities, which could include agronomists in this instance, are falling victim to the deficit model of thinking because they incorrectly believe that people are unaware of and unable to conceptualise uncertainty or unpredicted future consequences. One also gets the sense that in some way, the agronomist in my research is defining the farmer's system and how to manipulate it, though it is not definitive how much of this is the agronomist defining the system and how much it is him helping farmers define it for themselves.

ResAg-6: Unfortunately this is a complex topic and you cannot just say these are the answers and if you try to say this to farmers, that it is complex, they just won't accept the answers. So what you need to do is empower them... it won't
happen overnight, but empower them to progressively understand the dynamic system they are in and what they can do to manipulate that system to their advantage.

A further example is Ag-S-13 who uses 'we' in the context of the agronomy company he works for. His language suggests he perceives he has legitimate authority; he is dictating to rather than discussing with the farmers what needs to be done perceiving that this is what the farmer requires or desires. He (or his company) is giving the farmer the knowledge to be 'proactive'. Although Ag-S-13 does work out a paddock plan with the farmer, he implies that while farmers participate in this activity, it is the agronomist that defines the boundaries of the management plan and the required action from the farmer.

Ag-S-13: We do out paddock plans in January and February with our clients and put a plan in place. OK this is a weedy paddock, what are we [agronomy company] going to grow there, what management techniques are we going to use, so that when it rains they [farmers] are on to it, they know what they are doing. They are not scratching their heads when it starts raining going what are we doing. So being proactive in how they manage their problems.

Ag-S-8 puts at least some of the blame for the above attitude and behaviour on the competitive market for agronomy consultancy. He says that agronomists try to differentiate themselves in the market which results in a type of power struggle among agronomists or agronomy companies to be seen as the one with the answers, implying that the farmer can leave it in their hands as they have it all under control. In the following comment he is referring to managing invertebrate pests, which is one context where this is prevalent. Again this situation has implications for whether and how farmers implement IPM tactics (see chapter 7).

Ag-S-8: And that is the thing in the market. Whether it is industry-based agronomists or consultants, everyone wants to differentiate themselves. Everyone wants to think that they are taking control of the situation; doing the right things, ticking all the boxes and saying we will take this course of action because our farmers are covered, therefore we are covered.

In one sense, the agronomists are trying to control the knowledge, or at least put significant emphasis on managing the knowledge. Again this sits close to the deficit model thinking and is also indicative of Bartlett's (2008) instrumental discourse, one which he argues dominates the extension literature. But when it comes to decisions
about weeds and invertebrates, all farmers in my research exhibit autonomy, control, critical thinking and reflection. This affects how they interpret and use the agronomist's advice. I argue as Foucault does, that the knowledge that is constructed is a consequence of the power that is woven through their relations (see Foucault & Gordon, 1980). In the context of complex problems such as weed and invertebrate management, the farmers in my research did not appear to afford legitimate authority to their agronomists or other experts as described in the resource-based power model. The agronomist's perceived authority is just that, a perception. Greater emphasis should be put on understanding these networks that power and knowledge weave through rather than on attempts to manage the knowledge (see Snowden, 2003). Understanding these concepts will help build more effective relationships.

The discourse about power and empowerment is not a binary one where a farmer, or anyone, will fit precisely into either a instrumental or intrinsic camp, nor can they be either empowered or disempowered. That is, as my data reveals, the elements defining empowerment and their influence will differ with farmers and context. Empowerment needs context and has many forms. Further, people are not empowered in all situations, but they can choose the circumstances where empowerment is important or necessary (Roberts & Coutts, 2007). Within this conceptualisation of empowerment then, I argue that when it comes to constructing knowledge and making complex agronomic and farm management decisions farmers are typically empowered. Certainly, for the farmers in my research it was never apparent that they were disempowered in these contexts.

My data reveals varied forms of the power-knowledge relationship between farmers and agronomists. Some agronomists have more intimate understanding of the farmer and attempt to facilitate farmers' construction of knowledge, in effect a co-construction of knowledge. There is an appreciation for farmers' learning journeys that Röling and van de Fliert (1994) describe. Others are closer to the instrumental discourse where there exists between farmer and agronomist often incompatible objectives, interpretations and meaning to problems, risk and advice. Ultimately, though, all agronomists in this research show a high level of care for the farmer and their crops. Most are explicit in their need to understand their clients' perspectives and motivations, and adjust their advice accordingly, though this does not necessarily exempt them from perceiving they have legitimate authority to manage and deliver knowledge. This perception is prevalent among a number of agronomists in my research, at least where weeds and invertebrates
are concerned. The final section in this chapter explores the role of women in farm decisions.

**Female farmers and women on the farm.**

Women are an integral part of the farm, and becoming more so; and farms themselves can be complex partnerships involving many people beyond the agronomy of the paddock (Vanclay, 2004). For this reason I considered the following questions: who is empowered on the farm, and what effect do women have on power-knowledge relations?

Most of the farmers interviewed were men, however, there were two husband and wife teams where both worked the farm as farmers and contributed equally to any management decision (F-7 and F-19). The husband and wife in both cases were present and participated equally in the interview.

I also interviewed what I describe as farmers' partners, which in this case were their wives (W). They are an integral part of the farm business, but they deferred day-to-day and longer-term agronomic decisions to the husband. These women were part of BCG's women's farming group under the banner of their Growth, Adoption, Productivity and Profitability (GAPP) project. W-1 and W-2 agreed to be interviewed in-depth after the GAPP meeting.

**Female farmers.**

The evidence already presented on empowerment and power-knowledge relations is equally relevant to the female farmers (F-7 and F-19). During the interviews, apparent was how they used the term "we" to describe their actions and rationale for decisions. In the analysis, apparent also are the concepts of agency, analysis, reflection and control, and autonomy and knowledge construction. Thus female farmers that I talked to are equally empowered.

The following are comments made by the women that are part of F-7 and F-19:

F-7: We had a paddock of Clearfield Barley and we were planning to put the clearfield chemical on it as [agronomist] advised, but when we went to look at it there wasn't much there to kill so we didn't spray.
F-19: We do the counting and monitoring [of invertebrates]. So I sweep the net and get the count. We pretty much have in our mind what we want to do, but we often run it past [agronomist] to see what he thinks.

Certain decisions are more about "I" where the female farmer takes responsibility for a problem.

F-7: I have done the sums and if there isn't that many weeds it is certainly cheaper to use manual labour than herbicides. I have often thought of doing it. Most herbicides are about $15/ha so if someone is cheaper than that then...

F-19: I know there are different types of slugs; I know they feed in different types of patterns; I know they over-winter and they lay eggs that are now coming out [in Spring], but how does that help me when I need to control my slugs in Autumn.

*Women on the farm.*

The farmers' wives interviewed for my research come from varied backgrounds, with varied off-farm interests, including part-time work. What was common to them all, however, was they were independent women with young children that they have primary care of during the day. They juggle the primary care responsibilities with farm labour jobs as required, for example, feeding sheep, carting fuel, or shifting machinery. To varying extents they are also responsible for the farm's book keeping.

The farmers' wives did not contribute to the agronomic decisions made on the farm. All five felt that they lacked the expertise and they respected their husbands' and so deferred such decisions to them.

W-1: In paddock, like what chemical to spray here or what crop to sow or how much fertiliser to put on, no I do not have that much influence anymore because my life has taken a different road with the family and other little things that I do.

W-2: I do not think I will ever have a major role in deciding what should be done. I can suggest things...I do not think my knowledge of farming...I am just learning. [Husband] has been in it for a while. He left school very young, so I really respect his decisions in that regard.

Their role in this aspect of the farm was on-call labour, but they considered this support role important to the success of the farm business—their farm business.
W-1: We are here for support and doing a lot of run around jobs and somebody has got to do it. If it is not me then you have to employ a part-time person to do it. Those jobs are still important to keep the farm working.

But this does not mean farmers' wives do not question farm decisions, or seek to understand their rationale. Four out of the five women at the GAPP meeting joined the group to learn more about the technical aspects of broadacre farming, not necessarily through a desire to become responsible for making the decisions their husbands make, but to understand them. One woman wanted to know the technical aspects so she could understand the numbers she uses to manage the accounts. For instance, where the numbers come from and what they mean.

Two main roles or responsibilities emerged for these farming wives that help understand the power-knowledge relations between the husband and wife. First, the farmers' wives were important sounding boards for many decisions, including agronomic-based decisions, but especially those involving larger, longer-term investments in the farm. The second, more authoritative role concerns decisions about the family unit.

The dynamics are different for each role, but there is autonomy and knowledge construction happening. There is also evidence of analysis and reflection, especially in the role of sounding board.

*Sounding board*

W-1: we are considering buying some more silos for this harvest, so my husband bounces ideas off me like that. I do not know all the technical stuff about silos, but again it is asking the questions, why this size, or why these ones, questions to make sure he has thought of every angle before he goes and buys them.

W-1: Yeh, we all know we use too many herbicides and if there was a way we could use less herbicides and get the same results we would. So we [husband and herself] throw around ideas.

W-2 and her husband have just gone through a farm succession plan and now operate separately from the husband's parents and brothers.

W-2: And especially now that we are on our own [re: farm] and he does not have his brother and his Dad, I find that I am the sounding board for everything now. So where decisions are being made, we are talking about it.
**The family unit**

It is the farm business as an entity where W-1 and W-2 have a greater role in decision making. Such decisions concern the viability of the business and have implications for the family unit.

W-2: We have just gone through a succession planning, a big one, because we were with [husband's] father and brother. We had to go through that succession planning, and I guessed I pushed that, you know and really drove that.

W-2: Like I said we are a partnership. For example, I know we are in a position, like last year we were cautious because it was our first financial year out on our own, so we were cautious in buying more land. There was more land available and together we thought...arrrr no, we had better give it a year to see how we go. We are in a position now and we were talking about this together on the weekend about we need to invest in more land. And I am pushing that, we need to buy another block now to set us up.

Below, W-1 is referring to how she is not the one generating ideas, but she will attend field days and participate in groups such as GAPP and bring ideas back home for discussion. She is driving or motivating a proportion of the discussion about the longer-term future of the farm business.

W-1: Both of us have been lucky to go on field trips to WA to see new things happening over there. So it is probably not me influencing things, but seeing what is out there, going to field days and talking to people and maybe bringing it back to the house to discuss overall.

Thus farmers' wives are empowered where there is a need to construct knowledge and make decisions that affect the family unit or farm business. They strive to analyse and reflect on the relevant data. They construct knowledge within relations with their husband and farming groups, and events such as field days. They are partners in the farm business and share autonomy and control in these areas, but because the husband is considered to have the agronomic expertise to manage weeds and invertebrate pests, those decisions are left to him.

**Summary**

At the start of this chapter I asked, what are the nature and significance of farmers' power-knowledge relations, how do they influence their knowledge construction and decision making and consequently, their state of empowerment? The answers to these
questions can be summarised as follows: I draw on Foucault's theory to argue that power exists through farmers' interconnected relations. Discourse, knowledge and how that knowledge is constructed occur through and as a consequence of the relations through which the power weaves itself. The agronomist is one of the more influential people in these relations but similar to Thompson and Scoones' (1994) observation there are competing knowledges that a farmer confronts in a process necessary to construct knowledge and inform decision making.

With appropriate context, which in this case is weed and invertebrate management, farmers' empowerment is enabled through their ability to exercise choice (see Kabeer, 2001): choice in the source of information, how they interpret it, what meaning or value it is given and discretion in how it is used to construct knowledge and hence inform decisions that facilitate and maintain their empowerment. This is agency and control and within the regulatory constraints of Australian agriculture (biosecurity, global trade, etc) it closely reflects what Bartlett (2008) calls intrinsic or true empowerment.

Conversely, farmers' empowerment affects the dynamics of any power-knowledge relationship. Their agency, choice and autonomy affects the nature of the discourse, how they interpret information, what meaning it has for them, and hence how knowledge is constructed and consequent decisions made. It affects how they perceive and manage risk and uncertainty. It underpins and facilitates and guides their evolving learning journey.

The relations a farmer forms along this journey are a crucial component as they underpin and help build the necessary social capital required to access the resources (social, cultural, economic, physical) to construct knowledge. The next chapter explores the concept of social capital and its role as a foundation for empowerment.
6. Foundations of empowerment

Chapter 6 examines the three foundations of empowerment that are the core concepts that support and facilitate farmers’ empowerment.

The first foundation is social capital. Two principal components of social capital, relationships and trust, emerged as significant influences on farmers’ knowledge construction and decision making. The second foundation is the relative concept, long-term. Uncertainties about weed and invertebrate management meant farmers and agronomists interpreted and constructed a different meaning to the concept of long-term that meant they interpreted the messages about IWM and IPM differently from that of scientists. The third foundation, let innovators innovate, concerns on-farm trialling and its role in not only reducing risk and uncertainty for farmers, but also one that facilitates farmer empowerment.

6.1 Social capital

Overview
In chapter 2, I describe many elements used to define social capital. One of the more important is relationships and their structure (Bourdieu, 1986). This is true also for farmers as Farmer 23’s comment emphasises.

F-23: The more I look at farming...it is a relationship business with a handful of key people: your staff, your contractors, your agro[nomist], your bank, maybe your accountant.

Individuals and groups that make up farmers’ interconnected network of relations will potentially represent different interests and therefore generate competing knowledges. It is within this contested dialogue and knowledge exchange, that knowledge construction, decision making and innovation happens (Gray, Phillips & Dunn, 2000; Thompson & Scoones, 1994). It is here also that research and extension operate (Thompson and Scoones, 1994). The farmer acquires and builds up social capital through investment in these relationships and the consequent connections of the networks (Portes, 1998).

This chapter provides further insight into farmers' relationships by examining two of their key relationships: the relationship between farmer and agronomist, and that between farmers themselves. Each of these relationships relies on the concepts of trust
and networking. I examine the mechanisms of farmers' networking and the role of trust. I also examine the crucial role empowerment plays in facilitating these two concepts.

Based on Gianatti and Carmody (2007), I define networking as the process a person uses to achieve varied and connected relationships. Networking is the action of sharing information, knowledge, or opinion via these networks that in the context of this research includes other farmers, farmer groups, friends, community members and groups, agronomists or agricultural-based industries such as the local agricultural supply store and seed or grain merchants. While the relationships of farmers in my research facilitated knowledge construction, trust was the glue that enabled and gave strength to a relationship.

The farmer-agronomist and farmer-farmer relationships are examined below, but to provide context to these two relationships, an analysis of the evidence supporting the significance of trust and networking is needed. Most of the farmer comments quoted below involve trust and networking, and will often be relevant to farmer-farmer and farmer-agronomist relationships.

**Networking.**

As farm systems increase in complexity, farmers' knowledge networks and how connected they are become more important (Gianatti & Carmody, 2007). Such networks allow improved knowledge exchange and greater awareness of new practices (Gianatti & Carmody, 2007; McKenzie, 2013). Dialogue within these relations enables the opportunity also to challenge attitudes and values (Gianatti & Carmody, 2007).

My data reveals the empowered farmer who, in displaying autonomy and choice, forges these relations, selecting which relations to pursue and the extent of involvement. Farmers 8 and 22 illustrate this.

**F-8:** I do not take everything they [neighbouring farmer] say because I understand they have zero interest in feed value out of crops and stubbles, so they are coming from a different perspective, so that is where I got the info on Garnet [canola cultivar], but it is another mixed farmer that I got the information on Brazil [canola cultivar]. He trialled it in the area last year with success, so I thought I would trial it this year.
F-22: You pick the neighbours out that you know, know their job...they will give you the truth; you know that they know how it compares to other crops. Last year, my wheat was the same gross margin as my barley, or you can talk to them and say do you use it for weed management as well...you pick their brain.

Farmers in my research will tap into their networks where they confront competing knowledges that prompt analysis and reflection (agency). Farmers' knowledge construction through networking is usually, though not necessarily, informal and social, and reliant on the trust inherent in those relationships. As noted above, Farmer 22's selective choice of neighbour, illustrates this more explicitly than most. Networking enables some of the means and agency that contribute to farmers' empowerment (see Bartlett, 2008; Kabeer, 2001). It is integral to the learning journey of farmers participating in this research. Farmer 01 is one of the more proactive in this sense, but all farmers in my research, in their own way, are trying to "get out of [their] own little hill" (Farmer 14) to learn and see how others cope. Such networking also illustrates how farmers learn from farmers, which is reflected in many farmer comments in this and other chapters.

F-01: One of the things I like about farming is the people I meet and I get on well with people and I have a great relationship with my agronomist...As a district we are learning...I am learning. I am learning off young farmers as well. It is a vibrant farming community. I am part of a farm improvement group...and we take trips to the Eastern states for a bit of learning.

The rest of this section examines the farmer comments relevant to networking and the criteria I used to analyse them.

**Analysis of Networking.**

To get an idea of the importance and extent of networking, of the 26 farmers interviewed 19 had comments coded to networking with 61 references. These numbers will be an underestimate of the significance of farmer networks because it was the earlier farmer interviews with broader, more open conversations that revealed their significance. Further, once it was apparent that the networking concept was saturated, it was rarely coded in last few interviews. See Appendix F for a more extensive overview of comments coded under networking and trust.

Networking by its nature involves knowledge relations, and therefore the implications of power also has significance as becomes apparent in the analysis of the comments.
below. I divide the comments relevant to networking into two key events: *What is happening during networking*, and *The result of networking*. The elements of each event are explained in detail below, but prominent throughout participant comments are agency and control, and the importance of networking as a foundation for empowerment.

*What is happening during networking.*

Networking can, among other things, have dialogue, exchange of ideas and knowledge, reflection, analysis and socialising (see Gianatti & Carmody, 2007). Each of these are apparent in the following elements that emerged from my data and which are described below. These elements and relevant farmer comments also make apparent empowerment's role in networking and ultimately how it affects farmers' knowledge construction.

This event has six elements. The first four (Filtering; Discussing ideas; Solving problems, seeking expertise and Getting perspective) involve competing knowledges that farmers interpret and give meaning to.

*Filtering:* This is where farmers sift different sources of information, opinions, ideas and assign different worth to each. Analysis, critique, and reflection are used to determine the degree of credibility of each piece of data, which is weighed up against farmers' own experience, values and attitudes.

Farmer 9 exhibits a powerful example of filtering that involves analysis of the ideas and information, and is part of his process of knowledge construction. Discussion and reflection relative to other farmers' activities and ideas are important also.

F-9: The information comes in and you filter it through different things. Our agronomist has a different group that gets us all together and a lot of ideas are talked about there, so this info comes from different sources and you talk about it with different groups.

*Discussing ideas:* Discussions include dialogue, analysis and critique. Parties will share and challenge each other's ideas or opinions. It is usually social and informal.
Farmer 11 relies heavily on scientific data from field trials and agronomic research, apparently giving minimal value to opinions, though he certainly thinks critically and challenges ideas.

F-11: You can get to people all day and get absolutely nowhere. It is looking for hard, broad data where somebody has done the hard yards and not full of crap. People can say this and that and I do not listen to anybody unless they can prove it.

Despite his dismissal of anecdote, his following comment shows he still needs his farmer relationships to get perspective and discuss ideas in a social context. There is more to dialogue than solving specific agronomic problems; there are social connections and social norms to adhere to.

F-11: I try and talk to everybody [Wife: He jumps every fence he sees.]... But we chat about agronomy, what they are doing, trying to achieve, why and how.

Farmer 14 considers his mobile phone an important tool to communicate and share thoughts and stories, but he also visits farmers to connect and again share stories. Equally, this quote is an example of Reflection and Getting perspective, outlined below. It illustrates the slow, calculated thinking and reflection involved in decision making.

F-14: A lot of farmers talk to each other. Everyone wants to tell you the good stories but you want to hear the bad ones as well...Probably on the headers now we are ringing each other up and talking all the time. It is a great social thing and I am trying to teach myself to get out of my own little hill... I drive down to [farmer's] place a couple times a year have a look around, maybe have a beer. I am interested in his rainfall, soil types; and then I do a lot of thinking.

Learning through social conversation between farmers seems to occur readily, but it will also happen between farmers and their agronomist.

F-2: So if I hadn't met the agro[nomist] up there and gone with him...I ended up having a good morning and while you are sitting there you are usually talking about stuff that is really important—agronomy stuff.

Getting perspective: Getting perspective is closely linked to Discussing ideas. It is going to see what other farmers do, how they do it and why. It is listening and learning.
Perspective comes from multiple sources that includes farmers and considered experts. Farmer 23 is one of the more active in getting as broad a perspective as possible. He interprets and weighs up the competing knowledges in his own mind to construct knowledge, learn more and help define his actions. He is displaying agency and control, but is dependent on his networks or relationships to facilitate and support this.

F-23: Most of my full time farming career up here I have been part of a financial bench-marking group...we have had intimate knowledge of each other's financials... I ask the same questions: how do I make good decisions on the farm when I am learning because looking over the fence and seeing what someone's crop looks like is only a tiny bit of the equation. So how do I do this [make good decisions], I mix with good people, mix with who I think are the best operators and I refine that in my own mind... so I worked really hard on those networks.

Solving problem, seeking expertise: Farmers use their networks, often individuals with specific expertise, to help solve a particular problem.

I asked Farmer 18 where he gets information when a problem arises. He taps into the expertise of his agronomist, at least some of the science, and industry, but not before talking to his "mates" for their thoughts. Occurring here also is discussion of ideas and problem solving within a social context.

F-18: Your peers [farmers] first. Then industry... I ring them [peers] up and say this has gone wrong, what are you doing about it. And that could be about anything, insects, weeds, grain marketing, machinery, technology issues, computers...you ring your mates, have a chat and see how they have coped with it. Then you go back to the science side of it, you go to your agronomist, a tech support person or whatever it may be.

Reflection: This is the opportunity for the farmer to reflect on what is being discussed and air these thoughts with others. While I argue that it is the informal and social environment that allows this to happen, reflection can also happen in isolation post-networking, which, in this instance means it could also be considered a Result of networking.

Farmer 5 is associated with farmer groups and has social interaction with other farmers and uses that to get ideas, and reflect on their value and whether he could apply it to his farm system.
F-5: Just being involved with other farmers... getting ideas and feeding off what they are doing around the place... There are things out there that are happening that you don't sort of know about and there is being involved with the more progressive type farmers, so you hear about other things that are going on... so I sort of use it as a knowledge base. You think, can I use that on my place.

Social: To varying degrees this is part of every element and reflected in all the above comments. It involves knowledge sharing and construction in the context of social interaction that can be, but is not necessarily, based on farming. This can occur via telephone or at social and community events.

The result of networking.
Once a farmer has used his or her network to gather and filter knowledge, there is an outcome that can include knowledge construction and decision making. There may also be further reflection or a perceived need to test and verify some of the knowledge. Learning is another outcome.

"Good" decision making: This is relative and, given the complex nature of a farm system, a good decision is what farmers perceive is the best or most right decision they can make at the time (see McGuckian, 2006; Snowden & Boone, 2007).

Farmer 22's comment concerns his investigation into whether to introduce vetch into his rotation for better weed management and as a feed source for his stock. He also talked to his agronomist and later trialled a new vetch, which provided additional data. His comment highlights a farmer's need for multiple perspectives, and the analysis and reflection required to make a good decision.

22: I talk to other farmers and I am thinking about putting vetch in and they might say why are you going down there, and then we all talk about it and it is good to get other farmers' advice for certain. Get as much advice as you can, I always try to.

Experimenting: Similar to Farmer 22 above, having filtered, analysed and reflected on the data gained from networking, the farmer may consider conducting an on-farm trial as a next step toward their own constructed knowledge. This concept is explored in detail in section 6.3.
Here Farmer 8, a mixed farmer, was trying to find a better canola variety than the one recommended by his agronomist, who suggested he stick with his existing variety because of the better weed control options. His comment also illustrates how farmers’ objectives are often in contrast to those of their agronomists, and how farmers' objectives (self-direction, agency) influence their decision making. Farmer 8's agronomist selected canola based on its weed control traits. Farmer 8 put a greater priority on feed value for sheep. Farmers filter and analyse/interpret competing knowledges to construct knowledge and make decisions that align with their objectives.

F-8: I did speak to them [neighbours] about Garnet canola...but it is another mixed farmer that I got the information on Brazil [alternate canola cultivar]. He trialled it in the area last year with success, so I thought I would trial it this year, just a limited area, only 60 acres.

_**Learning:**_ This is where the farmer acknowledges they learn specific things, get a new perspective or understanding on things. It can be incidental or deliberate. Research has suggested that strong formal and informal networks enable more adaptive farmer behaviours and greater opportunity for farmers to learn about innovations (Howden et al., 2007; Nelson et al., 2007). The quotes below from Farmers 9 and 14 illustrate one of the more powerful ways all farmers in my research use their networks to learn.

F-9: The Normanville Cropping Group, in different forms, has been going for 20-30 years. I try to go to as many of the talks and meeting as I can...share information...You get to have a walk around other people's farms and see what is going on. You are not always learning, but sometimes you pick up bits and pieces.

F-14: Look I have learnt so much off [two local farmers]. I have a mate up past Ararat who I have learnt so much off.

Networking and the inherent power–knowledge dynamics is linked to stronger connections to the community, which in turn fosters trust and risk mitigation (Sligo and Massey 2007). Trust too appeared as integral to the networking and their connections of the farmers in my research.

**_Trust._**

Trust is hard to define, which is not helped by the near infinite contexts that influence its effect and how it might be interpreted. How we assign trust is unclear and ambiguous (Renn, 2008). How trust is created is equally unclear (Siegrist, 2000). This reflects my
experience with my interview data as I tried to define trust and articulate its influence. As evident, however, in many of the farmer comments above, trust plays an important role in farmer relationships and hence knowledge construction. This section further explores the role of trust in relationships and how it supports empowerment.

To help define trust, I followed a method similar to how I defined empowerment: I used my interpretation of what emerged in the interview data, underpinned by existing theories. From my data emerged the following three key filters: community trust; continuity of association; owning, managing a farm. As filters, they help farmers facilitate and engender trust, and are what a farmer uses, consciously or unconsciously, to develop and sustain relationships. They are described in more detail below.

- **Community trust**: defined by a natural or greater trust in people or knowledge with connections to the local community. Community trust can extend to sharing personal experiences such as financial management or hardships that one might not share otherwise.

- **Continuity of association**: time is required for a farmer to judge credibility and for trust to be earned. Thus a longer relationship with a community, group or individual is associated with greater trust. This is enhanced further where that association has a local connection. Fleming et al. (2014) made a similar observation suggesting that successful agricultural extension and knowledge transfer is reliant on the long-term development of personal relationships. Sligo and Massey (2007) also associated farmer trust and information sharing with longevity of contact, though it was a general observation and alluded only to its potential to help mitigate risk. Here I argue its role and significance as more definitive. Effective engagement in a relationship appears difficult without it.

- **Owning, managing a farm**: if you own or manage a farm you share an identity with the farmer and understand the perspective of the farmer. It engenders trust because you are one of them and will understand (see also Sligo and Massey, 2014).

The role of these three filters in facilitating networking and hence empowerment and knowledge construction are examined in the farmer comments that follow.
In the context of the farmer relationships in my research, continuity of association was forged through community and social processes that in turn engender trust, establish credibility and understanding. Thus, although described as a discrete filter, continuity of association is intimately linked to community trust. Either filter was not apparent without the influence of the other. Farmers 23 and 24 connect their trust of their agronomist to all three filters.

I asked Farmer 23 his thoughts about a reference another farmer had made about his agronomist being local. Farmer 23 relies heavily on his agronomist and trusts his advice which he linked to the importance on having roots that tie a person to the community, and a farmer's dislike of change. Thus he seeks continuity in a relationship noting also that it takes years for an agronomist to learn the function of a farm system.

F-23: Three answers: he is a farmer, he is like me, so he should know what I am doing. Two, if he is a local famer that is demonstrating to me that he has got the networks to learning stuff. Three... he is from the area, he has a farm so he is going to stay here and not leave. And this is an industry with a fair bit of churn and we do not like change. It takes an agronomist a few years to get up to speed with your farm, so if I can see someone who has a tie to the place who is going to be here 10 plus years.

This is similar for Farmer 24. Trust has been established because he has known his agronomist for years and he is part of the local farming community.

24: I just have a guy [agronomist] attached to a chemical company who I have known for years and years. The guy I am with at the moment came off a farm up in the Mallee and they are still up there that family, and you can talk to him... and he knows farming backwards and he comes out and drives around your paddocks and says this is what you want to spray and you go off and buy a drum of this and a drum of that.

Continuity of association is also recognised as important among agronomists as exemplified by Ag-S-9. Most agronomists expressed similar sentiments to him; all recognised trust as important. Agronomists recognise their advice and the outcomes are being judged and they need to earn clients' trust, though as illustrated already in chapter 5 this understanding sometimes fails to extend to understanding a farmer has agency and control and is thus empowered. This will become more evident in later sections.
Ag-S-9: Trust is becoming more and more evident in the relationship between the agronomist and farmer. Some will go, no [agronomist], we trust your advice, we have worked with you long enough... I guess there are certain aspects of the farming business where they know, well the grower has absolute confidence in you as an agronomist to provide them with the best advice on weeds because you establish that relationship over the years and they know how you have gone about it before.

The above comments establish the significance of trust for farmer relationships, but without context the influence of one or more of the identified trust filters suggests that trust acts as a heuristic for farmers’ decision making. Certainly trust is implicated as a heuristic to negate the need for knowledge and reason where complex or risk-based decision making is involved (see Siegrist & Cvetkovich, 2000; Sjöberg, 2001).

For farmers in my research, however, an information source had to first pass the scrutiny and reflection that occurs in the filters of continuity of association and community trust before trust could be earned. Farmer 23 alludes to this when he notes that owning a farm means you are likely to remain in and be part of the community, thus you are subjected to this scrutiny. See also McKenzie (2013).

Once established, trust can then act as a mental short-cut, but that is because the analysis, critique and reflection have already been applied to a long history of experiences with such sources. Farmer 12’s trust in his agronomist has been earned through a 20-year relationship. This continuity of association allows room for some mental shortcuts when it comes to interpreting complex science and use of farm chemicals.

F-12: We have had him [agronomist] for about 20 years.
ME: When you encounter science-based info[rmation] from your agronomist...how do you recognise it as good advice or knowledge?
F-12: It gets back to trust I guess where you just hope he is telling you the right stuff.

Even where trust exists, farmers in my research did not defer decision making to trusted sources without some form of oversight. Farmers in my research make an attempt to gain multiple perspectives on a problem, perspectives that are reliant on trusted relations and networks, many of them with strong community links. Once earned, trust may become a heuristic in some decision making such as herbicide recommendations, but control and agency remain.
One distinction between my findings and the literature cited above about the use of trust as a heuristic is that the literature examines trust toward corporations and public scientific institutions and regulators. Deferred trust (or mistrust) of such institutions can be affected by existing attitudes (biases) to the risk or the institutions (Eiser, Miles, & Frewer, 2002). In contrast, much of the science being judged and interpreted in my research is community or regionally-based science done to solve local agronomic problems. The relationships a farmer forges in this context are considerably more intimate because they form within a geographically small farming community, and hence they are typically long-term, thus affording greater opportunity to judge and reflect on a source's credibility. The initial research is done by industry and public research institutions, but much of what the farmer judges are the localised trials done through local farming or agronomy groups, or interpreted through trusted sources. A number of farmers in my research report skepticism of any data or research from industry, but again, control and agency mean it is simply scrutinised to a greater degree than something from local and trusted sources.

Findings from one study by Wynne do align closely with my data. In establishing explanatory concepts for understanding public responses to scientific knowledge and advice, Wynne's research with UK Cumbrian hill farmers puts greater emphasis on social relationships, networks and identities derived from trust rather than trust itself (Wynne, 1992a). Wynne suggests that the beliefs farmers construct, including their perception on the credibility and trustworthiness of different scientific and other social actors, are functions of the social networks with which they identify (Wynne, 1992a).

The social processes of the local community that Wynne says help enable and generate the farmers' beliefs is a process similar to what I identify as community trust. The beliefs farmers construct are part of the process of knowledge construction and can be thought of as the cognitive component that underpins an individual's attitude. The other components are emotion and behaviour (see Cary et al., 2001). These beliefs, along with farmers' values and worldviews, compete against the multiple knowledges confronted in relationships. Beliefs are challenged and reflected on within these relations. These relationships, those within farming communities and between farmers themselves, emerged as a key social process that influenced their knowledge construction and decision making. The trust functioned as a glue working at the community level that
helps form and then keep intact the social processes, and hence relations. It is the presence and process of networking, enabled by trust, that helps construct knowledge and inform decision making.

McGuckian (2006) observed that a shared context between the information source and the farmer is critical. My research expands on this by revealing the three trust filters used to build and connect networks and both maintain and facilitate farmers’ empowerment.

The importance of this shared context is evident in the two most important farmer relationships identified in this research. The first is the one with their agronomist, the second with other farmers. These relationship are explored next.

**Farmer–agronomist relationship**

The relationship a farmer has with their agronomist emerged as one of the most important in their management of weeds and invertebrate pests. It is arguable whether the farmer–agronomist relationship should come under the definition of social capital because it is a business relationship rather than a community process. I would argue that the nature of the relationship, while business in essence, fits the definition of a community process as it contains elements that define social capital such as trust and networking that are driven by social processes. Further, although not applicable in every circumstance, many farmers form strong, long-lasting relationships, even friendships, with their agronomists. Most of the agronomists participating in this research are also local farmers, owning and managing farms in their region or helping run the family farm, so they are part of the farming and local community and farmer–farmer network as well as the agronomy networks. Comments from Farmer 4 and his wife and Ag-S-8 support this argument and reflect the sentiments of many farmers and agronomists in this research.

F-4: I have a lot of respect for the agros because I have been with them for a long time. I really value their input...That is the other thing with our agronomist, they are also good friends, they're business associates and good friends as well.

F-4(wife): And that happens in a small community.

Ag-S-8, also a local farmer, is referring to visiting his next client after our interview to help facilitate a discussion among the farm owners and sharefarmers, where one party
perceives the other has become irrational in their decision making. I suggested this was not a standard role for an agronomist.

Ag-S-8: Yes, especially during the drought years you were a social worker more than an agronomist. Once people get to know you, it is surprising what they will consult you on.

The farmer sought the agronomist not just for their expertise, but as a sounding board, a learning opportunity, and as a trusted interpreter of complex science. They sometimes became friends, confidants and, as illustrated by Ag-S-8, a facilitator in family issues. For all farmers, the agronomist was a critical component in farmer decision making about weed and invertebrate management. Of these multiple agronomist roles, the main one concerned advice on the use and application of chemical (herbicide and insecticide).

Table 4 outlines the key roles farmers identified for their agronomist. I define these roles below. The roles are recognised and discussed in the literature. For example, see Ingram (2008) and McGuckian (2006). My analysis goes a level deeper to try and understand the motivation for using the agronomist in this way and, as became apparent during analysis, to explore how these uses facilitate and function as a foundation for farmers’ empowerment. Although my analysis focused on the use of agronomists specifically for weed and invertebrate management, many of the roles, such as sounding board and learning opportunity, apply more generally.

**Table 4 List of Principle Reasons a Farmer Uses Their Agronomist for.**

<table>
<thead>
<tr>
<th>Role of agronomists (as perceived by farmer)</th>
<th>Number of farmers stating they use their agronomist for this reason</th>
<th>Numbers of references made for each use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical expertise</td>
<td>25</td>
<td>62</td>
</tr>
<tr>
<td>Filter, interpreter, honest representation of science</td>
<td>16 (A) 13</td>
<td>31 (19)</td>
</tr>
<tr>
<td>Fine tuning</td>
<td>12 (A) 1</td>
<td>13 (A) 2</td>
</tr>
<tr>
<td>Crop rotations</td>
<td>15</td>
<td>22</td>
</tr>
<tr>
<td>Learning opportunity</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Sounding board</td>
<td>13 (A) 5</td>
<td>24 (A) 9</td>
</tr>
<tr>
<td>Broader perspective</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Herbicide resistance testing</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Notes: (A) = Research agronomist/agronomists’ perception of their role in their relationship with farmers.
The agronomist roles defined.

Chemical expertise
Nearly all farmers defer this role to their agronomist, from the selection of chemical to application rates, water rates, and chemical combinations.

Filter, interpreter, honest representation of science
This role illustrates the agronomist's earned trust. Here the agronomist is trusted to source credible information, especially complex scientific or technical data, to interpret and distil what the farmer requires and provide an honest representation of it.

Fine tuning
The farmer has a good overall knowledge of their farm system, but the specific expertise of the agronomist in certain areas can make nuanced improvements. It is chasing an edge to improve the bottom line, improve efficiency, or avoid disaster altogether. It is especially apparent with chemical advice.

Crop rotations
Linked closely with chemical expertise, the farmer will often consult their agronomist about crop rotations because it determines the chemical strategy for weed and, to a lesser extent, invertebrate management.

Learning opportunity
The learning is active and can be deliberate or anecdotal. For instance, the farmer may plan to find something out by asking the agronomist, or learn it anecdotally through conversation about agronomy or agriculture generally.

Sounding board
Farmers use their agronomist to test the validity of their ideas.

Broader perspective
The farmer uses the agronomist to find out what is happening on farms and with agronomy outside their own farm system: what problems have farmers and agronomists experienced, how have they dealt with them, what has worked, what has not.
*Herbicide resistance testing*

Farmers may suspect they have a patch of resistant weeds and ask the agronomist for a second opinion, but time and inclination mean they rely on the agronomist to collect and send the suspect plants off for testing.

Chemical expertise; Filter, interpreter, honest representative; Broader perspective, and Sounding board are the dominant uses and are the ones analysed here. Although agronomists are sought largely for their expertise in chemicals, this role overlaps with many others identified in Table 4. For example, fine tuning often involves tweaking the use of existing chemicals to save $1/ha; the farmer will get their agronomist to filter and interpret new chemical knowledge; and one reason for crop rotations is to ensure different chemicals are used to reduce the risk of resistance. The reliance on chemical expertise is investigated first before a more in-depth look at Filter, interpreter, honest representative; Broader perspective; and Sounding board.

*Chemical expertise*

With the potential exception of one farmer, this is the one role that all farmers in my research, to varying extents, relied on their agronomist for. The exception was a later interview that focused on IPM. The farmer's use of his agronomist for chemical expertise was not directly discussed.

Much of this reliance on chemical expertise is because of the technical knowledge required to keep up with the latest chemicals and the regulations for their use. Farmers lack the time or inclination to do this so defer this expertise to their agronomist. Farmer 26 reflects this attitude.

F-26: Between chemical names, chemical types. They are just always changing, generic names. I cannot keep track of that. It just really got so hard. He [agronomist] should be up to speed more on that than me... So I just do not try to do that side of it any more.

A farmer's reliance on this expertise ranged between minimal and total reliance. Minimal reliance might involve getting their local reseller recommendations to compare to their own chemical strategy. For instance, Farmers 11 and 3 will seek the agronomist's advice on chemicals, but consider it as more of a guide.
F-11: His main role is to sell chemicals to us I think [laughs]. Someone to bounce ideas off. He will write up an annual plan. Everything is itemised, chemicals, brews rates, water rates, etc. So you know how much money you are going to spend before you start. It just gives you something to look at.

F-3: [Agronomist] gives a recommendation. I quite often do not use it because it is too expensive. I think I can do it cheaper sometimes. I've been doing this a long time and I have a bit of an idea of what to use.

Total reliance is where the agronomist, based on an assessment of the weed situation done with the farmer, would provide a detailed recommendation including chemical mixes, application rates, water rates and timing. Such farmers would follow these recommendations precisely. Farmer 12 is typical of these farmers.

F-12: The sprayer does not go into a paddock without talking to the agro[nomist] beforehand. This is just to get a handle on the rates, sprays, etc...the herbicides are more about [agronomist] coming out just before we want to sow to look at the paddocks...so I rely on him a fair bit and that he knows what he is doing.

But are farmers such as Farmer 12 disempowered? Have they deferred control and choice to the agronomist? Is this a situation where farmers are passive recipients rather than active decision makers?

Comments from Ag-S-9 and Ag-I-01 would imply this is the case. They suggest that farmers rely on them too much and become incapacitated without them. Note that Ag-S-9 relates this observation to only some farmers but his tone and expression during the interview suggested he thinks these particular farmers lack the confidence and understanding to risk spraying any chemical without the agronomist's input.

Ag-S-9: Some farmers won't get on the boom spray without ringing me. They want to know mostly technical stuff to do with the chemical application—rates, brews, etc. Some farmers are too reliant on their agro[nomist]. If they cannot reach their agro[nomist] then they won't go ahead with the spraying and miss their window [to spray].

Ag-I-01 reflects this sentiment and perceives also that farmers do not want to understand a problem, they just want the agronomist to give them an answer or solution to the problem. The farmer defers control and the decision making to the agronomist.

Ag-I-01: They [farmers] want the agro[nomist] to tell them what to do. They do not want to understand what is going on.
As noted in chapter 5, a small minority of such farmers exist. No farmer in my research, however, fits this description. And as noted already in chapter 5, such apparent passive acceptance seems rare. Oversight and scrutiny (analysis, reflection) of the agronomist's advice occurs, even where trust is established through one or more trust filters. See also comments by Farmers 10 and 23 below. The farmer maintains agency and control.

An anomaly among this reliance on agronomist expertise for chemical use is with insecticides. For a number of reasons, farmers are more averse to using insecticides and they will more likely reject advice for their use. Use of insecticides is affected by a range of values, worldviews and attitudes that are distinct from those influencing weed management. This anomaly is explored further in chapter 7.

Filtering, interpreting, honest representation.

This is the second most popular use for their agronomists. Again, trust is important as is farmers' ability to tap into their networks as part of the analysis and reflection on any agronomist's interpretation of knowledge. This knowledge could include details of new chemicals, field trial data, the value of new crop cultivars, or soil science. Comments such as the following from Farmer 10 are typical of many farmers:

F-10: I do not know much about it to be honest. I leave it up to the agronomist and what they can tell me basically...I do not read the research reports the way I should.

Regardless of this apparent passive deference to the expert, there is scrutiny (analysis, reflection, autonomy, control) equal to what happens with advice about chemicals. Despite his comment above, appropriate context shows Farmer 10 tries to ensure he has some background knowledge of a problem to enable him to critique agronomists' advice. He also judges the credibility of such advice against his own experience and gut feel.

F-10: I want some knowledge of the issue or problem myself...So I have some questions to ask them [agronomists]. They will have their spiel and then I can ask them my questions...I guess some of it is gut feel, some of it is agronomists and some of it is history—what has worked elsewhere or previously.

Farmer 23 indicates a similar lack of interest in the actual science and relies equally on the agronomist to distil and interpret it.
F-23: Unless it is really of a high level of interest to me I do not want to know that much about the science. I would expect on good leading stuff the agro to be far more across it than I am and most of the time bringing that to me.

What is important is his trust in the agronomist to give him an honest interpretation of it. Continuity of association is important to earning this trust.

F-23: I have to have enough confidence in you either based on your reputation or from the relationship that we have built up over a long time that you are going to be giving me some solid information rather than some seat of the pants, fly by night stuff.

What farmer 23 also illustrates is that although he indicates, as did many farmers, they have minimal interest in the technical aspects of the science, they will question and judge the credibility of that science.

F-23: I want to know if it is good science, if it is valid. We are talking about credibility. Whether it is researchers or field trials, like the NVT [National Variety Trials] and disease trials across Australia where there is loads of replication and different sites.

Agronomists too perceive one of their roles is to filter and interpret the science for the farmer and pass on the knowledge they perceive the farmer wants.

Ag-S-7: As an agro[nomist]... you develop a relationship with a farmer and they are relying on you to pass on the knowledge with their chemical application through to farm planning.

The issue is when agronomists misinterpret this role. For most agronomists in my research, this was client and context dependent, but some agronomists imply that farmers are uninterested in understanding a problem, even incapable of doing so. According to them, farmers only want the minimal information necessary to solve the problem.

Although it may not apply to every farmer they have as a client, Ag-I-01 and Ag-I-2 are more abrupt and forthright in their thoughts about this. In this context, I would argue agronomists perceive their expertise as authoritative and a resource to control knowledge and farmer action.
Ag-I-2: Farmers are too busy to be calculating and getting their heads around all the technical stuff, the background knowledge and understanding. They want the nugget of distilled knowledge or tool that can be applied simply in the paddock. They want the agro to do all the other stuff, to become expert in the technical stuff for them.

Ag-I-01: There is a lot of people who cannot deal with the complexity of farming, that is part of the problem. They do not have the cognitive skills. But they do not need it. They just need to know they need to do these things to manage their seed bank.

A further point is that agronomists in this context perceive they need to remove the complexity, to keep it simple for the farmer. I argue this removes the ability of the farmer to assess and judge the veracity of an agronomist's interpretation, which all the farmers in my research make attempts to do. Thus it conflicts with many farmer comments such as those of Farmer 23 above that emphasise that while they do not desire to understand the technical details, they will still assess the quality of that science and the credibility of the person interpreting it for them. For instance, often they want to assess how sound the scientific method is by finding out how many replicated trials were done, and where they were done. Some farmers have talked about checking certain statistics such as Least Significant Differences (Farmer 9) or whether graphical data is presented in a way that presents a true picture and does not distort the data (Farmer 7). So although they may not want to know the how (though some do), many want to know and assess if the method and analysis is sound and the source credible.

Sounding board, Bouncing ideas around.

In this instance, farmers used the agronomist to check their hunch or to reinforce a thought or idea. It is another way to reduce uncertainty and risk in their decision making. It was important for 13 farmers and mentioned 24 times. See Table 4.

Evident among nearly all comments relevant to this use were the concepts of control and autonomy. Farmers made it clear it was their thought or idea and that the agronomist was just one expert source the idea would be bounced off. Any amendment of the idea or understanding was a result of their analysis and reflection. Farmers 7 and 11 are indicative of how farmers in my research used agronomists this way.

F-7(2): It is another person thinking about the same problems. [Husband] and I can bounce ideas around but sometimes it is good to have someone outside.
F-11: It [agronomist] is a good sounding board, but I am reading research and trials from all over Australia and the world, and he [agronomist] is just one source out of many. He is not the gospel.

Agronomists also accepted that this was a function they served. Ag-S-4 is pondering the reasons that even good farmers with years of experience need an agronomist.

Ag-S-4: One word, reassurance. I am the backboard which they bounce ideas off. Everyone needs someone to talk to, needs someone to associate their ideas with and to reassure themselves they are doing the right thing.

Broad perspective.
As noted already, farmers get multiple perspectives on things, including the perspectives of other farmers. The agronomist not only has a specific expertise and perspective, they also have numerous other clients so get to see what is happening throughout a farming district and usually beyond if they have agronomist networks they tap into. For a farmer, the agronomist can provide a snapshot of who is doing what, what has worked and what hasn’t. The agronomist is, as Farmer 9 describes, a single portal to many perspectives.

F-9: Being the group [agronomist] is in, they have a lot of people on the ground so they are seeing a lot of different farms so they can distil all these ideas and pass that info onto us, so I guess it is a portal to what a lot of what other farms are doing.

Farmer–farmer relationship.
Farmer–farmer relationships are those between farmers themselves, or farmers and farming groups. I include small, district-based farming groups because they are funded and run largely by the local farmers and sometimes small grants. An example is the Normanville cropping group which represents a small farming district in Victoria's East Mallee. The extent of farmer–farmer relationships is evident in many of the comments in the above sections, Trust and Networking. Although differences exist, the power–knowledge relations between farmers achieves similar objectives to that of the farmer–agronomist: to analyse and reflect on competing knowledges, reduce risk and understand uncertainties, facilitate farmers' knowledge construction and inform their decision making.
Nearly all farmers mentioned a social element to any farmer–farmer engagement, for example, Farmer 10, who also alludes to the importance of community in farmer–farmer relations.

F-10: I suppose I am on enough committees you see people that often. Community committees, kids' sport, local hall or the CFA [Country Fire Authority]. And within these committees there are farmers you keep in touch with...I will often ask other farmers I know if they know anything.

Farmer 10 also highlights that there are certain farmers that are sought out specifically for their experience, expertise or leadership in certain contexts.

F-10: He [neighbour] is very open in what he does. He does not hide anything, and I believe he is honest. If he has a failure he will tell you. He does not try and silver coat it, and of course, it is just over the fence so we see each other a bit and phone calls. And he has always been, in my terms, a bit of a leader in farming.

Eastwood, Chapman and Paine (2012) observed something similar when studying the social learning networks of Australian dairy farmers. They referred to these "leader(s) in farming" as translators that act to bridge a boundary between the explicit or technical knowledge and tacit understanding of the farmer. Essentially they play the agronomists' role of filtering and interpreting technical data. And similar to the farmers in my research, these farmers are considered valuable members of farmer networks and have a high degree of credibility with farmers.

Seeking out other farmers is also an integral component of networking. Farmers 18 and 22 below emphasise this and the importance of multiple perspectives in facilitating empowerment and making informed decisions.

ME: Where do you seek info should you have a problem and what sources of info do you tap into to keep up to date?
F-18: Your peers [farmers] first...I ring them up and say this has gone wrong, what are you doing about it., and that could be about anything, insects, weeds, grain marketing, machinery, technology issues, computers...you ring your mates, have a chat and see how they have coped with it.

F-22: Before I started putting wheat back in I asked all the neighbours. Most of the ones I talked to have been growing wheat for a long time, and that is a sure sign, if they have been growing wheat for a while, you are thinking it must be going OK.
Summary.

Farmers with strong formal and informal networks are more likely to have the opportunity to learn about innovations and to possess adaptive behaviours (Howden et al., 2007; Nelson, Adger, & Brown, 2007). Such networking is linked to stronger connections to the community, which in turn fosters trust and risk mitigation (Sligo & Massey, 2007). This aligns well with the evidence in my research. But it is the role of empowerment that is crucial here also, and important to consider when engaging farmers, building relationships to construct knowledge and solve research or complex agronomic problems such as those associated with weed and invertebrate management.

Gaining trust is enabled through the factors I identify as community trust, continuity of association and often also the shared identity of being a farmer. These elements are inherent in farmers' relations and ensure that trust is earned rather than simply afforded to an expert authority, as suggested by Ag-I-01, or as a heuristic because of their own lack of knowledge. Once trust is earned, however, it may function as a heuristic to shortcut some farmers' decision making.

Thus the empowered status of the farmer facilitates their ability to build social capital through networking with trust acting as its glue. Conversely, it is social capital that maintains and acts as a foundation for farmers' empowerment. Knowledge construction therefore relies on farmers' networks and the trust holding them together.

The next section examines the second foundation supporting the concept of empowerment. This is the concept of long-term and short-term thinking, a relative term, but one that affects the interpretation and meaning of IWM and IPM messages targeted at farmers.

6.2. Long-term, short-term thinking

Overview

For the varied participants in my research sample "long-term" is a relative concept when they consider management strategies for weeds and invertebrates. The science suggests farmers need to consider a 10-20 year management strategy for weeds using IWM and up to 10 years for invertebrate pests using IPM. This contrasts with the 3-5 years that farmers and agronomists typically consider a long-term strategy for weeds and 1-2 years
for invertebrates. As IPM is discussed in detail in chapter 7, most of the focus in this section will be on weeds and IWM.

For IWM and IPM, I argue that perceived uncertainties underpin much of this difference in the interpretation of long-term. But for IWM, the unknowable uncertainties such as those linked to climate and, to some extent, chemical resistance raise questions about the value of IWM that make it difficult for farmers and agronomists to put weed management into the context of a 10-20 year time frame. There are also mixed messages coming from science and industry that exacerbate this.

This section examines the different perspectives on long-term, what underpins these differences, how this affects farmer and agronomist interpretations of the science and the farmer-targeted messages about IWM and IPM, and the consequences of this on farmers' decision making about weed and invertebrate management.

I also examine the contexts where farmers do have long-term objectives and strategies, and how these provide a foundation for farmers' empowerment. The farmer values, worldviews and attitudes that underpin these longer-term objectives point to ways to reframe messages about IWM and IPM.

**The scientific long-term.**

**Weeds.**

Much of the science-based literature on IWM that is targeted at Australian broadacre farmers and agronomists is supported in some way by the GRDC through initiatives such as the IWM Manual (Integrated Weed Management in Australian cropping systems, 2014) or through university-based research groups such as the Australian Herbicide Resistance Initiative (AHRI). Although all the literature assessed in this research that examines the efficacy of IWM talks about the need for a long-term outlook for IWM, it is the IWM manual that specifies the requirement for a 20-year outlook.

Calculating returns over the longer term such as a period of 20 years is a better approach for determining the value of the economic benefits of IWM (Storrie, 2014, p.8).

The GRDC IWM manual is one of the principal documents available to Australian farmers and agronomists to help them implement IWM. The rationale for the 20-year
outlook is that this is the time required to get a return on the investment in IWM and to account for the economic factors associated with reducing the weed seed bank and managing the effects of HR (Storrie, 2014).

Other research rarely specifies what long-term is, but they allude to it in their discussion. For instance, a French team required a six-year research trial to determine if different IWM strategies could be effective at reducing weed infestation (Chikowo et al., 2009). Newman and Adam (n.d.) review an 11-year trial to determine the economic advantage of using harvest weed seed control to manage rye grass and the seed bank, though it was year eight when growers using these tactics had reduced their rye grass to manageable levels.

Industry also publicly endorses and markets this longer-term outlook. The following is a comment from a commercial barley breeder breeding herbicide tolerant crops who suggests a 6-year outlook is too short.

> If farmers wanted to continue to enjoy the benefits of herbicide-tolerant varieties...it was critical growers took a long-term view rather than falling into the trap of focusing on fixing short-term seasonal issues. "We spend a lot of money developing varieties with this trait and if they are not managed correctly the trait will be worthless in five or six years". (Moody, in Webster, 2015)

**Invertebrates.**

The scientific rationale behind IPM's long-term strategy is that this is the period required to establish a stable beneficial invertebrate population and balanced predator-prey interactions that allow management with minimal chemical input (Horne & Page, 2008a). The actual time frame is dependent on the chemical history of the property. Farmers with minimal use of broad spectrum chemical will more quickly and cost effectively establish a beneficial invertebrate population than those with a history of sustained chemical use (Horne & Page, 2008a).

Sci-8 is a research scientist and IPM consultant working with farmers to help them implement IPM on their farms. He talks of time frames of 4-10 years to establish a beneficial population.

> Sci-8: you do not start IPM today and the next [day, year] you are full on. It is a system you have to develop. You have got to allow 4-5 years to allow good
fauna back into paddocks, but you might be pushing out to 10 years to get a really good biological system, resident fauna, up and running and that is a big, a long-term investment that growers have to understand.

This perception of long-term differs from that of farmers and agronomists. I examine the farmer and agronomist perceptions and what underpins these differences next.

**The farmer, agronomist concept of long-term.**

Farmers and agronomists are in stark contrast to scientists when they consider a long-term strategy for weeds and invertebrates. Farmer 25 is indicative of farmers in my research sample who do not look beyond five years for managing weeds. Most, such as Farmer 5, do not plan beyond two or three years. For invertebrates, it can be even less time, as Farmer 6 alludes to.

F-25: Weeds and weed seed set affect you well beyond that, 2, 3, 4, 5 years for some. We are looking at them longer-term. We are doing things now and we are targeting even low levels of weeds knowing that...

ME: What about invertebrate pests and their management?

F-25: Probably looking pretty short-term for those.

Farmer 5’s longer-term plan for weeds is two years.

F-5: And these other paddocks I am going to go into I know I have a rye grass problem that I know I have to clean up...I will go this is what we have been doing over the years with what sort of chemicals so we do not keep using the same ones...And I need to think two years ahead.

Farmer 6 is referring to the use of insecticide to manage invertebrate pests and is typical of most farmers and agronomists in my research sample. Despite understanding that there are long-term consequences to the use of broad spectrum insecticides, management decisions are restricted to the insect burden they face that year only.

F-6: We try and avoid it [spraying insecticides], but if you have that idea what do you do? Do you go broke or do you use them? It is a hands on, year–by–year thing.

Agronomists have a similar perspective. As Ag-S-4 says, most management strategies for weeds are targeting a specific problem paddock or patch and the strategy is to manage the weeds and a potential HR problem, but it is still just a three year plan.
Ag-S-4: Where you have a bit of resistance, you have to develop a bit of a strategy that will be profitable for the farmer. You do need to really sit down with the farmers...and go here is what we need to do over a period of time, here is a 3-year plan.

Ag-S-13 perceives three years is sufficient to manage a weed problem, then you move on. You manage the problem visible in the paddock, not the ongoing potential risk.

Ag-S-13: If you have bad rye grass or a weed blow out OK, the best management technique here is putting a hay crop in for two years, so we are not having seed set for a 2-year period. In that next third year period we can be putting this crop in and getting the most out of that and move on. So that is a 3-year approach.

**Uncertainty about the future.**

The different perceptions about long-term weed and invertebrate management are apparent, but what underpins farmers' and agronomists' concept of long-term in this context? It varies, but what dominates my data are the uncertainties about the future. For example, there are uncertainties about how long existing herbicides will last and about physical factors such as the climate.

There is uncertainty also about the economics of continuing with their existing management strategy versus the cost of implementing additional IWM tactics. For instance, a farmer's financial position can influence attitude and behaviour regarding management decisions. This is well documented in the literature (see Llewellyn et al., 2004) and noted by Farmer 14 below who is juggling the acknowledged need for IWM tactics with the need to make money from each acre.

F-14: We are after maximum dollars of every acre. We cannot have land sitting around. We cannot say, if we have a weed problem...because of the price of land down here and the rate costs are so high...so we cannot have a spare acre sitting around thinking I am going to spray top that and I will put a crop in next year and have fallow country.

Financial constraints were alluded to by most farmers in my research sample, though the influence was variable and inconsistent over time. For instance, Farmer 23 notes that his improved financial position means he is able to consider more effective weed management tactics.
F-23: Both my approach to N\textit{itrogen} and weed management...I reckon I have a better approach to both of those now, now that we are in a better financial position than what we were mid-drought, five years ago.

Nevertheless, the most influential factors that emerged from my data to account for the differences in perception of long-term were the largely unknowable uncertainties such as those associated with climate and other physical or biological factors concerning weeds and HR. For instance, Farmer 4 talked about how the results of HR testing helped determine his crop choice, which in turn allowed chemical rotation to manage HR, but the unpredictable climate meant he was not prepared to plan beyond three years.

ME: with crop choice, how far into the future are you planning for managing HR?
F-4: With one paddock, I thought if we went about 2-3 years. You cannot go longer than this because the seasons will dictate more than anything else what will happen, or not.

All farmers in my research sample employed one or more weed management tactics in addition to herbicides and crop rotation to manage HR. Still, the dominant questions about the status and consequences of HR on their farm were, how long have I got until the herbicide fails and I am forced into alternative action? What is the best strategy: continue with the existing herbicide-dominant strategy and hope new herbicides or technology will arrive in time, or invest time and resources into implementing more effective IWM tactics to extend the longevity of the existing herbicides? The former strategy is a form of technological optimism or optimism bias that a number of farmers in my research exhibited. For instance, Farmer 9 acknowledges HR and its implications, and uses hay and crop rotation to keep it at bay. But he is counting on technology to develop a solution before the herbicides potentially fail.

F-9: I do not know about [HR being] inevitable, but my tactics will draw it out long enough for research to happen, or other chemicals come off patent so they aren't as costly.

Llewellyn et al. (2005) and Llewellyn et al. (2007) also found among farmers varying degrees of optimism and uncertainty about whether new herbicides will arrive in time, which they linked to the likelihood of farmers adopting IWM tactics. They found that farmers more uncertain about a replacement herbicide being developed were more likely to adopt IWM tactics. Conversely, those farmers expecting replacement
herbicides to arrive in time to replace existing herbicides before they failed were less likely to adopt IWM tactics. The reason for this optimism toward new herbicides remains speculative with further research required to assess what influences it (Llewellyn et al., 2007). I argue that part of the answer may be because of mixed messages from science and industry that exacerbate the uncertainties and affect to some extent decisions about whether to implement additional IWM tactics. I examine these mixed messages below. In chapter 7, I argue farmers’ high confidence in their ability to manage HR as a further reason for this optimism.

**Mixed messages.**

An IWM principle is to rotate your herbicides and use cultural (non-chemical) tactics alongside the chemical tactics to minimise selective pressure on weeds and therefore slow the evolution of HR, and extend the efficacy of herbicides (Storrie, 2014). Two key messages from the GRDC that are embedded in this principle are that IWM is economic over a 10-20 year time frame and there are no new herbicides in the pipeline, so we need to conserve the ones we have. This is further exemplified in the following comment from GRDC-1:

GRDC-1: We [GRDC and science generally] are seeing it more from a bird's eye view and saying well we actually are running out [of herbicides]. We are finding some new innovations and it is giving us some time...It is likely to be another decade before we will see a new active [herbicide] registered.

Similar comments, such as the following from GRDC's Ground Cover Magazine, are found throughout the farmer targeted literature on IWM.

It is extremely unlikely that new modes of herbicide action will become available in the near future. (Paterson, 2013, p.4)

A similar sentiment occurs in the scientific literature.

Industry has not brought a novel herbicide to market in over 30 years, and the rapid rise of multiple resistance in weeds leaves many farmers with increasingly intractable weed control problems. (Heap, 2014, p.1310)

Contradicting the above is research promoted through farmer-targeted events that I observed. These events were webinars, crop walks and GRDC Grower Updates. The
Grower Updates are forums for growers and agronomists to learn about the latest developments in cropping.

Sci-5 is a university-based weed scientist who I observed talk to farmers at these events. The content of his presentations contains comments similar to the one below from his interview with me. He says new herbicides are being developed and close to commercialisation. Indeed, he is involved in the research that is behind more than one of these.

Sci-5: Yes, we are working with industry on a few new chemicals [herbicides]. There is new and exciting stuff that is selective in wheat and canola, one at least with a new MOA. At least 3-4 years away from commercialisation.

There is research that also contradicts the message that IWM is economic in the long-term, and that we need to conserve our existing herbicides. Sci-6 conducts research in the development of bio-economic and risk modelling tools to make farming more sustainable. She has presented research to farmers and agronomists that shows, in many situations, a farmer is economically better off to continue using two of the more common broadacre MOA herbicides until weeds evolve resistance to them rather than trying to conserve their efficacy for the long-term.

Sci-6: We particularly looked at the example of conserving herbicides [Group A and B] or using them all up early on. It worked out it was economically more attractive to run out of herbicides and then introduce the IWM package. And that is what farmers were likely to do on the ground as well. They "hit the wall" and then turn to a less convenient package.

Sci-5 has a similar opinion.

Sci-5: I think the majority of farmers will continue doing the simplest thing until they run into resistance [HR], and rightly so, because they have some new herbicides, so they say when we run into some issue then we will get another herbicide. And because of the research done here at [university] working with companies to get a couple of new herbicides out. It is working.

So how does a farmer make sense of this? The uncertainties and mixed messages certainly seem to hinder the ability of farmers and agronomists to put weed management into the context of a 10-20 year time frame and proactively manage HR and the weed seed bank as the GRDC describe.
ResAg-7 gives an extension perspective. He says that IWM's perceived uncertainties make it "a big ask" for farmers to develop a weed management strategy 10 or more years ahead. If they do this then many cultural decisions about how they should farm and their objectives for the farm and family may need to be considered, and priorities may need to change. He implies a conflict between the scientific motivation based on quantitative rigour and economics and the cultural frame that influences the farmer's concept of long-term. ResAg-7 does not specify what these concepts are, but based on what my data reveal about farmers they include different frames of reference about the uncertainties of herbicides and the threat HR poses to cropping. I examine these in chapter 7.

ResAg-7: Well that is the assumption, the modelling [that IWM is economical over 10-20 years]. But you take an irrigated grower who has many more choices than the average Mallee farmer. That point [hitting the wall] for an irrigated farmer might be 30 years off. I do not know, it might be 10 for some. If you ask someone to make a 10-30 year cultural decision. That is a big ask.

So what do farmers do? It is the empowered farmer managing the farm according to their self-defined objectives who decides "what works". Farmer 12 illustrates this when he refers to his use of sheep as an IWM tactic. Sheep can be introduced as part of a pasture phase to manage weeds and extend the longevity of herbicides.

F-12: Even BCG were [saying] no sheep, no sheep [in the cropping system] and now all of a sudden sheep are back in. Mixed messages. I just do what works.

Farmers and agronomists understand the science of IWM, but they place a different meaning on it. There are farmers' objectives and values that IWM and similar strategies must align with, and aspects of this are explored next.

When farmers think long-term.

Farmers in my research do think long-term and there were two apparent contexts where this seemed to occur. One context is the objectives for the farm business and family that are based on building a sustainable, resilient business. I use three codes from my data to describe and analyse this context: Legacy, Empire building, and Attachment to land. The second context is based on farmers' value for natural systems that includes those operating within their farm systems and the wider environment. Both contexts are defined by farmers' and their families' self-defined objectives and choice (agency). These objectives and their values influence the meaning that information has for
farmers, how they interpret it and construct knowledge, and therefore make longer-term decisions. This has implications for engaging farmers and agronomists about weed and invertebrate management.

_Empire building, Legacy, Attachment to land._

Empire building, Legacy and Attachment to land are often linked through farmers' objectives and values. Collectively, they help describe what motivates farmers' thinking beyond the year–to–year cropping program. A key objective for all farmers in my research is to build a resilient and sustainable business for themselves, their family and future generations. It helps underpin and motivate a farmer to think in timeframes that stretch beyond 20 years.

Empire building, or buying more farm land, requires financing over 20-30 years, with long-term goals and objectives. The link to legacy happens when they buy this land to support children or other family members who want to farm with the family or in their own right. Farmer 2 is typical of how farmers merge the objectives of empire building and legacy.

F-2: People are trying to expand, it is a tightly held area, it is a reliable area. It is long-term thinking. You have got to try and expand your operation and that is what is going on all the time...you are buying that land not to make something off it for next year and to make a profit, you are buying that land so that you or your family will farm it for another 20, 30 or 50 years.

Farmer 2 also merges his objective to build a resilient asset for his family with his attachment to the land. These self-defined objectives and values also involve autonomy and choice, which influence the knowledge constructed (priority for family and their ability to farm into the future) and consequent decisions made (buying land is a better long-term investment than, for example, investing in a new header).

F-2: It has been in the family a long time and other bits have been bought recently. It forms a bit of our identity, which can be a dangerous thing...A lot of us feel a close connection to our land, whether that is because we have been here a long time or because we have worked hard to buy it. It is not something you are likely to easily give up...All your decisions are long-term. You are buying land and paying it off over 20 years.
Farmer 22 also illustrates how a farmer will merge his emotional attachment to the land with the farm as an asset and business. It is his attachment to the land and need to maintain the land for future generations that allows him to think long-term.

F-22: I value the farm as something that has been in my family for years and as something I would like to carry on for a while yet...It is like anything, you always try and leave something the best way you can...you treasure the business you are in...trying to leave it in the best way for your son and hopefully he does the same thing...In a business sense, I believe it is nice to be able to keep the business going so you try to look after it for the long-term.

Farmer 6 does not have children, but he does have strong family and emotional connections to the farm. He wants to expand the farm and improve it to ensure he has something of value to pass on, in this case to his brothers and their children. This objective influences many of his decisions.

F-6: I worked in [local town] for a while, did an apprenticeship, but to me there is that family thing here. But yeh, I would like it [farm] to grow and accommodate whoever wants it after me. It is not like I see it that when I retire at 60 or 70 I am going to sell it and that is my retirement package. I want to make enough to...lease it..or hand it on to. You could sell off and go and have a good life travelling or whatever, but I enjoy it and I would want the farm to grow and be more efficient and accommodate whoever.

It is more anecdote than data because it is Farmer 23’s perception about other farmers, but his comment suggests that without some attachment to land you are less inclined to have a long-term vision for the land.

F-23: I would say it tends to happen more with share farms or lease properties...we've experienced this with our most recent property purchase where it had been share farmed for 10 years, and yeh, they were farming it for today and if there was any long-term view it was three-six months before the lease finished.

Farmer 23 was one of only two farmers in my research sample who lacked a strong emotional attachment to the farm from the perspective of farming as a lifestyle and career. He took over the management of the family farm strictly from a business perspective. Thinking about his farm long-term means assessing whether it will return enough to justify continuing.
F-23: Long-term [is] 20 years. Sustainability, it has ...the farm has got to return the equivalent what I could get elsewhere. If it does not I do not want to be there [on farm].

But that does not mean Farmer 23 does not have a long-term agronomic objective. He is the only farmer who explicitly linked good weed management to the long-term monetary value of the farm. Farmer 23 perceives that good weed management will increase the value of his farm as a saleable asset. His objective is to improve the capital value of the farm, one of the ways to do this is to ensure he has long-term records of effective weed management and a low weed burden.

F-23: My farm is an asset and it has got a value, and if you drill into that and try and work out what makes up that value. If it has a low rye grass issue, it is worth more than if it is a rye grass mess. If, for some reason, we had an end game in 10 years time where we put it on the market, it has got to be worth more if there [are] good records, we have good fertility, minimal weeds issues...so, there is the short-term stuff where it costs you money and yield, but in the longer-term it is contributing to asset value.

The second concept for long-term thinking, valuing natural systems, is most apparent in invertebrate pest management, which I examine further in chapter 7. A small number of farmers discussed it in the context of weeds.

Valuing natural systems.

The few farmers that discussed a value for natural systems relevant to weeds did so in varied contexts but all involved what might be considered a sacrifice of some form. For Farmers 01 and 20 this sacrifice is potential profit, a factor relevant to invertebrates and IPM examined in chapter 7.

Farmer 01’s value for his natural system means he accepts the cost to manage weeds in his wildlife corridors and the loss of this land that could potentially be used for cropping.

F-01: We have about 19% of our farm natural or reveg[estation]. We have a lot of paddocks on our place for the size of the farm. Each paddock is lined with trees to make wildlife corridors: a haven for weeds, hence the hand pulling and extra labour. A neighbouring farm has one paddock of 1200ha and no trees to make it more easy to manage. For us there is more to farming than long productive paddocks.
Farmer 20 is a young farmer in his 30s. Two considerations influence his weed management decisions: one is the agronomic decisions concerning the crop, for instance chemical rotation; the second is the big picture of those decisions on the long-term sustainability of the farm and the physical environment that the farm operates within.

F-20: We want to be profitable and sustainable, but to be sustainable we need to manage our weeds properly. If we have one year that is profitable but not sustainable then we pay for it for three or four years after that...The environment comes into it as well. This paddock at the front of the house has been continuously cropped since 1979 and it should do four-five ton of barley. You cannot do that for the 35th year unless you have looked after the paddock for the last 34. So it is all big picture not small picture.

**Summary.**

Farmers and agronomists face perceived uncertainties about IWM and IPM. The uncertainties of IWM are exacerbated by mixed messages and both affect how farmers interpret the science, what meaning it has for them, and their concept of long-term. This interpretation and meaning can conflict, or at least is misaligned with farmers' self-defined objectives for their farm, family and business, and their values. Farmers and agronomists understand the scientific messages and accept them, but as I examine and discuss in section 6.3, the learning journey of the empowered farmer is one of their own design and does not always align with the objectives of science. Understanding the contexts where farmers do think long-term could help re-frame messages about IWM and IPM to align better with farmers' values and contexts where they think long-term. Farmer 23's comment (p. 143) reveals one possible way to reframe the messages, but as noted already, every farmer is different, as is their journey of knowledge construction and learning.

The final foundation is examined in the next chapter and investigates the role of farmer innovation and farmers' use of on-farm trials to analyse, reflect and construct knowledge.
6.3. Let the innovators innovate

Overview

Farmers innovate and trial their own and other innovations to reduce uncertainty and risk. I extend this understanding and argue that trialling is part of a complex narrative about farmer empowerment.

I divide the chapter into four sections. The first section gives an overview of research that provides context to my research data. The second section explores the importance of farmer trialling to facilitate empowerment and emphasises the role of power-knowledge relations. The third explores the implications of the less-than-scientific method that farmers typically use to conduct trials, the changing attitude toward the nature of data versus anecdote and the role farmers might play in generating more scientifically rigorous data. The final section explores IPM-based trialling and potential reasons for a lack of farmer and agronomist-driven IPM trials.

Farmer trialling in perspective.

The ability to conduct on-farm trials or experiment is a key step in a farmer's learning process to help them assess risk, reduce or understand uncertainties and make informed decisions, including those associated with technology transfer (see Abadi Ghadim et al., 2005; Baerenklau, 2005; Barham, Chavas, Fitz, Ríos-Salas, & Schechter, 2015; Guerin & Guerin, 1994; Pannell & Zilberman, 2000).

The above research, however, is typically quantitative and incorporates on-farm trials into statistical modelling to identify factors that affect adoption and predict its likelihood. A further emphasis is on risk factors that affect profit and productivity (Abadi Ghadim et al., 2005; Pannell & Zilberman, 2000).

Although trialling is important to assess risk and uncertainty, I extend this understanding and argue that trialling is part of a complex narrative about its largely unexplored connection to farmer empowerment. I argue that the knowledge constructed from this process of trialling and experiment allows further analysis, critique and reflection. Importantly, in the context of my argument, it facilitates agency and thus empowerment.
Key concepts from my data about farmer trialling support what is well established in the literature. I describe them briefly below because it is important context to the core themes of this thesis:

- **All farmers experiment.** For example, see Abadi Ghadim et al. (2005), Guerin and Guerin (1994), Auges & Zouvelekas (2006), Vanclay (2004). McKenzie (2013) noted specifically that there exists not only a farmer's self-belief in their ability to conduct trials, but a recognition that innovation and experimentation is what they do and have always done. An exception appears to occur with IPM. Farmers, even farmer and agronomy groups, rarely, if ever, conduct IPM-based on-farm trials. There are a number of potential reasons for this that are explored at the end of this section and in chapter 7.

- **Local is good.** There is need to understand how something works at the local or farm level and a high value is put on locally generated information (Llewellyn, 2007; Pannell et al., 2006).

- **Getting a rough idea.** Farmers design and conduct experiments to simply get an idea of what is happening. The approximation to good experimental design varies widely (see Thompson & Scoones, 1994). This observation has implications that are explored further in the analysis below.

**Trialling happens and it is driven by empowerment.**

This section examines the role of farmer-led trials as one of many factors examined in this research that facilitate and maintain farmer empowerment. Conversely, empowerment itself is a driver of trialling. Empowerment motivates the farmer to conduct on-farm trials to construct knowledge and avoid being a passive recipient of information. Farmer 18 articulates well the significance of this motivation, when he remarks, "You have to know what works". See full quote below.

As noted already, farmers typically do not make specific reference to their empowerment or agency. These are abstract concepts that are not part of how farmers conceptualise themselves. As Dunn et al. (2000) note, a conscious understanding of their empowerment will only come from an awareness of the cultural construction and the structural forces that shape it, something they say, most farmers are unaware of. Instead, farmers describe their reason to innovate as more concrete and specific. For instance, to test different seeding rates and find which density creates the most effective
crop competition against weeds. Their empowerment is unconscious, but it is implied in their commentary.

In this section, I also examine the role of power–knowledge relations in trialling. Farmers’ relations are a complex interconnected network of actors, some of whom conduct the science. They include agronomists, others farmers, research scientists, and farmer groups, and they are crucial to help farmers filter, critique and reflect on knowledge and make decisions about what idea or technology has sufficient worth to trial on their own farm. Farmer 18 is more explicit and outspoken than other farmers in my research about the role of these relations in his knowledge construction.

Farmer 18 exhibits autonomy, agency and control—empowerment—which is apparent when he describes the research and knowledge constructed through trials he conducted with SFS and DPI, but then has to repeat on a larger scale on his property. He sifts through the hype and critiques ideas to find those of value. He has to "know what works". He has agency and control. And so continues his learning journey.

F-18: You have got to have the science and they might eliminate a heap of different things, but as I said to the fellow who looks after the funding for the DPI... pay the innovators to innovate. Say to [farmers], you go do that at farm scale and we [DPI] will pay you to take the risk out of it, and they will make it work.

You have to be careful you do not get wound up with all the hype...You have to know what works. You need to look at the trial itself, not who is doing them...just because you have been told something does not mean it is right. If I think it has merit I might trial it internally...They [SFS trials] are good, but you have to be able to replicate them at farm scale and that is what we did with DPI and SFS. What worked on a trial plot and treated with kid gloves might not work on a farm scale. What Vic NoTill and SFS do is a starting point for doing larger stuff internally.

Farmer 18 perceives it is the farmers who are the innovators; that they, using the scientific expertise as support, should be defining the research problems and objectives, and managing the trials. Farmer 18’s empowerment therefore affects the nature of his relations, especially with SFS and DPI, and how he constructs knowledge and makes decisions.

Inseparable from knowledge is power. Foucault argues power is the network of relations that enables knowledge construction (Foucault & Gordon, 1980; Heiskala, 2001). Thus,
as noted with Farmer 18, an empowered farmer affects how power circulates and affects relationship dynamics. What this illustrates is that, as Snowden (2003) emphasises, to build effective relations and networks it is more important to understand the relations that power and knowledge move through than trying to manage the knowledge itself.

Farmer 15 also says it is the farmers who innovate. He describes farmers who define the problems and objectives and through analysis and reflection, initiate trials and use their observation and judgement to make decisions and judge the worth of the object or idea being trialled. Again, this is evidence of autonomy, agency and control. Evaluation of farmer trials, however, appears similar to that observed by Thompson and Scoones (1994), where they are more likely to produce anecdote than data.

F-15: I guess a lot of this stuff that the GRDC and [researcher] at DEPI³, who has tried to put numbers on self sown pastures and clovers in the cropping program, we were probably doing that 10 years before he started to put numbers on things...It is like the guys in the district who are trying to grow the pulses such as faba beans and lucernes, they tend to be in the forefront a lot of the time before somebody comes along and does the number crunching on it.

Most farmers in my research sample mentioned some form of relationship with research groups. Such relations were more likely with local farmer groups that conducted research, but sometimes it extended to broader organisations such as CSIRO, universities, government departments and industry.

Farmer 11 is an example of farmers' relationships with scientific organisations. In Farmer 11's case, this includes the primary research data from around the world and what he taps into locally. He says he is "playing around on the edges", yet he compares his own trial observations to the science. Similar to most farmers in my research, he relied on the science and the people doing it as a reference to compare against his own experiments, to assess what might be worth testing on their farm and to seek expert advice from. There is liaison with those conducting the research and conversations with other farmers about it. Farmers judge the credibility of the science, interpret it and use it to help construct knowledge and make decisions. Farmer 11's constant testing of ideas illustrates how he gathers and compares data to better understand the uncertainties and

³The DPI, DEPI are the previous acronyms of the different Victorian State Government departments responsible for agriculture. At the moment it is called the Department of Economic Development, Jobs, Transport and Resources.
therefore manage risk. There is constant analysis, evaluation and reflection that allows him to construct his own knowledge and maintain control and therefore agency and empowerment.

F-11: What we would do is probably an elementary trialling...we are just playing around on the edges, it is just...to get a bit more confidence with what you are doing...but then you always refer back to the hard data done by the different research organisations and compare them to whatever it is you pick up on your farm...We are always testing ideas. Always testing different rates of fertiliser and herbicide and we are yield monitoring.

Farmers assess and reflect, but at some point they have to decide what has sufficient value to trial on their farm. Where there is conflicting information a trial is one way to work out what will or will not work on the farm. Farmer 12 emphasises this point. Like all farmers in my research sample, Farmer 12 first weighs up or filters the varied information sources he gets, which include the media, and newsletters from agronomists, farming groups and associations such as Western Australia No-Till Association. Farmer 12 notes how trialling itself is a form of analysis and reflection. He interprets and constructs knowledge to manage his farm system in a way that aligns with his objectives. His comments also reflect the role of gut feel, where his experience and intuition are weighed up against what is known or perceived. Analysis, reflection and control are evident. Note also the role of the agronomist in trying to get the farmer to experiment with different chemical products. The power–knowledge relation in this instance has a dynamic that will be explored further in the next section.

ME: That is a lot of different sources of information. If there is conflicting information, how do you weigh up such information?
12: You have to get it to work in your paddock haven't you.
ME: How do you figure that out?
12: That is experience. You look at what you think might work and give it a go. I am pretty keen to give things a try on a small scale to see what happens...The agronomist will always come out with different sprays and say try this on a strip.

So far I have shown that complex decisions are typically based on knowledge constructed within interconnected relations. These relations host knowledge sharing and varied discourses, but Farmer 18's relations are different from those of Farmer 15. Each relation, each discourse is unique. Again, this emphasises that rather than focus on managing knowledge, it of greater importance to understand the knowledge relations and how they facilitate knowledge construction and learning. The relations illustrate
also that innovation is not an event, a point in time; it is on-going and, for farmers, it is social. This introduces the concept of the learning journey.

**The learning journey.**

Industry and farmer groups put some emphasis on a need to accelerate farmer adoption of R&D with the implication that such adoption is vital to farm productivity and viability (GRDC, 2014; Rice, 2015). What farmer-led trials help illustrate is that farmer learning is typically iterative. It is made up of observation, critical thinking and reflection, of which trialling is a vital part. Farmer 4’s comment is indicative of this.

F-4: The pace of change is increasing, but I cannot see any golden bullet. We work around the edges. Using trial and error, we’ll have a go, test it, tweak it; and find out what worked.

My data illustrates that for weeds and invertebrates, and indeed potentially any on-farm trial to understand complex agronomic problems, farmer-led trials or those initiated by farmer groups that farmers monitor and assess, are part of an extended, reasoned and continually evolving construction of knowledge. Trialling also facilitates and strengthens agency and control rather than simply acting as the end point in the decision to adopt or not. Coughenour (2003) also observed that farmers who implemented no-till cropping became embedded within no-till cropping networks and engaged in a never-ending process of social construction of new techniques that require their shared cultural knowledge. Innovation is an on-going process rather than a one-off event that focuses on a single point of adoption.

I argue then that in the context of complex problems such as weed and invertebrate management and complex innovations such as IWM and IPM, adoption as a concept, or at least as a key objective, is questionable. I argue instead for a shift from an emphasis on adoption to the farmers’ learning process, or learning journey. In the context of this discussion, a farmer's journey incorporates analysis, critical thinking, dialogue and reflection within their social networks, and on-farm trialling.

Farmer 22 is indicative of the socio-cultural process of knowledge construction and the role of farmer trials. Farmer 22 was seeking a pulse crop to introduce into his rotation that among other things would help with weed management and fit in with the objectives for his livestock, which meant it could be cut for hay and preferably be
grazed. Over time, he observed what was happening in the district, he talked to neighbours and a number of agronomists and analysed competing knowledges. He then decided on a specific cultivar of vetch he thought worthy of trialling. Farmer 22 also illustrates the incremental and iterative approach to farmer learning. He understands he needs to effectively manage weeds, but he has agency, self-defined objectives and control. He is not assessing whether he should adopt IWM. He is exploring options to improve his weed management in ways that will improve productivity, and fit in with his management system and objectives for his farm. In this context, he is an empowered farmer on a journey that requires continual assessment of and reflection on new and competing knowledges and his self-defined objectives. Knowledge is constructed and varied decisions are made along the way, but it is a journey without an end point.

F-22: I never realised, but vetch can be grazed I always thought with vetch you put it in for crop or hay or harvest.

[Agronomist] said lupins would love that country. And I said I do not like lupins: too many failed crops, and they are to be stripped. You cannot cut them for hay. There are too many farmers around here that have tried lupins for about 4 years then [gone], because they didn't perform. He [agronomist] said if you do not like lupins you are going to have to go vetch. I said that suits me because I can cut it for hay, but he didn't mention then that I could graze it.

I was talking to a neighbour last year and he said I graze my vetch...let it come up then I cut it for hay. I said, vetch? ... So I thought we'll give it [a trial] a go...A couple of paddocks. One bigger one, just because these paddocks are ready, coming out of cropping.

With the exception of a handful of farmers in my research sample, on-farm trials, although extensive, typically produce anecdote rather than rigorous scientific data. What this means for farmers generating knowledge useful outside of individual farms is examined next.

**What to do about anecdote.**

This section explores the implications of my observation that many farmers in my research are typically satisfied with an on-farm trial that gives them a rough idea of what is happening or what will or won't work in their system. Farmer 11 is typical of this approach.

F-11: look these [trials] are just guides when you are doing these things, but then you always refer back to the hard data done by the different research organisation.
This approach typically produces anecdote, not data. For instance, when they described their on-farm trials, farmers in my research appeared to give only cursory attention to the potential variables. Given the varied farming systems and physical environments, it means any results are not easily transferable to another farm.

F-5: If you are going to try a new crop you might chuck in 20ha to see how it works, you just try a little bit.

Farmer 11 is referring to the use of narrow row spacing to create crop competition.

F-11: It is just observation, because you can see where the machine drives a little bit wider and...you see weeds, so that is enough for me, just observation.

A small number of farmers in my research thought in principle that the ability to conduct on-farm trials with greater scientific rigour would be advantageous. In practice it was another matter and lack of time and support is a key impediment. As Farmer 15 notes above, it is the role of the research organisations to "put numbers on things".

Farmer 11 supports this sentiment. He also thought it was something better left to those with the expertise and resources, a perception in contrast to Farmer 18 above who wants researchers to "let the innovators innovate".

F-11: Farmers are too busy trying to get the crop into the ground. They cannot be twiddling around too much...You'd also have to stop work for a week to do it and you'd need the professionals to help... You cannot do everything. I have a lot of respect for the research people we have now.

Although farmer trials tend to produce anecdotes when considered in isolation, nearly all farmers in my research used trialling as just one data gathering tool. As noted already they assess other trials, talk to experts, agronomists and other farmers, they visit field days, search the web and read reports. They gather and compare multiple datasets. Some of these data are qualitative, some quantitative, some anecdotal. Before Farmer 22 trialled vetch in his rotation, he talked to specific neighbours, agronomists and checked out vetch crops in the district. As he says, "Get as much advice as you can, I always try to".
In other areas where quantified data is accessible they use it, such as Farmer 14's more intensive use of soil tests and attempts to access soil moisture probes.

F-14: The first thing is the soil tests. I used to be a bit random with this, but since [son] has come home we are right on it to ensure we cover all the soil types and rainfall differences...there are these moisture probes in the area. If we can know the moisture we will know if there is enough moisture for the weeds to grow and help us quantify the time for spraying. We need to use more data.

The difference between anecdote and data in farmer-initiated trials is not binary. Some trials are more rigorous than others, though the evidence in my data indicates that unless they have received expert support, few on-farm trials would compare with trials done by research organisations. Nevertheless, evidence from research agronomists indicates a potential change in farmer attitudes. Research agronomists such as ResAg-1 state or imply that more farmers now seek their expertise to achieve trial data with greater scientific rigour. ResAg-1 also notes the lack of comparable data from farmer trials and perceives they and grower groups have a role to be this expert support and to make any data accessible to others.

ResAg-1: I went to this CMA and said I have two farmers and an agro in this area that want to see some replicated trial work on a paddock. It won't cost much money at all...but it will give us answers. A lot of farmers do this, but do not need the statistical proof, but if someone else wants to try it or we want to tell others about it, well, where are the numbers. The grower [farmer] groups have to take that next step.

Further, in the description of their engagement with farmers on this topic ResAg-1 and ResAg-6 give an insight into the empowered farmer and dynamics of the power-knowledge relations between themselves and farmers. Their interaction with farmers emphasises that it is the farmers who initiate the contact to seek help. The farmers come with an objective and ideas on how to achieve it; they define the boundaries and objectives. In this instance, ResAg-1 and Res-Ag-6 perceive their roles as facilitators in farmers' knowledge construction. Their role is to assist the farmer in their quest to get a more robust understanding of what is happening on their farm. My research, however, was unable to observe the actual engagement or interaction of ResAg-1 or ResAg-6 with these farmers over time, thus the power-knowledge dynamic such as how the problems, and project objectives and boundaries are determined is unknown.
ResAg-1: I had a farmer the other week call me saying I have put chook manure on my paddock for years but I want to measure what the benefit is, how can we do that, is there any money available?

In addition to self defined objectives and boundaries, ResAg-6 notes that the farmers will analyse and reflect on a range of views. They will gather multiple datasets and filter, interpret competing knowledges, and participate in varied discourse to construct their own knowledge.

ResAg-6: I find the thinking of farmers I talk to ever so slowly changing. They are starting to say, I like the look of that. I have a paddock I am willing to take out of production and try it. That is where we come in. For example, a farmer this morning on the phone asking for ideas about what might work for me. He will still have his own ideas and he will talk to different seed sellers who have a different range of products.

Farmer groups illustrate already how a collaboration between themselves and farmers can generate scientifically rigorous data. A small number of farmers in my research sample proactively work with farmer groups in this way. The farmers and farmer groups had similar objectives and thus there were advantages for both parties. As noted already Farmer 18 is one of these. Farmer 20 is another. Farmer 20 and SFS, the local farmer group, are actively exploring ways to combat HR and have collaborated on trials to assess the potential for hay to manage weeds and HR, but also to profit from it.

F-20: We are heavily involved with SFS. They have some of their trials on our place. We were doing some hay trials with them. We put wheat, oats and three different types of pasture mixes.

In contrast to research agronomists, the sales agronomists I interviewed typically dictate to the farmer what to trial and how to do it. The trial is usually for an agronomic input such as chemical or fertiliser that they need to sell. It is one factor that distinguishes them from the research agronomists in my research, though as Ag-S-11 notes, the farmer will still decide the value of any product.

Ag-S-11: Yeh we do trials with farmers. Or we get them a new product and go right this is a new chemical can you do a couple of strips up the middle of your paddock. Then if they do it, they will go, yup that works, or no I am not trying it again.
Ag-S-7: So the ability for us to be able to go to your place and go here are the latest products, let me spray some strips out here and you actually take them and show them, it is the best way to get that point across.

In this scenario, the agronomist is defining the boundaries and objectives for any trial or experiment on a property. It is a product demonstration that has a purpose for sales agronomists who are doing their job. Some sales agronomist firms do conduct more extensive and robust trials but the purpose is still product demonstration, and the data collected is theirs. The farmer's problem and objectives typically do not influence the purpose, design and outcomes of such trials. Farmer 22's experience is indicative of this. However, he was happy to have this trial done on his farm because it coincided with his idea of reintroducing wheat into his rotation and this was a trial for a new variety of wheat. The trial aligned with his own objectives.

F-22: They [agronomists] normally donate the seed, but it was our fertiliser which we were going to put in the paddock anyway. We harvest it...They bring a weigh bin, so they know the exact area, they have it pegged out and measured so they know that that [yield] is X ton/ha.
ME: Do you give him data such as how much fertiliser went on, when it went on, rainfall, etc?
F-22: Yup, that's it.
ME: What happens with the data once all that is worked out?
F-22: They obviously take it away somewhere and put it into a system somewhere so people can have a look at it. During the season you will have farm days, so they will say [F-22] is having a trial and the agro will run the course for those coming to look.

Impediments such as time, resources, or they simply do not see it as their role mean not every farmer in my research will actively participate in an opportunity to make their trials more scientifically robust and meaningful to other farmers. So unless there is adequate support or need they are unlikely to change this attitude. But there are some (such as Farmers 18, 20 and 25) actively engaged with research to conduct scientifically rigorous trials, and if the observation of the research agronomists interviewed in my research is valid then an increasing number of farmers also see the value in doing this. This is echoed in McKenzie's (2013) research. Some farmers she interviewed saw value in support to establish their own research trials and to ensure they get useful results that can be conveyed to others. They too wanted help with trial design, monitoring, data collection and analysis (McKenzie, 2013).
McKenzie (2013) argues a case for future research to investigate the role of farmers as potential intermediaries of innovation, noting that should farmers' innovation become recognised there is a need for appropriate institutional frameworks to support farmer engagement and innovative capacity. Farmer 18's call to pay the farmers to innovate reflects this argument, though it became apparent in the interview that Farmer 18 would rather not be an intermediary and instead maintain autonomy and control, and ensure he helps define the objectives and boundaries for any research. Indeed for farmers in my research sample, this is how most on-farm trials happens now. The farmer defines the objectives, has autonomy and control. What is required for appropriate scientific rigour is support. This begs the question, how to incorporate and support the potential for farmers to conduct scientifically robust trials into their learning journey? This is discussed further in chapter 9.

The final section briefly examines the contrast between trialling to improve weed management and that to manage invertebrate pests.

**Trialling IPM.**

Compared to weeds, there appears to be substantially fewer trials to improve management of invertebrate pests. For instance, Farmer 25 does considerable on-farm trials with new herbicides and cultural weed control strategies, but not so with invertebrate pests.

ME: Do you do any farm trialling relevant to invertebrate management?
F-25: No.

The key purpose of this section is to provide a brief quantitative examination of data to illustrate this difference and examine potential reasons for it. There are many potential reasons, including a lack of basic knowledge about invertebrates and that IPM is a perceived a greater risk than IWM. This will be explored in more detail in chapter 7. In this section I will examine what appears to be agronomists' low confidence in any trial that could show farmers the benefits of IPM, at least in the short-term.

**The numbers are telling.**

All farmers in my research mentioned they set up trials or test ideas to improve weed management. From my conversations with them and agronomists this seemed standard
among other farmers in their networks. With IPM, the only trials farmers or agronomists mentioned were those to test different baiting regimes for snails and slugs.

So what is happening here? The paucity of trials concerning management of invertebrate pests is notable also in agricultural research. Online Farm Trials is a project led by the Federation University Australia for the Australian grains industry. It collates a range of crop research datasets, including crop trials, and literature into an open online digital repository. Although not exhaustive, the data from this repository presented in Table 5 is indicative of the low number of trials to improve invertebrate management compared to other agronomic problems including weeds (Online Farm Trials, n.d.).

**Table 5 Farm Trial Data Showing Numbers of Different Agronomic Trials Around Australia.**

<table>
<thead>
<tr>
<th>Trial category</th>
<th>Number individual trials</th>
<th>Number different trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicides</td>
<td>297</td>
<td>166</td>
</tr>
<tr>
<td>Insecticides</td>
<td>36</td>
<td>9</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>386</td>
<td></td>
</tr>
<tr>
<td>Fungicide</td>
<td>229</td>
<td></td>
</tr>
<tr>
<td>Sowing (rate, timing, etc)</td>
<td>184</td>
<td></td>
</tr>
</tbody>
</table>

Note. Trial data from Online Farm Trial's trial browser. The "Number of individual trials" counts the total number of actual trials, which include replications of the same trial done in different trial sites. The "Number of different trials" is the number of different trial projects, where replicate trial sites are not counted. The trials represented in the "Insecticide" category included one trying to reduce bird damage, two trialling different bait and cultural techniques for slugs and snails, five investigating ways to manage Barley Yellow Dwarf virus, and one trial investigating efficacy of seed treatment to control aphids in winter cereals. So only one trial involved management of invertebrates, other than slugs and snails, and only two trialling cultural techniques, which again was to manage snails and slugs.

Figures for the number of different trials were counted for herbicides and insecticides only as they are the focus of this research and to illustrate that IPM-based trials are significantly fewer than for other agronomic problems.

**IPM hard to measure, hard to observe.**

Ag-S-9, Ag-S-7 and Ag-S-10 are typical of sales and research agronomists in my research. They know about IPM, they understand the purpose and basic concept of it, but a number of factors, such as the perception that they bear the burden of risk, hamper their ability or willingness to consider IPM-based trials. Similar to nearly all
agronomists in this research is an apparent conflict between their lack of faith in what an IPM trial will achieve and their in-principle support for IPM. This is also discussed in more detail in chapter 7.

Below, Ag-S-7 discusses his concerns about running an IPM-based trial. He posits that the farmer wants to see a financial benefit from any IPM trial, but perceives a trial is unable to reveal this in a single short-term trial.

Ag-S-7: You could say, let's hold off, we want to track some beneficials here, we do not want to bomb them out, but then they suffer some grub damage... you sort of feel like, not that you failed, but you know that you have done a good thing as far as your IPM goes, but their bottom line has been hampered and that is the first thing that most blokes will look at, and I guess if you can prove that you are...we are saving you down the track...if you can prove on the spot that we are much better because we have done this, yes you have suffered $50-80/ton loss because of the damage but we have improved this, if they can visually see you have improved it they will be happy.

Ag-S-9 works with two clients interested in IPM, but he perceives that IPM trials are more difficult than IWM trials and have outcomes that are hard to measure in the short-term. He is comfortable conducting IPM experiments with the two farmers interested in it because the burden of risk has switched to the farmers. Ag-S-9 also comments on a common observation among agronomists and those working in extension that farmers need to physically observe something for themselves to help them understand and validate it. This emphasises again how important on-farm trials are to a farmer's learning journey and supports my question above that asks how best to incorporate, support and facilitate more rigorous on-farm trials into this journey.

Ag-S-9: This year I have tried to adopt two farmers that are what I would call pioneers in my little clientele, and I have tried to work with them and educate them on their insects and then try to communicate with them that we need to start using alternative insecticides, if we have to use insecticides at all. The problem is like doing replicated trials is extremely difficult when it comes to insects. Getting farmers to do a demo, fantastic, but it is not just the one year benefit or one year yield assessment you have to do. It is a long-term thing. Whereas IWM is a lot easier to assess, the short- and long-term benefits. But with most of the IPM it is just so hard to measure short-term. If you cannot measure something short-term it is hard for the farmer to see if he is doing the right thing unless he believes he is doing the right thing.

Ag-S-10 lacks confidence that even a longer-term trial will provide meaningful results.
Ag-S-10: Yeh, you need a case study. I’d say you'd need a 3-4 year case study where you have to have a farm that has not used any nasty chemicals for a few years to get the beneficial population to where it needs to be and to see if you can get a good enough benefit out. It is an unknown too. You might do this for 3-4 years and spend 100s or 1000s of dollars and a fair chance you’ll find out it didn't cut the mustard.

How agronomists typically understand the efficacy of an IPM trial is in contrast to Sci-8's experience. Sci-8 is a scientist and IPM consultant and works with farmers to help them implement IPM systems on their farm. He believes that an IPM-based trial can be simple with observable results in one season. He too perceives that if farmers can be convinced to do the trial it will reveal to them the potential of IPM, and it does so because such a trial lets farmers learn for themselves; they get a "feel" for how it might work. Again, this is suggestive that on-farm trials facilitate farmer agency and empowerment.

Sci-8: I get groups and I get volunteers to put out little trial plots, and I measure for these people what it is for their broad spectrum spray that it isn't killing by having a bit that they do not spray. So you collect what is there from the sprayed bit and the same for the un sprayed bit and when you look at them you go well what you thought you were killing isn't even here. It is a really good demo for people just to show you didn't need to spray the whole paddock. What I do is say, here are some possibilities. If you really want to know, stick to the conventional approach for most of it, but leave a piece, a small trial on your place with your conditions...it gives them an attachment to an outcome. It is alright to say, someone else did it. It is best they learn from themselves. So we can take a safer option for the bulk of it and they won't suffer economic losses. But if you want to do this for real on a bigger scale, leave a piece of a paddock this year and see how you feel because they have to get a handle on how it might look.

Summary.

Core themes from my data about farmers' trials are reflected in commentary by McKenzie (2013), Bartlett (2008) and Coughenour (2003). Bartlett and Coughenour especially, describe on-farm trials as part of farmers’ continual process of knowledge exchange and learning that comes from self-direction, critical thinking, reflection and evaluation (empowerment). This is influenced by the social and cultural knowledges that are part of the interconnected power-knowledge relations farmers are embedded in, and it is these relations we need to understand if we are to improve engagement with farmers about IWM and IPM. This describes how on-farm trials help facilitate farmers' empowerment. I argue that empowerment also acts as a driver of on-farm trials. It is what farmers do to ensure they maintain agency and control. I argue further that,
especially with complex problems such as weeds and invertebrate pests, the learning, knowledge construction and decision making that occurs is part of a journey that takes precedence over and reduces the importance of adoption as an objective.

On-farm trials and farmer innovation link to my other identified foundations of empowerment. On-farm trials, as part of the knowledge construction and decision making process, is social and rarely done in isolation (Vanclay, 2004). It involves interconnected knowledge networks held together by trust in which there are multiple, competing knowledges and discourses that farmers weigh up against their values and experience.

With IPM, however, most farmers and many agronomists in my research face constraints that impede their ability to reach a decision that would enable them to trial or test an idea and hence change their invertebrate management strategy. The constraint is primarily caused by lack of knowledge. A consequence is doubt or uncertainty about IPM. Sci-8 implies risk and uncertainty can be understood and managed by helping farmers set up trials on their farms. Ag-S-7 and Ag-S-9, as do other agronomists, consider the uncertainty about IPM in the context of their reputation. This perceived uncertainty and fear of reputation damage impedes their willingness to conduct IPM trials with farmers. This is the basis of the analysis and discussion of the next chapter.
7. The IPM story

Overview

Weeds and invertebrate pests are detrimental to crop yields and farm productivity. IPM and IWM are strategies designed to slow down the evolution of chemical resistance in weeds and invertebrates, and are considered by the GRDC and relevant scientific research groups such as CESAR (The Centre for Environmental Stress and Adaptation Research) and AHRI as a more sustainable form of management. Yet there are differences in how farmers and agronomists perceive and interpret each strategy. Some differences are stark; others more subtle. They are differences that have implications for understanding farmer decision making about weed and invertebrate management, which the final section of this chapter will analyse.

The focus of this chapter, however, is on the factors that affect farmers' and agronomists' knowledge construction and decision making to manage invertebrates. The key factor that emerged was a lack of knowledge about pest and beneficial invertebrates. This knowledge deficit created uncertainty about IPM and resulted in risk averse decision making, factors largely absent with IWM.

Figure 5 below depicts the components of the knowledge deficit and what the consequences are that affect knowledge construction. The knowledge deficit comprises a lack of certain skills, and perceptions about IPM that create uncertainty. The uncertainties have consequences: fear of crop loss and fear of reputation damage. The latter led agronomists to give risk averse advice. The heuristics Affect and Availability were apparent also and affected how farmers and agronomists interpreted, understood and reacted to the uncertainties. Affect is emotion, feeling and dread linked to too many unknowns that generate a fear of crop loss. Availability is the salient memory linked to an experience that farmers and agronomists want to avoid repeating. In this case that is normally invertebrates causing severe crop damage and the different repercussions of that. Both heuristics are discussed further in chapter 8 but their influence appears in a number of comments throughout this chapter.
This chapter contains four sections. The first section provides context to the rest of the chapter. It provides an overview of farmers’ and agronomists’ existing attitudes toward IPM and invertebrate management, and how these have changed in recent years. The second section examines what constitutes farmers’ and agronomists’ knowledge deficit. The third section examines how risk and uncertainty are framed. It also examines the consequences of how farmers and agronomists interpret the risk and uncertainty, and how this influences knowledge construction and decision making. The final section examines in greater detail the factors that distinguish IPM from IWM, and how farmers’ interpretations of IR and HR differ from those of scientists and other proponents of IPM and IWM.

7.1 Changing attitudes and practice

Shifting attitudes.

As noted already and examined in more detail later in this chapter, farmers and agronomists are less likely to implement IPM tactics than IWM. But the farmers and agronomists in my research are aware of IPM and there is an attitude that acknowledges a need to move away from a chemical-dominant management strategy. This section examines existing attitudes toward IPM and the management behaviours of farmers and agronomists. I put this into context of how well Australian farmers and agronomists are adopting IPM.

Farmers 18 and 20 are indicative of all farmers in my research and reflect this changed attitude that recognises the need to manage invertebrate pests differently.

F-18: Years ago when blokes used to chuck insecticide in with every [herbicide] spray mix they did, they built up resistance and created issues. They got rid of the beneficials and left the gate open for the bad ones.
F-20: You start going through paddocks you haven't worked up for 10 years or so and start plucking rocks and you will see 5 carabid beetles [beneficial insects] under there. Previously we would work it up and hit it with chemical and sow the crop and go well there are no bugs there, but we learnt we were causing more problems than we were fixing.

The attitude change has led to some farmers implementing some IPM tactics. For example, for many crops, the preventative, or insurance spray, is now considered bad practice. There is a similar attitude about the paddock-wide application of insecticide where pest invertebrates might be found in parts of a paddock, but the whole paddocks would get sprayed just in case. More often now, farmers will apply insecticide only to the affected parts of a paddock.

Farmers 26 and 13 are indicative of the change in attitude about insurance sprays and paddock-wide spraying, where dimethoate is a broad spectrum insecticide.

F-26: Winter crop: Years ago I would spray dimethoate pre-sowing, post sowing mainly for RLEM [Red-legged Earth Mite], that sort of stuff. I haven't sprayed dimethoate in that context for nine years now.

F-13: I didn't have a private agronomist then, just the reseller agronomist and he would say tip the insecticide in every time you put the herbicide out, it does not cost much maybe $2/ha, and you do it and you have got rid of the insect issue. That was the general recommendation. I thought why?

Agronomists have a similar attitude to the farmers, but as examined later in this chapter, for a number of them it is a principle rather than a practice as many still include an insurance spray on their recommendation to farmers, especially for high risk crops. Certain farmers in my research, however, will ignore this recommendation (except for high risk crops such as canola). This is a further point of difference with IWM. Farmers in my sample will tend to closely follow agronomists' advice regarding herbicide use. They are less inclined to do so with insecticide.

Ag-S-10's motivation to at least think differently about invertebrate management came when he assessed his management of a faba bean crop and noticed how different the outcome was to his colleague's. His decision to forgo an early broad spectrum spray resulted in less pest damage.
Ag-S-10: The key one was, we sprayed a faba bean crop and there was a lot of beneficial insects in there. One agro worked on part of the farm. He sprayed the beans early with insecticide that just killed everything. I left the bit I was in charge of [didn't spray]...When the numbers of heliothis were higher, I did actually use the nuke everything [broad spectrum] spray.

The other agro, he had to come back and spray again, but in that time between the two sprays he had copped a lot of damage because the heliothis had come back, and there was no beneficials...Probably that incident, when I first started made me think [about using insecticides].

The one contradiction in my data comes from Sci-8 who consults with farmers and agronomists on IPM and who suggests insurance sprays are still common. He places much of the blame for this on the sales agronomists linked to chemical industry incentives. None of the farmers in my research fit this description, though to different extents, it does describe some of the agronomists.

Sci-8: Once in the rut they [farmers] tend to stay there unless they change their whole approach so lots of insurance sprays [are] done which actually ensure you go down the road to resistance build-up of your pest mites. There is a lot of money tied up in farmers' practice for chemical companies.

Despite the acknowledged need to reduce agriculture's reliance on chemicals for invertebrate management, most farmers and agronomists in my research are reluctant to change behaviour beyond what I have described already. The potential reasons for this are underpinned by a lack of knowledge and are examined later in this chapter.

So, there is a positive attitude toward the need to reduce the reliance on chemical control and this is reflected in some adjustments in invertebrate management. But how far away are broadacre farmers from what this research defines in chapter 3 as true IPM?

**IPM is a great idea, but...**

In chapter 3 I describe Kogan's (1998) adoption curve that outlines the different levels of adoption. His Level 1 lists as the minimum number of adopted tactics, the monitoring of pests and beneficials and use of selective insecticides. Level 3 is closer to the true IPM defined in this thesis. See Figure 1. The invertebrate management strategy of most farmers and agronomists in my research aligns closely with the conclusion by Nash and Hoffman (2012) that found most Australian broadacre farmers sit below Kogan's Level
1 IPM threshold. This section gives some context to the progress of Australian farmers and agronomists toward true IPM.

Nash and Hoffmann (2012) suggest frugal financial management will occasionally drive some farmers into Level 1. For the farmers in my research, this frugality typically concerns a decision whether to use an inexpensive broad spectrum insecticide or more expensive targeted insecticide that does less harm to beneficials. As Ag-S-7 and Farmer 19 imply below, in most instances this will mean the broad spectrum is chosen.

Ag-S-7: I can say to you, I believe we should be using a selective chemical and it is going to cost you $7-8/ha. Or we can come in with a dimethoate and it is going to kill everything, but it is $1/ha. If you are looking at your bottom line and guys around here are talking thousands of acres, so that sort of saving is a massive impact on their bottom line.

Farmer 19 reveals they would consider the targeted insecticide if its cost was similar to the broad spectrum, which at the moment it is not. They also imply that while their greater priority is profit they understand the need to avoid broad spectrum insecticides if possible.

F-19: We are economics focused, but at the same time if there is small difference in cost between hard or soft chemicals we would probably go the softer chemical. But the IPM strategies are certainly not at the forefront of our focus.

Although some Australian farmers may stray into Kogan's Level 1 and attitudes have shifted to now recognise a need to reduce reliance on the chemical approach, I argue that instead of following Kogan's adoption curve, the journey of farmers and agronomists in my research is stalled and if anything has flatlined. See Figure 6.
I argue that much of the reason for the flatlined progress is caused by a lack of knowledge, one that creates uncertainty and affects knowledge construction and decision making. The next section examines this and its implications for engaging farmers about IPM.

### 7.2 The IPM knowledge deficit

**The knowledge deficit components.**

In a report for the GRDC, Rice (2015) noted a lack of farmer knowledge about invertebrate management, but emphasised a need to increase adoption of IPM. To boost adoption Rice says farmers need to better understand life cycles of the pests and their predators, and to learn effective monitoring techniques and understand the different control thresholds. These skill and knowledge deficits are apparent in my data also, but the purpose of Rice’s report is to highlight GRDC’s "priority issues", including those for IPM-based research (Rice, 2015). Although the report identifies gaps in research knowledge, it offers few tangible solutions, or understanding of the implications of these skill and knowledge deficits that will improve engagement with farmers and agronomists about IPM. This section identifies the key skills and components that constitute the knowledge deficit and examine the factors that need to be considered if this knowledge gap is to be corrected.
The significant skills and components of the knowledge deficit identified in my data, which are examined below, are the following:

- lack of field skills such as invertebrate identification, especially the beneficials; knowledge about invertebrate pest behaviour; and predator-prey interaction in farm systems;
- perceived lack of scientific evidence to underpin IPM tactics;
- monitoring
  - monitoring pests only
  - thresholds and gut feel.

**Lack of field skills.**

A disparity exists between farmers' and agronomists' knowledge of pest invertebrates and their knowledge of beneficials. Based on their self reporting about their knowledge level and how they monitor invertebrates, which is usually only the pests, the implication is that agronomists and farmers in this research can identify the important pest invertebrates, but have limited ability to identify beneficials.

The following farmers do most of their own monitoring which indicates they can at least identify some pest invertebrates. Some will share the responsibility of monitoring with their agronomist.

F-22: Visual, yeh get out there and turn the leaf of a plant. Normally during the day they will live underneath the plant, so you turn it over and see how many [pest invertebrates] you have got.

F-24: I have my net and I go and have a look every now and then.

F-13: Yes, always netting. We have sticky traps.

Nevertheless, Ag-S-4 suggests that farmers struggle to correctly identify a number of pest species.

Ag-S-4: They had it [aphid], but not what they got told they had. The insects were misdiagnosed and this is where a lot of the trouble comes into it, is misdiagnosing insects.

Sci-8 applies this sentiment to agronomists also, but implies the lack of identification skills applies more broadly to any invertebrate.
Sci-8: What has become really evident to me over the years with not all, but most agronomists, is their field skills of what is what regarding invertebrates is really poor. How can they encourage, promote and help growers with an IPM approach if they do not know what they are looking at?

Most farmers and agronomists in my research acknowledged or implied they are better at identifying pests than beneficials. This is made more evident in some of the comments below. All farmers and agronomists in my research, however, are aware that beneficials exist and can affect the pest populations. What they lack is the taxonomic skills to identify them, an understanding of their role in predator-prey systems, and how they fit into the ecological niche specific to each farm system. This latter point is notable by its absence in any conversation with farmers and agronomists, but according to Horne and Page (2008) all these skills are critical to implementing and managing an IPM system.

Farmer 25 is indicative of most farmers in my research whose knowledge of pests is better than the beneficials.

F-25: We probably know a little bit about the pests that cause crop damage, and I for one and I am sure a fair few do not know enough about the beneficials.

Agronomists also admitted that although they could identify some of the important beneficials they lacked sufficient understanding to apply it in an IPM scenario. Ag-S-10 and Ag-S-7 are indicative of sales agronomists in my research sample. This factor was not discussed in any detail with independent agronomists.

ME: So how do you assess the beneficials in this situation?
Ag-S-10: It is easy enough to assess some of the beneficials...I suppose it is a learning curve...like I know what most of the beneficials are, but I am not 100% on which beneficials are doing most of the work for us in a particular crop. I sort of know, but I am guessing that at different times of the season and for different pests it is going to vary a lot, so it is probably not that easy.

Ag-S-7: I can identify the basic beneficials, but whether we are not educated enough to say well here is one of these, here is that, this is going to do whatever to these grubs, whether we know ourselves enough about what the beneficials are doing and I suppose populations of beneficials you need to control a certain level of pest infestation.
Many agronomists in my research have done formal IPM training. This appears to have increased understanding of IPM, but there remains too big a knowledge gap that creates too many uncertainties to risk advising an IPM strategy. Ag-S-13’s comment reflects those of other agronomists who have done similar training.

Ag-S-13: It probably comes back to my lack of understanding of what I could do...I probably do not understand how you create habitat for your beneficials to a large degree. I [did] that course with Paul Horn and I didn't learn how to do that there.

While there is an self-acknowledged lack of understanding about IPM, farmers and agronomists also perceive or believe that IPM lacks sufficient science to support its implementation. Again, this exacerbates the uncertainty and risk associated with IPM.

**Lack of evidence.**

This thesis does not examine the reality of any paucity of science that underpins IPM. But, whether it is belief or perception, many agronomists and some farmers in this research claim this paucity exists. While I do not endorse the sentiment that there is insufficient evidence to justify adopting IPM tactics, Sci-8 and Sci-9 give some credence to the notion that gaps in the scientific knowledge exist. Sci-9 implies also the link between a knowledge gap and the uncertainties of IPM.

Sci-8: The weed thing is way ahead of the invertebrate thing because the problems with weeds have been around longer and we know what we have got and what is resistant, etc.

Sci-9: It is hard to say, 'this is how you do IPM'. There are a lot of unknowns when you move away from chemical only control. Our knowledge about threshold and predator biology is patchy for many species.

Despite the above concessions, Sci-8 and Sci-9 are consultants who proactively encourage farmers to implement IPM. One would expect therefore that they find any risks with IPM acceptable. Sci-8 implies this with his following comment where he believes that his existing knowledge can provide a high level of certainty about the outcomes of any IPM scenario.

Sci-8: I think there is more predictability about implementing [IPM] actions now and where they will end up. I am basing this on all I have seen in the field and documenting it...So if I see a situation that someone wants to go in then I can go it is likely these are the outcomes.
Such confidence does not extend to agronomists and farmers. Ag-S-9 is referring to the use of economic thresholds underpinned by science and developed to help determine if and when an insecticide application should be used. His thoughts about the lack of science to underpin them reflect those of Sci-9 and therefore may be justified to some extent. Note also his memory of high crop loss because of reliance on these thresholds. This example of the Availability heuristic reduced his confidence and affected his future decision making.

Ag-S-9: There is not enough information regarding thresholds and understanding about monitoring. The research is vague when it comes to thresholds and how to use them. It is hard to put thresholds into decision making when there is the vague amount of research...We haven't got a yield penalty, we haven't got a dollars per ha loss of production. The agronomy industry has a low-moderate confidence in these thresholds. I have seen high levels of loss because of these thresholds. Whereas in a lot of weed research there are thresholds, there are exact results.

Ag-S-4 acknowledges a need to change management of invertebrates, but suggests that until he sees some convincing data that IPM will facilitate this he considers he is left with the chemical option.

Ag-S-4: I do agree we are probably knocking out our beneficials and we need to do something different to try and enhance our beneficials. But until something comes along the only thing I can do is look after our crops as best we possibly can.

Farmer 23 also perceives a lack of evidence, which may exacerbate or influence his "low risk approach" and is one factor impeding any change of attitude or behaviour about invertebrate management. The affect of Availability is also evident relative to his decisions concerning the use of seed treatments in canola. His memory of failed chemistry has created uncertainties about relying on seed treatment alone, despite his belief. It means he uses residual insecticides as well as seed treatment.

F-23: I am confident seed treatments alone will do the job but having seen earlier chemistry not work causing a very detrimental economic outcome I take a low risk approach. Some new and high quality research may convince me to try a different approach on some paddocks in the future.

It is hard to monitor and apply an observation to invertebrate management if you cannot identify the invertebrate, but as Ag-S-9 notes some perceive the science is too "vague"
to develop quantitative tools to assist management. Thus invertebrate monitoring is largely looking for pests species only, thresholds are just a guide and gut feel becomes important. These factors are examined next.

**Monitoring.**

Farmers emphasised lack of time as a key constraint to monitoring, but as it is not a knowledge related constraint, nor one that generates uncertainty, it is noted here only. When it comes to monitoring invertebrate pests, my data reveals the process is far from a precise science and places a considerable reliance on experience or gut feel to guide decision making, even where economic thresholds are available to help calculate economically damaging levels of pests (see chapter 3). Beneficial invertebrates were rarely considered in monitoring. The few known species were often noticed but their presence rarely affected decision making in any calculated way.

**Monitoring pests only.**

I recorded only two examples (one farmer, one agronomist) where beneficials were intentionally monitored and used in the decision-making process to manage the pests, and then only in specific contexts. The number of pests in a crop and gut feel (experience) are the primary influences on invertebrate management decisions. Ag-S-4's and Ag-S-9's description of monitoring and consideration of beneficials is indicative of farmers' and agronomists' reliance on gut feel to *get a rough idea*.

Ag-S-4: No to be honest I do not [monitor beneficials]. I do see beneficials and I do note that if I do see a shit load of beneficials I'll go OK we won't be spraying that paddock...I haven't seen it in too many paddocks.

Ag-S-9: You probably do not count them. You probably could, well you should, but I suppose, yeh, if I am consistently finding beneficials there that is good enough.

Decisions about when and whether to spray are context dependent. Although Ag-S-11 has one of the more considered approaches to monitoring beneficials, invertebrate management decisions are dependent on many variables and, as examined further in the next section, gut feel is often heavily relied upon. Ag-S-11’s first comment below acknowledges that in some contexts the presence of beneficials will affect his decision about whether to spray. His second comment below, however, appears to contradict this because he says he does not monitor beneficials and has no concerns about resorting to
broad spectrum insecticide. What it is indicative of, however, it that monitoring beneficials is rarely standard or actively done.

Ag-S-11: [In] a sweep net there might be wasps, some heliothis, some lady beetles. You look at those numbers and go, from a random sweep across the paddock, I found one heliothis, but I found a lot of other beneficials. I am not going to spray. I might come back in a week and sweep that paddock and go no, we have to do something here, the heliothis have increased and the beneficials haven't controlled them. So I go, we have to look at a spray.

Ag-S-11 uses the term "nuke" to mean applying a broad spectrum insecticide to kill everything.

ME: What about beneficials? Do you monitor for them?
Ag-S-11: No.
ME: But if you have a sweep net and you are using that...
Ag-S-11: A sweep net is different. Something earlier on where you are looking for your cutworms, lucerne flea, earth mites that will do you damage on your younger cereals. You look and go we have hit an economic threshold, he is running across the paddock, with the cost of the broad spectrum, we are going to nuke the lot.

Farmers 23 and 25 are indicative of farmers who will do some monitoring themselves, but note only the pests. Farmer 25 refers to his reliance on his agronomist for advice about monitoring beneficials, though implies it isn't standard practice.

ME: Is monitoring [beneficials] part of the plan though?
F-23: The normal things we are monitoring for is the things that are doing the damage, but if that were an option it is a discussion I would have with the agronomist. I would generally look to him for that feedback.

Farmer 25 links his inability to consider beneficials in his management strategy to his lack of knowledge about them.

F-25: No, we do not monitor [beneficials]. We observe a few in the field but we do not monitor them. We do not identify what numbers of beneficials...we do not know.

Thus the focus is on the pests only and when monitoring reveals their numbers reach what is considered a nominal or economic threshold (see chapter 3), the pests are usually sprayed with a broad spectrum insecticide, though some farmers and agronomists are open to the option of targeted insecticides where applicable and
affordable. The use of thresholds and the influence of gut feel is examined in more detail next.

**Thresholds and gut feel.**

Farmers do count invertebrate pests and make a visual assessment of plant damage, but in my research sample it is usually the agronomist that calculates the likelihood of economic damage and provides options and advice on management. Whether this advice is followed depends on farmers' values, worldviews and interpretation of the risk. Those who value natural systems (see section 7.4) are less likely to follow advice that recommends broad spectrum spray. Farmers 19 (1 and 2) are the only exceptions as they will monitor and assess the risk themselves, though will still run their thoughts past the agronomist for a second opinion. They are also exceptions as they are both former agronomists with tertiary training in agricultural science.

F-19(2): I sweep the net and get the count. We pretty much have in our mind what we want to do, but we often run it past [agronomist] to see what he thinks...

Economic thresholds exist for some broadacre pests, but not all. Most thresholds for insects in broadacre farming are nominal thresholds which are those where research has yet to establish a reliable relationship between pest density and yield loss. It therefore relies more on the experience of the farmers and agronomists (NIPI, 2014b). But whether economic or nominal, the use of thresholds is again mostly restricted to the agronomist.

In broadacre agriculture the use of thresholds is also varied and open to interpretation, which is possibly because of the predominant use of nominal thresholds. One consequence is an apparent greater trust in gut feel and local knowledge than the thresholds alone, which are often seen as flawed or unreliable. The threshold is merely a rough guide, or as Nuthall (2012) argues, they are merely learning tools to enhance gut feel. Indicative of this argument are Ag-S-11 and Ag-S-4, who make a subjective interpretation of the risk based on their own or interpretation of a threshold and their gut feel to generate advice for farmers.

Ag-S-11: You look at them [thresholds] and you understand, but you take your spin on them as well...You have got to work out, and sometimes it can be rough or it could be a guess...In your head. You see it takes time and when you get
more experience, you are in the paddock, and you go right that needs to be sprayed.

Ag-S-4: If you see more than about 20 [pest invertebrates] in a square foot, to me, that is enough numbers to warrant a spray because you know full well it is definitely going to decimate yield.
ME: Is that based on a formal threshold? Someone has done the science and said here you go.
Ag-S-4: It is a figure I came up with. It could be wrong, or right, I do not know. But basically it is a figure I work off.

There is also the feeling that the complex nature of a farm system is incompatible with the relative simplicity of thresholds, hence gut feel is perceived as a better guide. Ag-S-10 is one that perceives a farm system to be too complex to rely on formal thresholds.

ME: There are economic thresholds out there, how do you use them to determine when to spray, when to use a broad spectrum versus a targeted insecticide?
Ag-S-10: It is a whole number of things, but it is basically what you would call experience. That is a broad term, but you know, you have several different things you have in your head.
ME: So it is not a formula or program that you plug numbers into and it spits out an answer on whether to spray?
Ag-S-10: No, no because there are too many variables for that to happen.

Ag-S-9 emphasised above the perceived lack of scientific evidence to support the thresholds (section 7.2). His following comment expands on this adding that the inconsistent nature of monitoring means he will trust his gut feel before thresholds, but there is still analysis and reason applied to what he observes in the paddock. He also supports Ag-S-10’s thought that the simplicity of economic thresholds are incompatible with complex farm systems.

Ag-S-9: There is not enough information regarding thresholds and understanding about monitoring.
    When you engage with farmers about thresholds there is an element of gut feel that has to come into the equation...We cannot always go on the science and the thresholds.
    There are tools available to establish thresholds [hesitant, thinking], but...quite often they do not reflect what can happen in the paddocks... if you didn't put gut feel into that equation you would be wrong more times with your assessment that you would be right.

The way thresholds are used in many respects reflects how invertebrates are managed overall. The farmers and agronomists in my research relied a lot on gut feel or
experience and used it to get a rough idea about the risks of pest invertebrates. The lack of knowledge and uncertainties underpinned, or at least exacerbated, this. Similar behaviour is observed in different agriculture contexts (see Deguine et al., 2008; Llewellyn, 2007; McCown et al., 2006). Emotive heuristics did not completely guide decisions. Reason, analysis and reflection were also evident. With the agronomists above there is evidence that reason and reflection operate to some extent in unison with intuition. For instance, Ag-S-9 comments that, "if you didn't put gut feel into that equation you would be wrong more times with your assessment that you would be right." Where time permits, agronomists analyse what they observe in the paddock, consider the variables for that paddock at that time, and compare that to their experience and their interpretation of the science-based thresholds. As Ag-S-11 illustrated above, agronomists merge their formal learning with the informal—their experience. "You look at them [thresholds] and you understand...You have got to work out, and sometimes it can be rough...You see it takes time and when you get more experience..." (Ag-S-11).

Although learning is an integral part of adoption (Abadi Ghadim et al., 2005) that will also help farmers understand the uncertainties, it is simplistic to think that education to give farmers the knowledge and skills will correct the problem of poor IPM adoption. For instance, Llewellyn et al. (2004) surveyed Western Australian grain growers to get an insight into their IWM practices and their perceived value for weed management. They found that adopters and non-adopters of IWM strategies were equally informed, which indicates knowledge is not necessarily a factor in adoption, nor a dominant one. In the same sense, I do not consider the apparent knowledge deficit as a barrier to adoption as a barrier implies something in need of removal that, once removed, adoption (or altered behaviour) will follow (Dunn et al., 2000; Gray et al., 1997).

Some literature does refer to barriers to adoption and in many contexts these barriers exist (see Abadi Ghadim et al., 2005; Guerin & Guerin, 1994; Marshall et al., 2012). As noted throughout this thesis though, I argue that adoption, although a functional and important concept, should not be a primary objective for such complex contexts as IWM and IPM. I argue instead that a more important outcome is understanding the process of knowledge construction that is used to inform decision making that may or may not involve adoption.
The knowledge deficit has a strong influence on how farmers and agronomists perceive, understand and react to IPM's uncertainties and risk identified in this research. How it affects farmers' and agronomists' knowledge construction is complex. It is therefore important to explore the uncertainties and perceived risks, and to understand them and their role in knowledge construction and decision making about invertebrate management.

7.3 Uncertainty, complexity, risk

The uncertainties apparent in my research have consequences that will require more than knowledge acquisition to have any benefits toward farmers' and agronomists' knowledge construction and decision making about IPM. The consequences are based around agronomists' fear for their reputation and farmers fear of crop loss. For agronomists, the consequence is risk averse advice because they perceive the risks of IPM too high and the burden of that risk is on them to produce the best crop. They fear advice that ends in crop failure or a downgrade in grain quality will harm their reputation and career. Farmers also fear crop loss and have salient memories of when crops suffered damage because they failed to spray. The heuristics Affect and Availability are evident here and influence both farmer and agronomist decision making.

This section will give an overview of how proponents of IPM frame uncertainty, complexity and risk associated with IPM and how their target audience, farmers and agronomists, interpret and understand it. Farmers, it appears, interpret the uncertainties of IPM differently from the proponents of IPM, which has implications for extension and its communication with farmers and agronomists about IPM. The section will then examine the consequences of these uncertainties and their effect on decision making, the agronomists fear of reputation damage, and the influence of the heuristics, Affect and Availability.

Framing IPM.

The GRDC's fact sheets for farmers and agronomists inform them about IPM and encourage its adoption. The following passages from these fact sheets are indicative of how IPM is framed as a strategy that is effective, economic and environmentally sustainable:
Explore IPM options and spray only when necessary. This will reduce economic and environmental costs and preserve insecticide efficacy into the future (GRDC, 2012).

Reducing reliance on broad-spectrum pesticides improves triple bottom line outcomes (economic, environmental and social) (GRDC, 2009).

Similarly, Horne and Page (2008) use their book targeted at broadacre farmers and extension to emphasise that the knowledge exists to successfully implement IPM, albeit with expert help. This implies that sufficient uncertainties are understood and can be managed. Similar to the GRDC factsheets, they also promote the economic benefits of IPM.

There is sufficient information to allow interested farmers to put IPM into practice but realistically this will occur where there is collaboration with entomologists who specialise in it. (p.1)

Cultural controls cover different farming methods and can be very effective. (p.2)

The benefits that farmers should expect to see after adopting an IPM strategy include increases in quality and yield. This is simply because there should be improved pest control without the negatives of pesticide impact. There should also be economic benefits that go beyond decreased pesticide costs—such as sustainable control of many different pests and reduction in the use of hazardous chemicals that can affect workers. (p.4)

These publications positively frame IPM for farmers and agronomists: we have the knowledge and IPM is an effective, economic and sustainable way to manage invertebrates.

What is missing from these publications and other farmer-targeted engagement is any in-depth discussion about the uncertainties of IPM. Sci-8 and Sci-9 allude to their existence above. For example, Sci-9 refers to the unknowns of IPM.

Sci-9: There are a lot of unknowns when you move away from chemical only control. Our knowledge about threshold and predator biology is patchy for many species.

One attempted exception was a workshop on IPM organised by NIPI. Although the workshop was targeted at farmers and agronomists and about 60 people attended, only six people identified themselves as farmers and three of these also identified themselves as agronomists. About 20 people identified themselves in an extension role, the rest
were research scientists. In the workshop, researchers presented on varied topics about invertebrate management in broadacre agriculture. In contrast to the farmer-targeted literature, the sentiment and emotion in the discussions and presentations was an open acknowledgement about the lack of scientific knowledge on the behaviour of invertebrates, especially of slugs and snails, but this applied generally when IR was discussed. This led to discussion about the uncertainties of IPM when applied on the farm. I did not perceive negativity or fear about this lack of knowledge and associated uncertainties. It was more a frustration. The lack of farmers meant any discussion occurred almost entirely between research scientists and some of the agronomists. Hence an opportunity to engage farmers about IPM, the state of scientific knowledge and associated uncertainties failed to attract its target audience. This raises questions about this form of communication to engage farmers about IPM.

The following paraphrased comments from the presentations of different scientists are from my observation notes taken at the workshop. They illustrate the acknowledged uncertainty and the gap in scientific knowledge about IPM:

The problem with trials is they are extremely variable making it hard to get good data...There is some lack of understanding of [invertebrate] feeding behaviour.

I have been working 30 years on this. Started with no knowledge. Still, lots of unknowns remain.

It is hard to show the effect of management tactics. There is a lot of noise, variability in the data.

There have been many experiments though they yield little in terms of helping management.

There has been one release of a fly [as a biological control agent for snails], but it is not working well. [We] are still trying to understand why its effect is minimal.

The workshop also had a discussion (Q&A) session with a panel of researchers who took questions and generated a discussion with the audience. I recorded the following (paraphrased) commentary:

Panel member (question directed to audience): How often are we uncertain about the cause of damage (from invertebrates)?
Audience (agronomist): There is too much other stuff happening. We do it with gut feel, for example, we operate on 50mm of rain per month and make decisions on rain.

Audience (scientist): How do you go about the logistics of monitoring. How often, how long, etc?
Panel member: Tricky to know. For instance, viruses come and go and we do not have a good understanding of it all. If you see aphids, it might be too late regarding viruses.

Audience (agronomist): How much do we know about the ecology of new insect pests?
Panel member: We have great information on the old ones. We haven't looked at the newer pests yet. We do not understand the basics...There is a lack of ecological knowledge on the beneficials also.

Despite these uncertainties the scientists presenting at the workshop were all IPM proponents and encouraging farmers to implement IPM tactics. But their commentary regarding uncertainties stands in contrast to the farmer-targeted literature about IPM.

**The farmer perspective.**

A contrast exists also between the message and framing of the farmer-targeted literature and how farmers and agronomists interpret it. This difference in interpretation is reflected in the following farmer and agronomist comments, which focus mostly on the perceived uncertainties and inefficacy of IPM:

Farmer 26 has attended IPM courses, yet there are still perceived uncertainties—the paucity of knowledge about the beneficials and their role in managing the pests—that make the risk of IPM unacceptable.

F-26: There is nothing really out there to say these are the beneficials in this crop and these are the ones that will take out these particular predators...And that is one of the hardest things with IPM. There is very little known about the beneficial side of IPM.

Farmer 6 is referring to how he does not monitor beneficials. He too has doubts about the efficacy of beneficials.

F-6: You would if you could [monitor beneficials], but I do not think in our environment they are controlling them enough without a fair financial loss. I might be wrong.
Ag-S-7's and Ag-S-10's perception that managing invertebrates has greater uncertainty than managing weeds is reflective of most agronomists in my research. This includes the perceived unpredictable nature of invertebrates and the difficulty in trying to plan for them. Ag-S-7 also notes that for him, the uncertainty makes it difficult to avoid using chemicals. Ag-S-7 can only deal with what is in front of him, which is a probability of whether wireworm is present or not. His conclusion is driven by the potential consequences and uncertainty and therefore the assumption that wireworm is present. The result is the decision to use insecticide. This is indicative of how most farmers and agronomists in my research approach management of invertebrate pests.

Ag-S-7: You have a rough idea of what weed spectrum you are going to face each year [and] a pretty good idea of what chemicals you are going to have.
But I just find things like the pests is you are assuming all the time. So I can say, we may face this false wireworm, we may not. If we do face it and we do not treat for it there is the potential to lose anywhere between 50-80% of your crop. There is also the chance that if we do not treat and there is not false wireworm there you will have no issue.

Ag-S-10 also perceives greater uncertainty with invertebrates compared to weeds. Again the uncertainty is the unpredictable nature of the invertebrates.

Ag-S-10: Weeds, as much as you have to get things done quick, within a timeframe; you know what is going to be there because they do not move.
Pests, we've had army worm [this year]. Now all the conditions say they shouldn't have been there and there hasn't been an outbreak of army worm for about 20 years...[laughs] it is a big unknown.

Thus farmers and agronomists perceive many uncertainties in IPM as unknowable or unquantifiable. Scientists or proponents of IPM consider many of these same uncertainties as quantifiable, known or at least manageable. The risks they perceive are those they can attach an outcome to based on probability (see Frewer et al., 2003; Riesch, 2012). In a similar outcome, Sjöberg (2001) too found differences between experts and the public, in this case it concerned the perceived risks of a nuclear waste repository. Sjöberg found the public much more skeptical about the completeness of the science on this issue than the experts. Although a significantly different context, farmers in my research are uncertain about the ability of the beneficials to manage the pests. Agronomists additionally are concerned with their ability to predict the behaviour or presence of the pest. These unknowns make it hard for agronomists to plan. What farmers and agronomists are certain about is that insecticide works. There is a recipe
and it is simple. In contrast, science and IPM proponents say the evidence shows that IPM works, it is cost effective, safer and sustainable long-term. Similar to Thompson and Scoones' (1994) argument, farmers and agronomists use different frames of reference when they consider IPM. Wynne (1992a) too notes that social judgements on the science and its validity mean science and the public interpret uncertainties differently, and any risk interpreted by science comes with an imposed meaning that may not be shared.

ResAg-8's experience with a farmer at an IPM workshop sums it up. The farmer perceived that chemical control provided relative certainty. With IPM there is too much uncertainty and risk.

ResAg8: I am spraying and I have control. He [farmer] is going I like the concept of [IPM], I just cannot see how I can make it work. And that was my first real introduction into this complexity stuff. There is a huge amount of risk, I lack the confidence and there is no recipe.

ResAg-8 talks about complexity in the context of the farm system and its effect on the management of invertebrates using IPM. Barr and Cary (2000), also say complexity hampers adoption of IPM. But every day farmers manage a complex system—their farm (Gianatti & Carmody, 2007; Jackson, Quaddus, Islam, & Stanton, 2009; Kingwell, 2011). As a consequence, farmers make complex decisions every day. McCown et al. (2006) make a distinction between complexity and uncertainty and say that it is uncertainty rather than complexity that makes managing farms difficult.

I argue that farmers can handle complex information and Farmer 26's comment below illustrates this. I asked him what he would want to know about beneficials, what questions would he ask to have confidence to at least trial IPM. His answer revealed that a key constraint is his lack of knowledge but importantly it revealed that complex knowledge is not a barrier, if anything it is required when communicating with farmers about this.

F-26: [long pause to think] I need to know how to ID the beneficials; what numbers [of beneficials] do I need to take out a number of pests. Life cycle of insects is another issue too, how long are they going to be there and how much damage are they going to do in that time frame, and it is one of the issues we are having with false wireworm in our trickle tape. We can put Chlorpyrifos
[insecticide] down and take them out, but how long before we have another lot come back in again?

Through his own research and observation, ResAg-8 supports this farmers’ need for complexity. He perceives farmers want this level of detail because at the moment it isn't being communicated to them and they are left to judge the risk for themselves. Extension, he believes, is communicating risk poorly.

ResAg-8: Exactly. A farmer wants to know this [uncertainties, risk complexity]. Dead right. This is the disconnect where extension is at, talking about risk. So the farmers work it [risk] out themselves and that is why the farmers learn this stuff and we realise this from talking to each other, ie I tried that and it didn't work. Why is that? It was too dry, not enough sub soil moisture. They learn it from each other and that is how they put their risk management strategies together, not from most extension.

Uncertainty is inherent in complex systems such as farms, and problems such as invertebrate management (see Darnhofer et al., 2010; Mitchell, 2009; Snowden & Boone, 2007). In my research, uncertainty is a consequence of the knowledge deficit, but my data supports the notion that complexity and risk themselves do not impede knowledge construction about IPM. Most farmers understand the risk as they interpret it and are prepared to bear the burden of that risk. In the case of IPM, it is the perceived uncertainties that affect farmers' and agronomists' knowledge construction and decision making. Without knowledge, though, farmers and agronomists are unable to assess and interpret the uncertainties, hence the farmer and agronomist's learning journey remains flatlined.

We access and interpret knowledge to understand the uncertainties and the risk they pose to our complex system (see Renn, 2008). The potential consequence of IPM's uncertainties for agronomists—a damaged reputation—is examined next.

**Risking reputation.**

All agronomists in my research revealed that philosophically they oppose the concept of the insurance spray, which is where insecticide is used as a preventative measure against potential damage from invertebrates (see chapter 3). This contradicts what appears to be a standard recommendation on many agronomists' reports to farmers: an insecticide application—the insurance spray. This section examines this contradiction and the conflicting emotions underpinning this. The most apparent motivation in my data to
account for this contradiction is agronomists' fear for their reputation. What underpins this is again, a perceived uncertainty of IPM. There are two main factors that exacerbate this uncertainty and increase agronomists' perception of risk: salient memories of failed crops and agronomists' apparent struggle to meet farmer expectations to protect their crop, which includes a perception they carry a disproportionate burden of the associated risk to achieve this. The fear of crop loss and the salient memory are examples of Affect and Availability.

Ag-S-7 and Ag-S-9 provide a sense of the conflicting emotions and reasoning behind the contradictory behaviour of agronomists. For instance, Ag-S-9 does not agree with insurance sprays but is also not prepared to have a farmer lose their crop. His understanding of how to protect the crop conflicts with his perception that he bears the burden of risk for the crop.

Ag-S-9: Many farmers will want to use an insurance spray with canola. I do not agree with it. I will use a perimeter spray. But as an agronomist I am not prepared to have a farmer lose his crop and I should not have to bear that burden of risk. The farmer should be able to understand and assess the risk and be responsible for this.

A lot of his motivation to reduce the risk to a crop is driven by fear for his reputation. He also notes that there is strong farmer emotion, beliefs and attitudes to contend with that affect how he manages the expectations of a farmer. Once again this emphasises the complexity of the issue.

Ag-S-9: We haven't really talked about the farmer's beliefs, the farmer's attitude to risk, and my risk of a farmer handling or not handling a problem in the right manner because I know what is going to happen. It is going come back to me and it is going to go to all his mates in the farming area and all of a sudden, my name is dirt.

Ag-S-7 reveals a similar sentiment, acknowledging the preference to use IPM tactics but he can justify not applying them because of the need to meet farmer expectations and protect his reputation. Implied in his comment also is his uncertainty about IPM and consequently his inability to be definitive about the risks of IPM.

Ag-S-7: [With broad spectrum spray] you are not only damaging the beneficial side of things, you are potentially targeting pests that aren't actually going to be a problem, but from our point of view, it is so hard because of something we
haven't ticked off it comes back to us because the farmer will go well hang on, you didn't tell me to put this insecticide out. And I go, I was hoping, HOPING, that with an IPM approach that we were going to have beneficials there and that it wasn't going to be an issue. Well straight away they are looking at you and going hang on, this is your job to help me grow the best crops.

A lot of Ag-S-7's motivation also stems from a fear for his reputation, which he is more explicit about here. It becomes an incentive and a further justification to avoid IPM.

Ag-RS-7: Ok yes, long-term they are better off spraying these more beneficial insecticides or trying to encourage beneficials to do the job, but I guess you are always worried that if that does not happen there is going to be a bit of egg on my face because I am advising them what to do.

Ag-S-9 and Ag-S-7 are indicative of a number of agronomists in my research that exhibit a form of cognitive dissonance where they attempt to reconcile their personal position that understands insurance sprays and use of broad spectrum chemicals are unsustainable or inappropriate with their conflicting advice to farmers that recommends chemicals as the frontline tool. As Ag-S-7 and Ag-S-9 imply, many of the agronomists in my research justify this recommendation to spray because they perceive they need to manage farmer expectations and because they bear the burden of risk for the crop. Intimately linked, however, is the more dominant reason for this contradiction, their desire to protect their reputation.

Farmers 5 and 13 make it apparent they too believe agronomists worry about their reputation and that this affects their advice. Farmer 13 is explicit in stating this. One point to note is that Farmers 13 and 5 use independent agronomists so the fear of reputation damage is unlikely to be restricted to sales agronomists. Note also that both farmers tend to ignore the recommendation to spray. Farmer 5 and 13 are coded as farmers that value natural systems, a concept explored in chapter 6.2 and further explored later in this chapter. These are farmers who, short of facing a crop wipeout, will avoid using broad spectrum insecticide, because of values that put a proportionally high value on natural systems operating on their farm.

F-13: Every year he [agronomist] puts an insecticide in their recommendations, but we do not follow it...The agronomist has his job on the line. If the farmer has a crop failure, he will probably use a different agronomist, so the agronomist will try to cover all situations.
F-5: He'll [agronomist] have the recommendation to include the insect spray and I just won't put it in... If there is some problem that comes up I guess he can say then to me, well I told you to use the insecticide.

Some agronomists such as Ag-S-13 are explicit about their need to tick the boxes to ensure they cover themselves against risk of crop damage and their own peace of mind that they have done everything right. It removes the burden of risk back onto the farmer.

Ag-S-13: Some farmers are reasonable and will say yeh I know I didn't do that when you told me to do it and it is my fault. Some people do not operate like that and say my crop has failed, your fault. The insecticide is offered in my program as a default, so that I know that it is done, I can cross it off my list. I can move on and not worry about it.

And again with Ag-S-7. He describes the use of a residual bare earth insecticide for canola applied just after sowing. Its use ensures that box is ticked. The farmer can see the agronomists are doing everything they can and Ag-S-7 is insuring himself against any risk. In doing so he protects his reputation.

Ag-S-7: Yup, this is like a week or 10 days after you have sown it. That allows you [farmer] to know that I have put protection there, I have done everything right, the crop will get out of the ground now.

So far, my data indicates that in the context of invertebrate management, agronomists perceive a lot of farmers defer risk to them. Should it all go wrong, the farmer will talk to other farmers about their agronomist's performance and put the agronomist's reputation at risk. Ag-S-13 above suggests only "some" farmers are like this. But how many are some? When I questioned the agronomists in more depth about this, they revealed only a small minority of farmers fit this description, but it is those few that the agronomists fear will put their reputation at risk. As a consequence such risk averse advice becomes standard across most of their clients. For instance, Ag-S-9 thought this proportion of his farmer clients was only about 10%, but those 10% were enough to justify his risk averse advice to a wider clientele.

Ag-S-9: Only about 10% have this attitude. [Long think about this] But I do not want any. It is my reputation at stake.

There are exceptions because like all agronomists in my research, Ag-S-9 talked about each farmer being different and his need to understand them and to manage their
expectations accordingly. Thus, while Ag-S-9 is not prepared to take on unnecessary risk, there are a select number of his clients who he is comfortable to advise differently, farmers who he knows desire a more IPM-based approach and will therefore accept the burden of risk that would normally fall onto the agronomist.

Ag-S-9: What I suggest to one grower may not be the same as to another grower, even if the scenario is exactly the same, the personality of the farmer is different, and the advice will be different because I have to take on board a bit of risk and if I am not comfortable with that risk, or the farmer is putting the risk on me then I am not prepared to wear the consequences.

Some agronomists' fear of reputation damage also comes from recent memory of a crop failure caused by a farmer neglecting to spray. This is relevant to farmers also. This fear and experience of crop failure are examples of the heuristic influences, Affect and Availability, and are discussed in the next two sections.

Affect.

An agronomist's fear of a reputation damage is an example of the heuristic, Affect. Affect is a form of emotion experienced as feeling (Epstein, 1994; Loewenstein, & Weber, 2001; Slovic et al., 2004; Slovic, 2000). Dread is described as a major component of Affect and, to some extent, it is apt here. It is defined by the extent of perceived lack of control, feelings of dread, and perceived catastrophic potential (Peters & Slovic, 1996). This section examines the role of Affect on farmers' and agronomists' decisions making.

Sjöberg (2003, 2004) adds "Severity of consequences" as an additional component to Affect. He argues that most of the dread items refer to severity of consequences rather than emotion. In the context of my research, a severe consequence is crop failure, which for farmers, given their emotional and financial stake in their crop and farm, is an understandable influence on their decision making.

Most of this severity of consequence in the context of IPM though is attached to high value, high risk crops such as canola. Farmer 8's comment below refers to his experience with a canola virus spread by aphids that threatened crops in the region at the time. He decided to spray based on the perceived threat rather than actual knowledge of whether the aphid and virus were present in his crop.
F-8: [Agronomist] has offices over in Hopetoun where they had total wipeout [with canola], so they were on high alert. I had 400 acres of irrigated canola in. At the time that decision had to be made it [canola] was just up, so you have a very fragile plant; there is no second go at it. That 400 acres would have been about $220,000 at the end of the year... all we knew was that it [virus] goes awfully quickly through the crop. From [agronomist's] experience over in Hopetoun and Buelah the canola really got a flogging. I just ran with it purely on the dollars.

Agronomists too, are influenced to varying extents by the consequence of crop failure. Ag-S-7 is one example.

Ag-S-7: If we do face it [wireworm] and we do not treat for it there is the potential to lose anywhere between 50-80% of your crop.

But as noted already, the more severe consequence for agronomists is damage to their reputation and credibility should that crop fail. It is this consequence that has the greatest motivation on their advice about invertebrate management.

**Availability.**

A second heuristic influencing decisions in this context is Availability. Availability or salient memory (see Hastie & Dawes, 2010) is apparent for a number of agronomists and farmers and is largely linked to a failure to apply insecticide, or an ineffective application that resulted in reduced crop yield and loss of income. For instance, experience with failed chemical application means Farmer 23 is not prepared to risk leaving out the use of residual insecticide in canola, despite his belief that seed treatments alone should be effective.

F-23: I am confident seed treatments alone will do the job but having seen earlier chemistry not work causing a very detrimental economic outcome I take a low risk approach.

Ag-S-7 sums up the experience of agronomists in my research.

Ag-S-7: I've had people that haven't sprayed a bare earth for false wire worm and had a crop completely wiped out. Now if I said to them [farmers] the next year, now do not spray...once it happens once with a farmer, they learn.
Ag-S-9 recalls a similar scenario with one client, but specifies it was lack of time that meant the insecticide didn't get applied as recommended, but the farmer's memory of severe loss meant that the following year insecticide was applied.

Ag-S-9: I advised a farmer who had not used a bare earth residual to monitor invertebrates in canola over the next 2-3 weeks. He didn't do it. Lack of monitoring because of time led to this example of high loss because he didn't apply the residual on the canola. He does not want to experience this again.

Memories of crop failure influence future action. As noted, "they learn", or wish to avoid repeating the apparent mistake. The future action is usually use of an insecticide. Farmer 21 has values and worldviews that make him a reluctant user of insecticides despite gentle urging from his agronomist. Regardless, his experience of partial crop loss has made him more risk averse and thus wary about relying on seed dressing, and more inclined to resort to insecticide.

F-21: We did get hit pretty bad at the beginning of this season with red spider and lucerne flea...she [agronomist] said you will have to spray and I happily went and sprayed in that instance...I would like to be flexible enough to wear a bit of damage, but I get nervous...Last cropping season we had a lot of lucerne flea and I thought...it will be right...basically the patches where we had the lucerne flea in the canola got wiped out and the canola did have a seed dressing on it and that has made me a bit wary about relying on seed dressings for lucerne flea and last year's experience has made me a bit nervous about wearing too much damage.

Ag-S-4's memory of a one-in-10 year insect population explosion is enough to justify his use of chemical as a protection against crop wipeout. Ag-S-4's inability to "pick" the outbreaks are another uncertainty that results in risk averse advice.

Ag-S-4: I do it [advise insecticide application] as a standard thing because I have seen paddocks...and look I believe with what I have seen over the years, especially around this year, we seem to have a 1 in 10 [year] blow out of insects...good luck trying to pick it, so I normally take in the protection.

The above comments show the varied contexts that apply to the influence of salient memories. Uncertainty, values/worldviews and time affected the decision to spray or not, but in each case the experience of crop failure resulted in the risk averse response of resorting to insecticide in following years.
My analysis of the evidence shows the significance of farmers’ and agronomists' lack of knowledge, how it creates uncertainty and in turn affects the perceptions of risk of IPM and consequent decision making. Distinct from this are other motivations that set IPM apart from IWM. These are largely driven by a set of values, worldviews and attitudes that are not apparent when the farmers in my research consider weeds. In some contexts, this is also applicable to the agronomists.

7.4 IWM and weeds versus IPM and invertebrates

I argue that every farmer and agronomist in my research sample is aware of or understands most of the different IWM tactics available to manage weeds and HR. They also understand the known uncertainties and risks associated with these tactics. The same cannot be said for IPM. I did not measure farmers' and agronomists' awareness and understanding in any quantitative way. It is my subjective assessment based on my qualitative data and analysis of the relevant literature. The key point I make in this section is that farmers (and often agronomists) interpret the science, risk and uncertainty of IWM differently from IPM. In this section, I examine these differences, and the key differences in how weeds and invertebrates are framed by science, IWM and IPM proponents, and the media. I contrast them against farmer attitudes and behaviours.

The different motivations for IPM and IWM are examined first. Understanding the differences is important context for any engagement with farmers about IPM and IWM.

IPM and IWM.

Farmers are motivated to adopt IWM tactics largely because of the HR threat. Most farmers in my research have or suspect HR in weeds on their farm, or are aware it is in the district. Ag-S-7 is explicit about this when I ask him, what does he perceive as the main motivations for his observed recent increase in the use of cultural weed management practices?

Ag-S-7: Weed resistance...Because we are seeing a lot of HR. You spray a paddock with Roundup and you get stuff that won't die.

In contrast, IPM, or at least the understood need to implement it, is motivated and driven largely by values and worldviews about the perceived effects of insecticides on
human health and the environment. These factors are not evident with weeds and herbicides.

There is a concrete reason for the relative aversion to insecticides. Farmers perceive insecticides are more toxic than herbicides. Farmer 23 and ResAg-8 express a common sentiment.

F-23: In canola we would use pesticides [insecticides], they are pretty nasty, they are effective, I just do not particularly like using them.

ResAg-8: When I am using these sorts of insecticides at home, it is full respirator and protective clothing, it stinks…it is horrible stuff.

However, the more salient, yet abstract motivations that influence farmer decision making about IPM and invertebrate management are linked to farmers' values and worldviews. These can be defined within two main concepts that emerged from my data: a higher moral value for invertebrates and a value for natural systems. They are outlined below.

**Moral value on invertebrates.** Farmers, at least, place some tacit moral value on invertebrates that is not applied to weeds. Farmers framed this argument around notions that insects are closer to humans or, despite their knowledge to the contrary, that plants are not living things. Some farmers struggled to articulate this tacit understanding.

**Valuing natural systems.** All farmers in my research exhibited values, worldviews and attitudes that reflected a value of natural systems. Natural systems are those ecosystems operating within and outside of the farm system. Grube, Mayton, and Ball-Rokeach (1994) describe a value hierarchy where values are ordered in rank of importance. In this sense, some farmers placed their value of natural systems high enough in their value hierarchy for them to forgo use of broad spectrum insecticides, unless serious crop loss was imminent. This also meant there was a greater preparedness to accept some crop damage from invertebrates before resorting to a spray. There is, however, a limit to this acceptability of crop damage, or risk. A high risk crop such as canola is one example where most farmers who place a high value on natural systems will still use prophylactic broad spectrum insecticide.
How these two concepts affect perceptions of IPM and invertebrate management are examined in more detail below.

**Moral value on invertebrates.**

Farmers' values, worldviews and attitudes underpinned the moral status they placed on invertebrates and the natural systems. Many farmers struggled to articulate the aspects of invertebrates that meant they were reluctant to use insecticide on them, but it was usually expressed along the lines of a perceived difference between animals and plants, or a need to work more with nature and that somehow our scorched earth or kill all approach was wrong and doing harm. This latter thought is expressed more by farmers coded in 'Valuing natural systems'.

Farmer 9 exemplifies the difficulty that farmers typically had in articulating their thoughts about invertebrates and how this affected their management.

F-9: I do not like using a lot of insecticides, so you weigh that up as well. Sometimes you just have to—it becomes obvious.
ME: Do you have the same aversion to herbicides?
F-9: No
ME: So what is the difference?
F-9: That is a good question. I suppose that thing in the back of your mind is that HR that you are trying to steer clear of.
ME: You also get resistance in insects...so the same principle applies.
F-9: That's right. That's strange isn't it. I dunno. You have made me think about that now [laughs].

The farmers who could articulate their feeling expressed them in ways similar to Farmers 12 and 13 who had a tacit understanding that invertebrates were somehow different to plants.

F-12: I do not see herbicides as harmful to living creatures, I suppose. Insects, people...You do not see a plant as a living creature and an insect is, I suppose.
F-13: Insects are closer to humans in what we are trying to kill. With an insecticide we are trying to kill an animal.

Valuing natural systems appears to be the more powerful of the two heuristics and is explored next.
Valuing natural systems.

Farmers are largely making reference to the natural systems operating in their own farm but their conversations indicate that they have similar sentiments for natural systems generally. The farmers place an intrinsic value on these systems; that they have a role to protect and facilitate the function of these systems, and this is somehow right.

I did not objectively measure the value, but six of the 26 farmers in my research ranked their value for natural systems high enough that meant they were less likely than other farmers in my research to use broad spectrum insecticides. Again, I did not measure knowledge in any quantitative way, but these same farmers appeared to have a similar knowledge about IPM as other farmers in my research. It was the higher ranking of their value for natural systems that set them apart; a value that acts as a heuristic when it come to decisions about use of broad spectrum insecticide. In all other respects, these six farmers managed invertebrates in similar way to the others in my research.

Sci-8 defined these six farmers as the "low hanging fruit". Then there are "the rest". Sci-8 is an IPM consultant and researcher. He is also a farmer and is personally motivated by environmental concerns relative to agricultural sustainability.

Sci-8: I do not see it [IPM] as gaining huge momentum. It has picked out people that are inclined that way and that has pretty much covered them for now and then there is the rest.

The heuristic, Affect is also apparent in many comments as values and worldviews are linked to emotion and feeling (Loewenstein, & Weber, 2001), which in this case is linked to a feeling that we are doing harm to the farm system and wider environment. Farmer 8 has a philosophy that we should work with nature not against it. He has strong feelings about "killing everything" that applies to systems on and beyond the farm. But as established above, Farmer 8 also resorted to using an insecticide when a potential risk from a virus rather than actual evidence of its presence threatened his canola crop. This illustrates the limits to the influence of this value.

F-8: The idea that you are going to kill every bad guy [pest invertebrate], you are kidding yourself...Now I might be wrong, but I am not convinced by the kill at all costs...It might be partly just the way I see the birds and bees and the whole environment. The idea you can totally control it...I am a bit philosophically opposed to killing everything.
Farmer 13's feeling about insecticide clarified when he experienced with his own \textsuperscript{4} \textit{Silent Spring}. This made him think something is inherently wrong with how we use insecticide.

F-13: The initial reason I said insecticides are no good is because in Moree in the late 1980s—cotton country—on 1 October every year they start spraying insecticide and they might do 10-12 sprays per crop each year. All you smelt was insecticides every day. On 30 September you would be covered in flies. Come 1 October there wouldn't be a fly in the sky. I said I do not want to go down that path.

Affect also expresses itself in the higher level of risk these farmers are prepared to accept when it comes to crop damage. Where many farmers in my research would spray, these farmers are prepared to wait longer and see what happens, and potentially accept a certain amount of damage to the crop. They will still spray, if serious crop loss is likely, which is an acceptable IPM strategy.

Farmer 5 is typical in his acceptance of a certain level of crop damage from invertebrates that achieves "a bit of balance in life on the farm with the ecosystem". Farmer 5 is also typical of most farmers who rank this value high and some also who represent the rest where they follow their agronomist's advice on herbicides, but often ignore the same advice for insecticides. Farmers 21 and 9 below are examples of this also.

F-5: [Agronomist] will come out and tell me I have to spray for insects, and I just do not do it. I do not think it is a problem. I haven't sprayed for 10 years. I mean the insects will be there. They might take out a patch, but if they are not totally taking out the paddock, I'll just ride it out. Up the back of your mind you are thinking...probably try and keep a bit of balance in life on the farm with the ecosystem.

Farmers 21 and 9 are not coded under valuing natural systems, but are examples of how farmers will often ignore agronomists' advice on insecticide, though ignoring in this case usually involves some form of liaison with the agronomist. Farmer 21 is one of those farmers wavering between the farmers who make up the rest and those coded as valuing natural systems. Farmer 9 shows again how agronomists do not monitor

\textsuperscript{4} \textit{Silent Spring}, Carson, Rachel (1962). Carson documented the effects of insecticides on the environment.
beneficials and rely on pest numbers as the primary decision-making tool for decisions about invertebrate management.

F-21: The likes of your ladybirds and so on...I do not like killing them...If we have an issue with an insect there is a lot more to and fro between us [agronomist and himself]. She leans towards using the chemical option whereas I back off on the chemical side. But if [agronomist] had said there were heaps of grubs and they will cause a major downgrade then I probably would have gone with the $4/ha [broad spectrum] spray.

F-9: No we do not always follow [agronomist's] recommendations. For example, we have been chasing the Diamond Back moth grubs in the canola and she would have said make sure you are checking regularly for DBMs and if they get to such a level then you can spray. I do not like using a lot of pesticides, so you weigh that up as well.
ME: Do you have the same aversion to herbicides?
F-9: No.

As noted already the uncertainties of IPM still place a limit on how much risk these farmers will accept. Five of the six farmers coded under this concept still resort to the use of residual and broad spectrum insecticide on high risk crops such as canola.

Farmer 5's response is typical, despite his claim above stating he hasn't sprayed an insecticide for 10 years. There is almost a mental separation between spraying invertebrates they know are in the crop and for which the risk can be assessed, and the use of a prophylactic spray in high risk crops such as canola where it cannot be known what invertebrate pests are present and therefore the risk cannot be assessed. The severity of consequences (Affect) has a strong influence in this context. It emphasises again the effect lack of knowledge and uncertainty has on knowledge construction and the ability to manage the uncertainty.

F-5: I will put insecticide on lucerne and canola when I first put it in the ground to get it up, but after that I rarely spray.

Where the abstract motivations, Moral value on invertebrates and Valuing natural systems are apparent it seems that farmers use a combination of reason and emotion to analyse and make decisions. According to Epstein (1994) and Slovic (2000), emotion is usually associated with rapid, heuristic-based mental shortcuts. Roeser (2010), however describes moral emotions that can be a source of reflection and practical rationality. Rather than such emotions being spontaneous, they can be the result of a long process
of reflection and intertwined with complex, long-lasting narratives, traits more characteristic of analytical thinking. Farmers describe moral emotions, for example being "philosophically opposed to killing everything" and prescribing a higher moral value for invertebrates than weeds. These emotions operate alongside and sometimes in contention with experience of crop damage and the moral and practical understanding of the need to minimise chemical use. I argue this facilitates what Roeser describes as a process of analysis and reflection that becomes part of many farmers' narratives that influence their decision making about invertebrate pest management.

Rather than a contrast between weeds and invertebrates, the next section examines the similarities that exist between farmers' risk perceptions of HR and IR, and contrasts them against how these risks are often framed by the GRDC, proponents of IPM and IWM, and some of the media.

**HR and IR.**

Increasing resistance to chemicals used to manage weeds and invertebrate pests has prompted scientific organisations and industry, for example, the GRDC, CSIRO, AHRI and CESAR, to urge farmers to adopt IWM and IPM as effective strategies to manage chemical resistance. Scientists and proponents of IPM and IWM, including research agronomists in this instance, frame the threat of resistance in ways that are at odds with how farmers and some agronomists in my research sample interpret it. This section examines these differences.

Although rarely framed as an approaching Armageddon, research agronomists, some media and other farmer-targeted literature that includes factsheets and training manuals (see below), tend to frame chemical resistance as an imminent disaster should farmers fail to adopt IWM or IPM. The messages for both HR and IR are framed around the following concepts that are discussed further below:

- **Sense of urgency to adopt;**
- **HR/IR will affect farmers' bottom line.**

The extracts below from the farmer-targeted literature, media and research agronomists participating in my research emphasise the above two concepts.
**Sense of urgency to adopt.**

This is the most prominent message and it is framed around the following threats: farmers are losing their key tools (chemicals) to manage weeds/invertebrates, and disaster is on their doorstep if they fail to adopt IWM/IPM and proactively manage the problem; there are no new chemicals with new Modes of Action (MOAs) likely to replace existing chemicals for some time; farmers need to adopt IWM/IPM to conserve the existing chemistry; and HR /IR is increasing at an alarming rate.

The first quote below is from an industry-funded website: *Diversity cannot wait.*

Herbicide resistance is a challenge no farmer can afford to ignore. On many farms, Australia-wide, it is already having a significant impact on farm profitability through reduced grain yields, and increasing the cost of weed control. In some areas it is even threatening the viability of winter cropping as we know it. (Bayer Crop Science Australia, n.d.).

Herbicide resistant weeds represent the single largest threat to Australian and global food security (Young, 2013, p.2).

Red-legged earth mite resistance to all known chemical control methods is just a matter of time in the eastern states, an expert has warned. ...“Reports of resistance were spread over thousands of kilometres…What was alarming was the rate of which it [resistance] spread (Webster, 2016).

This loss of glyphosate’s effectiveness is creating great concern in industrialised farming systems globally.

    Research and farmer experience have shown that failure to adopt IWM leads to herbicide resistance
    In the intervening period herbicide resistance has become far more widespread, reducing the effectiveness of a wide range of herbicide modes-of-action (MOAs) (Storrie, 2014, p.7).

ResAg-01: Weeds and pests we do not have answers for...the answers aren't just take it off the shelf and apply it. That is why it is hard and why the problem is becoming greater and greater. Every year the problem is getting bigger.

ResAg-6: There is some immediacy now though as there is good data...that says our herbicides are failing rapidly and you look at the projection of that and in a few years some of the herbicides we rely on now won't work. It is a fairly easy picture to paint. We are heading for a cliff.

The exception among research agronomists was ResAg-7 whose concern, at least about HR, reflected more closely the concerns of farmers.
ResAg-7: We can change crop type, change herbicide group, put grazing in there, we can cut for hay, we can desiccate. I can give you a lot of techniques to slow the process down. But there is no good evidence to say the whole [resistance] thing is going to blow up.

**HR and IR will affect the bottom line.**

This concept is framed around the perception that adoption of IWM and IPM has financial, environmental and social benefits. Non-adoption will put these benefits at risk.

Herbicide resistant weeds are becoming increasingly common, and resistant weeds bring new challenges to the farm business, particularly for the bottom line (Senneker, 2015).

Explore integrated pest management (IPM) options and spray only when necessary. This will reduce economic and environmental costs and preserve insecticide efficacy into the future (GRDC, 2009).

The above extracts paint a grim, yet optimistic picture: resistance poses a high risk to cropping, yet there is hope if farmers adopt IWM and IPM. If they do not then farmers are "heading for a cliff" and disaster looms. Farmers too understand and accept the risk resistance poses, but their concern about it is minimal, bordering on apathy for some. I make a distinction between risk and concern that I define below. Following this, I use farmer comments to examine the significance of this difference.

Risk as defined by Fox (1999) and Jasanoff (2012) appears in two forms: the quantifiable form that calculates probabilities of harm to productivity and profitability, and the socio-cultural form that is subjective, socially constructed and prone to socio-cultural influences. How I rank risk in this research is subjective and based on my conversations with research participants. I define a farmer's perception of high risk as one where the farmer considers there is a high probability of serious harm to farm productivity and profit. Low risk is defined as what a farmer perceives as a negligible probability of serious harm to farm productivity and profit. No farmers considered the risk of HR or IR to be low. All ranked it is as medium to high with most ranking it high or close to high.

Concern is considered something akin to a farmer's interpretation of where the risk ranks in level of importance as well as a reflection of their perceived ability to manage that risk. There are many factors that a farmer will rank as high risk, but the risks
considered manageable will be ranked lowest and therefore of minimal concern. For instance, as noted, nearly all farmers said HR and IR were high risk, but all ranked HR, at least, of low concern largely because farmers have a high level of confidence in their ability to manage it either with their existing strategy or with tactics they know they can access if they need. Further, a number of farmers described what I termed an optimism bias where they had trust in a new technology, or more likely that a new chemical will be developed to help manage resistance. This has been noted in other research (see McDonald, Thwaites, & Retra, 2006).

Mixed farmers are more likely to have the lowest concerns about HR because their solution to any weed problem or HR is to put the problem paddock into pasture and graze the problem away. Farmers 4 and 12 are indicative of this attitude. Farmer 12 also mentions introducing legumes into his rotation and crop topping as additional tools he has introduced, but pasture and grazing are his safety net should weeds or HR become an unacceptable threat.

F-4: There is no dispute that it [HR] is there. You’ve just got to work around it the best way you can...If I have a paddock that defies all the tricks at beating weeds then I will take it out of production and run livestock on it for a number of years.

F-12: Weeds are not that big...We did have rye grass problems—HR problems—a few years back, but we do not seem to have much of an issue with that now. ME: What has happened here then? F-12: Just the legumes and crop topping lupins has been a good thing to do. And when we do get a paddock that is no good we just sow it down to pasture. Suddenly the negative [rye grass] becomes a positive. It's in the pasture for the sheep.

Farmer 9 is a continual cropper, he knows the harm HR can cause, but he too perceives he has sufficient tactics to deal with it. There are things of greater concern on his farm. He is also indicative of farmers who exhibit an optimism bias. In this case, he is confident his existing tactics will stall HR long enough for new tools to become available.

F-9: I do not know about [HR being] inevitable, but my tactics will draw it out long enough for research to happen, or other chemicals to come off patent so they aren’t as costly...It is feasible to manage, but I have got other things I need to spend money on.
Farmer 11 is also a continual cropper but he relies on crop competition as his key tool. At the time of my first interview with him, he only grew two crops in his rotation. Between the first and follow-up interview, he decided to introduce a third crop because he said he knew he was "pushing the envelope" regarding weeds. He acknowledged the risk of resistance was high. Regardless, his concern about HR remained low because of his high confidence in his ability to manage HR.

F-11: It [HR] is an issue there is no doubt about it. But as I said before it does not really concern me because I have crop competition.

Agronomists also revealed similar confidence in managing HR.

Ag-S-4: Resistance is going to become a bigger issue, but at the moment it is manageable. It is not that hard to work out a program to manage it.

Farmer 2 is the exception, perceiving HR as high risk as well as having what I judged as medium-high concern about it. His response has been proactive management for a number of years. He is still similar to all farmers, however, having high confidence in his ability to manage HR. I judge, he is also one of the few farmers in my research sample whose weed management strategy closely fits the definition of IWM used in this thesis.

F-2: They are telling us it [HR] is a growing concern...I knew I had a couple of patches of rye grass coming through the sprays and that is a real worry and risk. I have been worried about it for a long time and been trying to do things right for a long time—for 20 years—So that is probably why we haven't really got many bad rye grass issues. So that is one of the reasons we've had sheep, pasture and fallow, green and brown manure crops in the rotations. I have done these over a long time to try and avoid HR taking off.

Risk and concern for IR is similar to HR, but one difference evident among agronomists is the lack of thought or discussion about how to manage it. Evidence examined already indicates that agronomists and farmers understand the management of HR using IWM tactics. Farmers are simply choosing when and what tactics to implement, something noted also by Pannell et al. (2006) and Vanclay & Lawrence (1994). This is not the case with IR. The only tactic they properly understand is chemical rotation, which emphasises again the knowledge deficit.
Ag-S-13 reflects these factors with his focus on chemistry as the frontline tool for invertebrate management and his lack of a plan to manage IR. At the moment he perceives he has sufficient "chemistry" (effective insecticides) to deal with it, but admits he lacks sufficient knowledge of alternative tactics. Further, I make a distinction above between risk and concern. Below Ag-S-13 says he is "concerned" about IR. I argue that what he calls a concern, is in fact a reference to risk as I define it. But the fact he hasn't made plans to deal with IR suggests his concern is also low.

ME: If you have insecticides as your front line tool how concerned are you about IR?
Ag-S-13: I am concerned about it but I haven't really put a plan in place to cope with it yet...It probably comes back to my lack of understanding of alternative options other than insecticides...we do rotate our chemistry. And that is probably another reason in that there is a suite of different products out there that I could use if I came across [IR]. But yeh it probably comes back to my lack of understanding of what I could do.

Ag-S-9 too is aware that IR is around. His second comment reflects the perceived low risk and minimal concern about IR. Further, IR lacks the same motivation as HR for agronomists to advise farmers on effective IPM tactics.

Ag-S-9: We know from a lot of the studies on RLEM that they are becoming resistant to organophosphates... so gone are the days when you can use broad spectrum organophosphate and expect 99.9% results.
ME: How much of an influence is the presence of IR having on your perceived need for IPM?
Ag-S-9: That is a good question. At the moment it is minimal, very low.

Thus unlike HR, IR provides minimal motivation for farmers to consider IPM. Environmental concerns motivate those few farmers who value natural systems. For other farmers that value sits too low in the value hierarchy to be of influence (see Grube et al., 1994). Farmers are still impeded by the uncertainties of IPM that include the unpredictable nature of invertebrate pests and whether beneficials can control the pests. This is in contrast to conclusions by Deguine et al. (2008) who, although working with cotton farmers, argued that IR and environmental concerns are key motivators for farmers to consider IPM. IR in cotton, however, has been prevalent for number of years (Deguine et al., 2008). In broadacre crops there remain a number of effective insecticides still available for most pests. This motivation may shift as IR becomes more predominant in broadacre crops.
For instance, Llewellyn et al. (2004) found farmers are more likely to adopt IWM tactics if they have HR problems. Further, Sci-8, an IPM consultant, has seen evidence of this in horticulture and believes that a similar motivation in broadacre will be needed to see greater use of IPM tactics.

Sci-8: It is well known if there are IR issues...we see that expressed more in the horticulture because they are ahead of the broadacre guys in producing resistant issues on their farms. You see that becomes a driver for adopting IPM, once the chemical approach no longer works well.

This potential outcome for broadacre is reflected in the concern for IR in stored grain pests, which is the exception to the abovementioned lack of farmers' and agronomists' concern about IR. Australian broadacre farmers are heavily reliant on one stored grain fumigant, phosphine (CRC Plant Biosecurity, 2016). About 80% of Australian grain is treated with phosphine (GRDC, 2015).

Ag-S-7 contrasts this concern about IR in stored grain with IR in field pests. He perceives farmers are starting to ask question and discuss IR in stored grain, questions that have yet to be considered to the same extent for invertebrates pests in the paddock.

Ag-S-7: But the fact that we have had issues with our herbicides people are going well where are we going here with resistance, but especially with stored grain it is becoming apparent there is IR with our weevils.

Farmer 23 implies IR in stored grain has motivated him to seek alternative, non-chemical approaches to control the pests.

F-23: But certainly things like grain insects—weevils and such—we are seeing resistance developing well and truly there. And we are looking to new forms of chemistry or other methods like aeration or refrigeration.

Every farmer and agronomist in my research sample has a good knowledge of weeds and the basic principles of HR. They are aware of and understand the nature, risk and uncertainties associated with IWM tactics. This is not the case with IPM. The knowledge deficit, uncertainties and their consequences pose different challenges in engaging farmers and agronomists about IPM.
Summary

What this chapter illustrates is that although the knowledge deficit on IPM needs to be resolved, a solution is more complex than teaching farmers and agronomists the science and the skills necessary to implement IPM. Having that knowledge will, by itself, not overcome the problem of 'adoption', which is an apparent focus of IPM proponents.

Farmers' memories and fears of crop loss need to be considered as they affect how knowledge is interpreted and what meaning or value it is given. The empowered farmer will also filter any knowledge through their social system, and their own values and worldviews. They will weigh it up against their experience and their objectives for their farm. Agronomists represent a different audience. Many have a similar knowledge deficit to farmers, but are affected by their need to protect their reputation and manage perceived farmer expectations. This conflicts with their understanding for the need to move away from a reliance on insecticides to manage invertebrates.

An important question is how do agronomists, and especially farmers learn and construct knowledge? The answer to this will require understanding their learning journey, what guides this journey, and how perceptions change along that journey. A second question then is how to facilitate and support this journey and therefore farmer/agronomist learning? This is discussed in chapter 9, which examines what the findings and analysis mean for engaging with farmers on IWM and IPM, with recommendations on how to achieve this.

Throughout the data analysis I have referred to the concepts of empowerment and power, risk and uncertainty, heuristics, values, worldviews and attitudes. To ground my findings in the theory and to provide context to chapter 9, the next chapter (chapter 8) explores some of the theory underpinning these concepts.
8. Reviewing the theory

Chapter 2 examined research to provide insight into farmers' motivations and what affects their knowledge construction and decision making. This provided context to and appreciation of my research data. This chapter examines the theories that underpin the concepts that emerged in my data, and my interpretation of that data. In each section, I discuss how the theories apply to farmer knowledge construction and decision making and more broadly to what it means for extension trying to engage with farmers about complex problems and technology adoption. These theories also help support the principal conclusions and recommendations I make in chapter 9.

Empowerment is the keystone concept and the basis of my research aim and question. In this chapter, I examine in more detail Weber and Foucault's conceptualisations of power and the theories about empowerment. I look at how their conceptualisations influence the different farmer participation models and extension theories.

Two paradigms about how people think and learn, objectivism and constructivism, are examined. I apply this to how farmers interpret and extract meaning from scientific knowledge and what this means for engaging farmers on complex problems.

I expand on the theories that define risk and uncertainty and how risk and uncertainty are interpreted and communicated. This includes the concept of ambiguity that was evident among the farmers in my research and is where scientists and sometimes extension interpret or give a meaning to the science and associated risk that is different than the farmer or public.

Uncertainty along with concepts such as intuition or gut feel can act as heuristics in some contexts. Gut feel, emotion and other heuristics have a significant role in farmers' decision making and this is also evident in my research. Chapter 2 explored how farmers use gut feel in tandem with reason. I examine in more detail the varied dual process theories (experiential/heuristics and reason/analytical) that are systems of thinking that affect our judgement and decision making.

Availability, Affect and, in some instances, trust are three risk-related heuristics that emerged as important influences in my data, and I examine some of the theories

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associated with them. I also examine how worldviews, values, beliefs and attitudes can also act as heuristics. In my research, these too had a role in farmer and agronomists' knowledge construction and decision making. A farmer's sometimes strong connection to the land and farming are part of value clusters that affect risk perception and decision making. The final section of this chapter examines the influence of this value set.

8.1 Power and perspective

In chapters 2 and 5 I gave a brief insight into Weber and Foucault's ideas about power and knowledge in the context of farmers' empowerment, knowledge construction and decision making. The study of power is immense and covers various disciplines (for example, psychology, sociology, political theory). This section is not intended to be an exhaustive analysis of power. The emphasis is on a more in-depth examination of aspects of the power-knowledge lens described by Foucault and the resource-based approach that emerged from Max Weber's classic definition of power and authority (see Gerth & Wright Mills, 2009; Uphoff, 1989). In this section I compare and then examine in more detail Foucault and Weber's conceptualisation of power that helped inform my research problem, aim and question. Principle elements of each conceptualisation that emerged as important to understand farmer knowledge construction and decision making are power, agency, autonomy, control and freedom.

Comparing Weber and Foucault.

There has been some attempt to find complementary relationships between Weber and Foucault's conceptualisation of power but it is beyond the scope of this thesis to discuss these. For insight into these relationships see Heiskala (2001) and Rudolph (2006). It was understanding the differences that helped expose how Foucault's concept of power applied more readily to my data and enabled me to interpret and understand its significance to my research problem, aim and question. The following section therefore expands on the discussion in chapter 2 and provides a brief overview of the key differences between Foucault and Weber's conceptualisations of power. I separately examine Foucault and Weber's concepts of power in more detail in the sections following.

A key distinction between the two concepts of power is that for Weber, there is the existence of authority and the concept that power exists as a resource external to the
actors. Foucault considers power not as a resource, but as something that exists through the network of relations (Heiskala, 2001).

Relationships are important in both concepts, but Weber considers relationships as a resource base for power. Hierarchy operates as an ingredient in the relationship in which there is an authority that emanates and controls from above (Coleman, 1997; Rabinow & Dreyfus, 1982). Foucault acknowledges hierarchy but differs in his interpretation of what is happening with power (Rabinow & Dreyfus, 1982). Foucault instead, sees power as a horizontal force. No command is needed as the system of power is self-activating through the interconnected relationships. Force is unnecessary (Rudolph, 2006). Foucault considers power is only exercised over those who are free. Where there is no autonomy, no agency to recruit, only an object to manipulate, then there is no relationship. "Slavery is not a power relationship when man is in chains (Foucault, in Rabinow & Dreyfus, 1982, p. 221).

Relationships between farmers and extension, especially agronomists, are crucial to knowledge construction and farmer decision making for complex problems such as weed and invertebrate management. Some of my data indicates that some agronomists perceive they have a form of legitimate authority that comes from their agronomic expertise. This expertise acts as the basis of their relationship with farmers and forms the apparent base of their power over farmers. What is less evident, but with more explanatory power, is that while the farmer acknowledges this expertise, the power is applied at least equally from the farmer and it is the relationship that is crucial for knowledge construction and thus where the power resides. It is these aspects of Weber and Foucault that form the basis of the discussion in chapter 9 and what I explore in more detail in the next two sections.

Weber.

The crux of Weber's definition of power and authority is represented in the passage used in chapter 2 and presented again below (see Uphoff 1989).

Power [Macht] is the probability that one actor within a social relationship will be in a position to carry out his own will despite resistance, regardless of the basis on which this probability rests. (Uphoff, 1989, p. 299)

According to Uphoff (1989), at the core of Weber's concept of power is the ability of an individual or group to achieve their objectives despite resistance. He also emphasises
Weber's use of the term "probability", which clarifies his notion that power itself is not an entity, but a statement about a probability that the dynamic of the relationship will enable a person or group, using one or more means (resources), to achieve their objective, potentially at the expense of others achieving theirs. That is, power through the associated relationship, does not exist. It is a probability only (Uphoff, 1989). "What exists is these means and the relationships they establish" (Uphoff, 1989, p.303).

In broad terms, Weber identifies power as being either authoritative (consensual, legitimate) or coercive (conflictual) (Simon & Oakes, 2006; Uphoff, 1989). Simon and Oakes (2006) consider most power relations involve a mix of both. Weber makes a distinction between power (Macht) and authority (Herrschaft). Although power refers to a concrete phenomenon, Weber conceptualises power as an abstract, descriptive term. It is authority that consists of concrete roles and relationships, and implies some element of voluntary compliance and legitimacy (Rudolph, 2006; Uphoff, 1989). Authority, though is also stated in terms of probability. Uphoff (1989) interprets Weber's description of authority as follows:

[Authority is] the probability that a command with a specific content will be obeyed by a given group of persons, despite resistance, regardless of the basis on which that probability rests. (p. 301)

Probability in this instance is explained by Uphoff's (1989) emphasis on Weber's further distinction between power, authority and legitimacy. For instance, a person can be in a position of authority but lack power if their authoritative position lacks support (legitimacy). Conversely, a person without authority may control sufficient resources to wield considerable power. "Authority and legitimacy differ in that one is a claim for compliance, while the other is an acceptance of that claim (Uphoff, 1989, p. 303).

Legitimacy is afforded when it is in keeping with the beliefs people have about what is right and proper (Uphoff, 1989). This does not prevent those in legitimate authority resorting to force. If they consider their (legitimate) commands are ignored they reserve the right to use (legitimate) force or to impose economic or social sanctions, which may or may not be accepted by the public (Coleman, 1997; Uphoff, 1989). This affects the probability and degree of authority afforded.

To the extent they [commands] are not accepted, this diminishes the probability that the commands will be obeyed. Thus the legitimacy of authority and
therefore of authority itself is best seen as a matter of degree and always liable to
some denial and refusal. (Uphoff, 1989, p.302)

In contrast, coercion lacks authority and the person or group exercises power through
force to make someone do something against their will (Simon & Oakes, 2006; Uphoff,
1989). Where extreme coercive power causes destruction of human agency, any power
relationship ceases to exist. It becomes instead violence or war (Simon & Oakes, 2006).
In any circumstance, Weber says it is not the power itself that is being possessed and
wielded to control. One can never possess power except as a figure of speech (Uphoff,
1989). Instead, what exists and is possessed is the means or resources (including
relationships) at a person or group's disposal that form the basis of social power and
enable them to achieve their objective (Simon & Oakes, 2006). French and Raven
(1959) provide an early example of further differentiating these resource bases. They
propose the following six resource bases of power that an influencing agent (the person
or group in authority, or exercising power through force) can use to change beliefs,
attitudes, or behaviours of others: reward, coercion, legitimacy, expertise, reference and
information.

Reward can be tangible rewards offered such as money or promotion. Coercion can be
physical threats, fines or fear of losing your job. Along with authority, Raven (1992)
includes more subtle forms of legitimate power such as reciprocity, for example, I did
you a favour so you owe me. Expert and referent power is affordance of power to those
we perceive have specific knowledge and skill and know what is right, or in the case of
referent power because we view them as a role model or someone we admire or relate
to. Information or persuasion is based on the logical argument an influencing agent can
present to enable change without the need for sanctions (Coleman, 1997; Raven, 1992).

Foucault.

Weber conceives power in terms of authority. For Foucault, power is never localised or
in anybody's hands as conceptualised in the resource base model. The notion of
authority does not exist. In a different sense, however, Foucault acknowledges that
hierarchy, domination and subordination do exist. Certain groups do have advantage or
control over others, but all groups in a relationship are engaged in power relations, even
if unequal or hierarchical. Power is applied from the top down and bottom up. Power is
exercised upon the dominant and the dominated (Rabinow & Dreyfus, 1982). It is
power with, rather than power over (Coleman, 1997).
In speaking of domination I do not have in mind that solid and global kind of domination that one person exercises over others, or one group over another, but the manifold forms of domination that can be exercised within society. (Foucault & Gordon, 1980, p. 96)

Power is relational for Weber and Foucault, but for Weber relations are a means or resource that can be wielded and used to achieve an objective. For Foucault, power is not a resource, but a network of relations (Heiskala, 2001). Thus, Foucault insists that power must be analysed as something that circulates or weaves through networks, reciprocal support and differences of potential (Foucault & Gordon, 1980). Individuals are just vehicles for the power (Foucault & Gordon, 1980), and power can only be understood through its connection to knowledge and discourse (Foucault & Gordon, 1980; Schirato et al., 2012). Snowden (2003) argues that people fail to understand this and focus on managing knowledge (as a resource) rather than the channels, or relations, through which knowledge (and power) circulate. I argue that Fleming et al. (2014) imply that science and extension need to incorporate this understanding into any farmer engagement or farmer participation model. For instance, they say it is impossible to have any knowledge construction without an established and long-term relationship between science, extension and the farmer. Without this, methods tend to revert back to the traditional knowledge transfer approach (Fleming et al., 2014).

Thus, power operating within these relations is the instrument that enables the formation and accumulation of knowledge. It is our methods of observation, interpretation and investigation. Using these instruments, power evolves and ultimately constructs knowledge. That is, there is no power relation without the correlative construction of knowledge (Foucault & Gordon, 1980). The point of articulation between the power and knowledge is discourse (Schirato et al., 2012).

Fazey et al. (2012) puts Foucault's ideas in the context of knowledge exchange, which they define as processes that participants use to generate, share and/or use knowledge. This includes knowledge brokerage which is becoming a principal role for agricultural extension (Fazey et al., 2012; Fleming et al., 2014; Rajalahti, Janssen, & Pehu, 2008). Similar to Foucault, Fazey et al describe power as a distribution of knowledge that involves knowledge exchange as a process of empowerment or disempowerment, where knowledge exchange is inseparable from the dynamics of power. They also consider
that power, as a distribution of knowledge, focuses attention on the need for appropriate theoretical lenses to understand the dynamics of empowerment and disempowerment.

Foucault’s power-knowledge lens offers a distinct contribution for knowledge management. Through discourse, it is a way to see power as a constraining and productive force to enable different ways of collaborating and engaging with each other (Foucault & Gordon, 1980; Heizmann & Olsson, 2015). Given this inseparability of knowledge and power in relations, it is unsurprising that learning and participation are also involved (Fazey et al., 2012). I discussed in chapter 2 the shift from diffusion theory to the paradigm of Farmer First, one of a number of participation processes that focus on greater farmer participation in research and development to emerge from the dissatisfaction with diffusion theory. The effectiveness and limitations of these participation models and other extension theories, and how they affect empowerment, power-knowledge relations, and consequent knowledge construction and decision making is discussed next.

8.2 Achieving participation to empower or to facilitate the empowered

This section examines an apparent objective in many participation models and participatory research projects to accelerate technology adoption and empower farmers. I outline an argument that, in certain contexts, questions this objective. I contrast these participation models against theories that suggest extension should focus less on facilitating participation to empower and more on understanding farmer networks. Such theories are more reflective of how I interpret my data. The research presented in this section recognises farmer empowerment arguing that in such cases extension needs to reconsider their role and how they engage with farmers.

**Participation to empower.**

There are many descriptions of farmer participation projects that list as a key objective a need to empower farmers. Although it depends on the participatory model or project, and the people involved, it implies that without access to these participatory processes farmers are somehow disempowered. This section examines examples of this and I outline an argument that questions this need to empower.

The GRDC funds a lot of scientific research projects and, where appropriate, urges greater farmer participation in such projects (GRDC, 2014). But it often frames their
project objectives around the need to identify ways to accelerate adoption of technologies and to empower farmers. This need may or may not be real. Regardless, there is nothing in their project reports to indicate that farmers are actually disempowered and therefore in need of empowerment. Further, I argue that a focus on acceleration of adoption may be incompatible with how farmers think, learn and construct knowledge.

I do not intend to detract from the value of the research nor the potential benefits to farmers, but I question the assumption that technology or knowledge needs to be delivered to farmers to empower them when there appears no attempt to ascertain if farmers are in need of empowerment. Empowered and disempowered farmers are also different audiences and require different extension strategies, something that is discussed further in chapter 9. I use the following three GRDC project outlines as examples where emphasis is on the need to deliver technologies and empower, factors evident also in the participatory models discussed in the section following:

A National Soil Quality Monitoring Framework
This project develops monitoring tools to improve decision making regarding soil health.

Together with tailored soil health workshops and computer training, this empowers growers to make better-informed management decisions with respect to production and longer-term soil sustainability (GRDC, n.d.-c).

Putting precision agriculture on the ground in Western Australia
This project, alongside its emphasis on accelerating the adoption process, is intended to understand the problems that prevent growers adopting and benefiting from precision agriculture (PA) technology.

The economic benefits that PA can deliver were widely communicated and tools developed to empower the industry to conduct their own analyses (GRDC, n.d.-a).

Delivering agronomic strategies for water repellent soils in Western Australia
The project conducted an extension program designed to empower growers and grower groups to identify the severity of non-wetting, water-repellent soils; the likely impact on grain yield, and the profitability of management strategies
including an assessment of the drivers, barriers and extent of grower practice change (GRDC, n.d.-b).

To varying degrees, the above GRDC projects encouraged and incorporated farmer participation in the research that included farmers' help to identify research questions, and on-farm trialling and evaluation of the technologies. As noted it is this perceived need for better farmer participation that has produced the numerous participation models. I discuss in the next section two of these participation models alongside other extension theories. The participation models further illustrate the common objective to empower farmers through adoption of technology or delivery of knowledge.

The participation models and other extension theories.
Farmer First was an initial step toward greater farmer equity in research and development (see chapter 2). It showed the potential of farmer participation and spawned multiple participatory approaches that sought to improve on Farmer First or adapt it to local agronomic and farmer requirements (Dunn et al., 2000). Many of these models have in common an aim to recognise the legitimacy of farmers' interests, objectives and knowledge (see Chambers, 1997; Fazey et al., 2012; Ingram, 2014). The many participatory models make a detailed review beyond the scope of this thesis. The following two broad examples are discussed extensively in the literature. In addition to the above aims, they aim to empower farmers. I also examine their alignment to either Weber or Foucault's conceptualisation of power. I contrast these participation models against theories that suggest extension should focus less on facilitating participation (to empower) and more on understanding farmer networks.

Participatory Rural Appraisal
Chambers (1997) describes a broad model, Participatory Rural Appraisal (PRA), that was developed in the early 1990s. PRA represents a family of approaches or methods, based on changes and reversals of role, behaviour, relationships and learning. This means managing and reforming power-relationships to enable empowerment (Chambers, 1997). It has evolved with time and locations, with participants adapting PRA to their own region. Chambers notes that many who have adopted this model have done so to empower those he refers to as "lowers", who in a hierarchical society include the weak, minority or subordinate. Such participation, it is thought, will help people generate knowledge about their own condition and how to change it. Chambers relates his ideas largely to developing nations that lack many of the resources and means that
farmers in developed nations have. But he also notes that people in developing nations can and should do much of their own investigation, analysis and planning. Local people, he says, have a greater ability to map, model, observe, and generally assess situations than outsiders (Chambers, 1997). Chambers describes a resource base model of power centred around an authority that uses this dominant position to affect behaviour. But the lowers he describes will likely have expert local knowledge, agency and interconnected relationships of which the "authority" will be part. From a Foucauldian perspective, it is questionable whether the farmers in the context of Chambers' research are truly disempowered and lack control.

Beyond Farmer First
Although Dunn et al. (2000) note the potential of Farmer First, they are also are critical of it. They instead advocate the concept of Beyond Farmer First, which is based on understanding farmers' objectives and interests, the relationship between the two, and the cultural construction of these interests and objectives among farmers, scientists and extension. They acknowledge, however, that understanding these factors will not alter the power relations. It is simply the starting point for those in the relationship to negotiate the objectives based on their respective interests (Dunn et al., 2000). Thus farmers are having a say in determining the boundaries and objectives of research, but they go onto say that the process requires more than participation by farmers and merely participating does not guarantee empowerment. Extension's role is to foster the cultural conditions that will empower farmers and to help farmers perceive their objective interests and to act on them (Dunn et al., 2000). Although in this model farmers are supposed to help define project boundaries and objectives, there remains an emphasis for the process, or in this case, extension, to empower farmers.

(Ingram, 2008) notes a similar role for extension. She says that in achieving more sustainable agriculture, mechanisms such as knowledge sharing, social interaction or group learning, and the various participatory approaches have been successful in some contexts. But critical to any success, she says, are the facilitators coordinating these group activities that empower, enable, re-skill and reorientate farmers and help them work out their objectives. Again this indicates that a key purpose of participatory approaches is to empower farmers. It also implies an authoritative role for facilitators to use their expertise as a form of power to affect behaviour change in farmers.
In research that adds a cautionary note to Ingram's call for facilitators to coordinate group activity and learning, Wood et al. (2014) found that with new scientific knowledge, farmers learn and gain most knowledge through informal, multi-dimensional relationships rather than one dominant, centralised scientific source that tends to be the scientists themselves. In other words, farmers value knowledge delivered by persons rather than roles (Wood et al., 2014). Leeuwis and Aarts (2011) pose a similar argument. They say that in similar contexts, actors, in this case farmers, will communicate more with each other about change-related matters during normal social activities than during formal meetings and other communicative efforts of professionals.

Wood et al. use systems theory to reveal network facilitation as a specialised function and argue that the challenge is not to theorise and legitimise new forms of specialist facilitation that link the expert knowledge source with those seeking the knowledge, in this case the farmer. This suggests the challenge is instead for extension to understand farmers' diverse and interconnected knowledge networks and how farmers use them to engage with science and construct knowledge about their farm systems (see also Eastwood et al., 2012; Oreszczyn, Lane, & Carr, 2010). Wood et al.'s perspective resembles Foucault's conceptualisation of power where authority does not exist and power circulates through relations to construct knowledge. It is also reflective of how I interpret the meaning of my research, which is explicated by Farmer 01 who acknowledges the importance of the varied people in his farming district and beyond for learning. It is these people that form the basis of his power-knowledge relationships and enable him to learn, construct knowledge and make informed decisions.

F-01: One of the things I like about farming is the people I meet and I get on well with people and I have a great relationship with my agronomist...As a district we are learning...I am learning. I am learning off young farmers as well. It is a vibrant farming community. I am part of a farm improvement group...and we take trips to the Eastern states for a bit of learning.

The empowered farmer is rarely acknowledged in the literature. As noted, the emphasis is on extension to facilitate the transfer of technology or knowledge to farmers and to empower them. Where the empowered farmer is realised, researchers are explicit in the need for extension to reconsider their role and approach to engagement with farmers.
Finding farmer empowerment.

This section examines the research that recognises farmer empowerment, and how extension can facilitate it. It underpins many of the conclusions and recommendations I make in chapter 9.

Nettle et al. (2015) provide a rare exception to the focus on outcomes that seek to empower farmers. They described explicit contexts recognising the empowered state of farmers and the need to consider this status in any engagement process. They explored whether existing ways of doing research, development and extension (RD&E) in the dairy sector contribute to farm adaptability. Although the research was a case study that only analysed one farm family, they note the family members exhibited empowered traits such as planning, learning, flexibility and adaptability (autonomy and control). They observed the family's engagement in discussion groups and courses to build knowledge and confidence to know what questions to ask and which advice to reject (self-defined objectives, control). The family actively engaged with a network of peers and experts, and they participated in an industry benchmarking process to evaluate progress and plan future change (self-defined objectives, evaluation, power relations). Thus they exhibited agency through analysis, critique, reflection and self-direction. They also showed capacity to build social capital through investment in relationships. This enhanced their learning and ability to adapt. Pretty and Smith (2004) found such investment in social capital also enabled construction of effective and connected relations that provoked behaviour changes and led to positive biodiversity outcomes in agriculture and rural biodiversity programs.

Nettle et al. still refer to the need for RD&E strategies to empower farmers but their emphasis is more on creating the cultural environment to enhance and facilitate the empowered farmer. For example, they highlight the need for collaborative RD&E designs to avoid information as the principal output and to think about how the process contributes to farmer empowerment (Nettle et al., 2015). This realisation shifts the role of researchers and extension to aid reflection and learning, create and facilitate networks outside social norms, and enable farmers to mobilise and act collectively (Nettle et al., 2015). Because there was only one farmer directly involved in Nettle et al.’s research, they acknowledge their framework needs to be tested and applied in more cases and contexts.
Leeuwis and Aarts (2011) expand this facilitative role for extension to include network building, social learning and dealing with dynamics of power and conflict. Network building could involve reconfiguration of relationships within and between networks, and formation of new networks. Leeuwis and Aarts describe social learning as relevant groups or individuals developing "overlapping or at least complementary perspectives on relevant models of reality, problems, goals and boundaries as a basis for identifying desirable, feasible and acceptable options for change" (Leeuwis & Aarts, 2011, p.26). This includes learning that is open about the uncertainties that hinder change, and collaborative investigation and experiment to develop common starting points (Leeuwis & Aarts, 2011).

The literature's concerns with many participatory models align with Bartlett's (2008) concerns about the instrumental discourse on empowerment. For example, farmers are given a greater role in participatory models but their contribution occurs within boundaries and objectives defined by others (see also Black, 2000; Ingram, 2014). In these situations, the farmer lacks control (see Llewellyn, 2007). For instance, Dunn et al. (2000) argue that although the Farmer First model involves farmers in the consultation process, they are expected to accept ideas rather than 'diffuse' their own. Similar to diffusion theory this has been criticised for being too behaviourist (see Dunn et al., 2000). Bartlett (2008) is one that advocates, in the appropriate contexts, a more constructivist approach to farmer learning or knowledge construction. Behaviourism and constructivism are ways of thinking and learning that are explored next. Understanding the ways a farmer thinks and learns in complex contexts is important to improve extension and underpins one of the core recommendations of my research.

8.3 Thinking and learning: constructivism and objectivism

To varying extents, agronomists and farmers assess, interpret and apply scientific knowledge to agronomic management. If extension is to facilitate a farmer's learning and knowledge construction it is important to have some understanding of the different philosophies and paradigms that attempt to explain how we learn and think.

Two philosophical paradigms on how we conceive reality and which inform our understanding on how we think and learn are objectivism and constructivism. Both are broad concepts with varied perspectives. They sit at each end of a continuum, though few people are proponents of either extreme. Most sit somewhere between the extremes
(Ertmer & Newby, 2013; Jonassen, 1991). I argue it is constructivism that is most applicable to explain how farmers think and learn in complex contexts. In this section, I briefly examine the central philosophical assumptions underpinning each paradigm and assess their applicability to farmer decision making.

**Objectivism.**

Objectivism is based on the premise that the world is real and that knowledge is external to the knower and independent of human experience (Ertmer & Newby, 2013). At the extreme end of the objectivist continuum, objective facts, or truths, exist independent of observation that we strive to know and assimilate in similar ways. Thus, the aim of objectivist-based learning models is to isolate our mental operations to discover how to most efficiently map the external reality onto learners (Jonassen, 1991).

Firmly positioned on the objectivist side of the continuum is the behaviourist learning theory. The behaviourist theory has an emphasis on eliciting observable and measurable learning outcomes. The normal goal of teaching under this theory is to use a specific stimulus to elicit a desired and measurable learning response. The learner is characterised as being reactive to conditions in the environment as opposed to taking an active role in discovering the environment (Ertmer & Newby, 2013).

A second theory of learning under objectivism is cognitive theory. Cognitivists are further from the extreme end of objectivism as they shift away from the need for overt observable learning behaviour and focus more on the process of learning that includes critical thinking, problem solving, and how information is stored and retrieved (Ertmer & Newby, 2013; Jonassen, 1991). Unlike behaviourist theory, the learner is considered an active participant in the learning process (Ertmer & Newby, 2013).

Despite these differences, the actual goal of instruction for both behaviourist and cognitive learning theories is often the same: to communicate or transfer knowledge to students in the most efficient way. Simplification and standardisation, where knowledge is deconstructed into simple chunks and irrelevant information is eliminated, are often part of this process (Ertmer & Newby, 2013).
Constructivism.

Objectivism puts emphasis on the object of our knowing (Jonassen, 1991); that knowledge is independent of the mind and can be mapped onto the learner (Ertmer & Newby, 2013). In contrast, constructivism values how we construct knowledge. Constructivists still believe in the existence of the "real" world, but contend that what we know is a function of previous experiences, values, beliefs that we use to interpret an event, or "reality" (Ertmer & Newby, 2013; Jonassen, 1991). That is, we create meaning as opposed to acquire it. There is no objective or predetermined reality, no knowledge independent of the knower, only knowledge we construct for ourselves (Ertmer & Newby, 2013; Hein, 1991).

Similar to cognitive learning theory, constructivists describe learning as an active process (Hein, 1991). But cognitive and behavioural theory describe the mind as a reference tool or mirror to the real world; constructivists say the mind filters and uses sensory input from the world to construct its own meaning (Ertmer & Newby, 2013; Hein, 1991). This meaning is not set in stone. It evolves with each new experience. Memory is under continual construction via a cumulative history of interactions or experiences. Thus, the internal representation of knowledge is constantly open to change (Ertmer & Newby, 2013). In the context of knowledge management, Schultze and Stabell (2004) make a similar comparison noting that a constructivist will view an organisation's knowledge as forever incomplete, inherently indeterminate and continually emerging.

Applying learning theories.

As you move along the objectivist–constructivist continuum, the focus of instruction shifts from the passive transfer of facts to the active application of ideas to problems (Ertmer & Newby, 2013). But learning theories associated with objectivism and constructivism are not mutually exclusive. For instance, Jonassen (1991) says that introductory knowledge, and teaching of basic skills in structured knowledge domains is better supported by more objectivistic approaches, but a more constructivist approach is appropriate as learners acquire more knowledge and need to deal with complex and ill-structured problems (see also Ertmer & Newby, 2013).

Although Bartlett (2008) is critical of the behaviourist approach in many engagement projects (see also Gray et al., 1997), he too notes it is often desirable to deliver
information to farmers and conduct skills training (behaviourist) alongside the facilitation of experiential learning and communicative action (constructivist). What needs consideration are the links between the two approaches and which takes precedence (Ertmer & Newby, 2013).

From a constructivist perspective learning is contextual (Ertmer & Newby, 2013; Hein, 1991; Jonassen, 1991). We do not learn facts and theories in some isolated part of the mind separate from the rest of our lives. We learn through what we know already, our values, our biases and our fears (Hein, 1991). We interpret information in the context of our own experience (Jonassen, 1991). Some of that learning experience is social and intimately connected with the people around us such as our teachers, peers and family (Hein, 1991). Hence, a constructivist considers it essential that learning takes place in context and that context forms an inexorable link with the knowledge embedded in it (Hein, 1991; Jonassen, 1991).

**Constructivism for farmers.**

Although generalising about extension projects targeted at farmers in developing nations, Bartlett (2008) contends the "political and technical elite" managing these projects perceive that the process of giving farmers knowledge will empower them, an approach Bartlett argues is behaviourist and one that hinders empowerment because it fails to recognise the importance of agency (Bartlett, 2008). Bartlett's preferred alternative is a constructivist approach where one assumes farmers act as autonomous agents, can think critically, analyse, experiment, reflect and knowledge is uniquely created by each farmer from these experiences (Bartlett, 2008).

In support of Bartlett's preference for a constructivist approach, Roling and van de Fliert (1994) imply farmers possess an inherent constructivist style of learning when they describe empowered farmers that rely on their own judgement and observation. They refer to the need for extension to facilitate this learning by enhancing their existing skills and collective decision making. They too talk about the need for a paradigm shift that requires recognition of farmers' autonomy, and emphasise a need to understand farmers' learning paths and find ways to facilitate these (Roling & van de Fliert, 1994).
A lot of the discussion relevant to knowledge construction concerns managing risk. It is what farmers do as part of managing a complex system. The theory underpinning risk and uncertainty in the context of complex systems is explored next.

8.4 Defining, communicating risk and uncertainty

In chapter 2 I briefly introduced risk and how it applied to farmers and their decision making. I distinguished risk from uncertainty and I examined how risk can be interpreted differently depending on a person's values and worldviews (ambiguity). In the following section I will expand on this and examine in greater detail the theories that underpin the meaning of my data discussed in chapter 9.

Risk and risk perception.

The social and localised influences of risk and the myriad ways we actively interpret messages and signals about hazards to arrive at our own risk understandings ensure there is a continued variety of interpretive approaches to understanding risk and uncertainty (Pidgeon, 2008). This befits the description that risk perception is a phenomenon in search of an explanation (Sjöberg, 2000b). Despite the varied interpretations, risk perception studies help us understand our target audience, their concerns, points of conflict and where trust and credibility are an issue. These studies also probe the mechanisms of how we process and judge controversial information, which allows effective discourse about risk and risk management (Renn, 2008).

Renn (2008) condenses risk perception research into the four main subject areas below.

To varying degrees, all four subject areas affect the knowledge construction and decision making of farmers in this research. They form an important part of the arguments and discussion in this and the following chapter of this thesis. Renn's four subject areas are

- intuitive heuristics of forming judgements and the processing of probabilities;
- qualitative characteristics of risk (biases regarding perceived severity and acceptability of risk);
- beliefs associated with the risk itself and the context in which it is embedded, such as the perceived trustworthiness of risk managers and regulators, and the stigma associated with the risk; and
- interests, values and worldviews that affect how people evaluate risks (p.219).
Refining understanding of risk.

In chapter 2 I used the following definition of risk:

[Risk is] a measure of uncertainty of an event happening times the severity of the outcome. (Riesch, 2012, p.92)

In chapter 2, I also briefly describe two broad concepts of risk: the scientific or technical form, and the socio-cultural form. The above definition of risk aligns more with the technical perspective where risk is a quantifiable entity. It ignores to a large extent the cultural perception of risk, where, as Riesch (2012) points out the definition of risk is often less precise and less concerned about what is quantifiable. I further expand here on the theory underpinning these differing conceptualisations of risk.

Risk analysis or risk perception exists as a scientific activity and an expression of culture (Kasperson, Renn, Slovic, Brown, Emel, & Goble, 2005). The socio-cultural form is socially constructed, multi-dimensional and interactive (Marris, Wynne, Simmons, Weldon, & Kline, 2001). The scientific/technical form is based on hazard and quantifiable risk. It calculates the probabilities of physical harm (Beck, 1992), or the product of probability and magnitude (Renn et al., 1992) that will quantify such things as the number of deaths, the likelihood of an event happening or the probability of harm or damage. This latter form of risk analysis predominates in policy and related risk discourse about science and technology (Beck, 1992; Slimak & Dietz, 2006).

Nevertheless, Renn (2008) argues that both concepts of risk are integral to defining and interpreting what are acceptable risks and both are based on a subjective mix of factual evidence, attitudes toward uncertainties and moral standards (see also Fox, 1999; Jasanoff, 2012; Wynne, 1992). Technical risk assessment, however, is unable to fully inform societal choices regarding technology (Kasperson, et al., 2005), and the socio-cultural perspective is complex, open to social definition and construction (Fox, 1999), and, according to (Renn (2008), lacks any accepted standard to measure cultural or social acceptability.

A vast majority of studies on risk perception show that, among other factors, much of our concern stems from divergent views about the tolerability of remaining uncertainty (Renn, 2008). Further, my data reveals that in certain weeds and invertebrate
management contexts, it is uncertainty rather than risk that has greater influence on farmers' decision making. I examine further the concept of uncertainty and its relation to risk next.

**Uncertainty.**

In chapter 2, I provide a basic understanding of uncertainty and illustrate how farmers manage uncertainties inherent in a farm system. The following expands on the discussion of uncertainty and examines some of the theories of communicating uncertainty in the context of risk.

**Refining uncertainty.**

We use probabilities to help predict uncertain events, but as Renn (2003) points out these predictions are themselves characterised by components of uncertainty and there are four components that Renn defines: variability, measurement errors, indeterminancy, and lack of knowledge. Together or alone, these components reduce the confidence in the estimated cause and effect associated with determining risk (Renn, 2003). I outline each component below and for each component I use examples from my data and the agricultural extension literature to illustrate this.

**Variability:** this is the observed or predicted variation in individual responses to the same stimuli. For example, the differences or uncertainty about how weeds and invertebrates will respond to the same chemical control because of variability in genetics of individual plants and animals. Variability also applies to the variable nature of spray equipment, farmer application and, as Farmer 4 notes, an unpredictable environment, which is one reason he manages weeds with only a 2-3 year outlook.

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F-4: I thought if we went about 2-3 years [to manage a weed problem]. You cannot go longer than this because the seasons will dictate more than anything else what will happen.
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**Measurement errors:** this occurs with imprecise or imperfect measurement and use of small statistical samples, and uncertainties of modelling. These are often expressed through statistical confidence intervals. This is apparent with agronomists' use of data support tools such as Yield Prophet, RIM (Ryegrass Integrated Management), climate forecast models and use of pest invertebrate thresholds (McCown et al., 2012; NIPI, 2014).

**Indeterminancy:** this results from a stochastic relationship between cause and effect. This is especially relevant in IPM where understanding of the relationships or
interactions between pest and beneficial invertebrates is incomplete. It is also relevant to models and the assumptions we make about the parameters of a model, though model in this context is in a social science or philosophical sense rather than the precise definition that applies in mathematics or statistics. For example, how non-scientists perceive risk is a kind of model (see Riesch, 2012).

*Lack of knowledge*: there is a limit to how much we can know, or have expertise in, especially as farming becomes increasingly complex (see McCown, 2002). For example, for farmers and agronomists in my research, insufficient or inadequate information is a factor evident in their response to IPM. Lack of knowledge can also relate to uncertainty (trust) about the information source (Abadi Ghadim et al., 2005; Thompson, 2009). There are also what Riesch (2012) describes as 'unknown unknowns', which are uncertainties that are difficult to manage because we do not know what they are, nor are we able to comprehend what they might be, constrained as we are by our imagination (Riesch, 2012).

The mere requirement for probability to assess risk, whether from a technical or social perspective means there will always be some level of uncertainty. Some debate remains, however, about whether and how to communicate this uncertainty.

*Communicating uncertainty in complex environments.*

Uncertainty influenced risk perception and decision making among farmers and agronomists in my research. There was also discussion among some of them about whether and how to communicate uncertainty. The research in this section examines the issue of communicating uncertainty. The research also underpins my argument in chapter 9 that uncertainty needs to be communicated as part of the engagement process.

Where uncertainty exists, the consensus is that it is better to communicate it than not (Frewer et al., 2002; Marris et al., 2001). According to Fischhoff (2012), the experts developing knowledge owe the recipients of that knowledge, the decision makers, candid assessment about what is known and unknown. For farmers, at least, this would seem appropriate given Wynne's (1992a) argument that farmers are capable of making decisions where uncertainty exists. ResAg-8 makes this point emphatically.

ResAg-8: A farmer wants to know this [uncertainties, risk complexity]. Dead right. This is the disconnect where extension is at, talking about risk. So the
farmers work it [risk] out themselves and that is why the farmers learn this stuff and we realise this from talking to each other.

Where these decisions incorporate social judgements on the scientific knowledge and its validity or completeness, it may mean farmers will interpret uncertainties differently from those of scientists (Wynne, 1992a, b).

The examples below indicate that not everyone follows the ethos that uncertainty should be communicated. The reasons for this vary, but range from apparent arrogance to misunderstanding the public's ability to comprehend or at least appreciate the existence of uncertainty, and a fear about what effect communicating the uncertainty will have on public risk perceptions about specific hazards.

For instance, research by Marris et al. (2001) into public perceptions of agricultural biotechnologies demonstrated that official institutions had a mistrust of the public and considered them incapable of maturely sharing difficult, multi-faceted decisions and their relevant uncertainties (see also Frewer et al., 2003). Wynne (2001) is critical of such institutions or relevant regulators. He says they deny any uncertainty, and although scientists and their institutions claim that the risks and consequences of their research are adequately known they in fact lack the ability to recognise the limits of their knowledge and, where it occurs, fail to communicate this to the public (see also Frewer et al., 2002). Further, Beck (1992) argues that science is increasingly unable to provide the information society requires to judge risk. Together this has led to a decline in trust of traditional experts such as those in science. Wynne (2006) concludes such authorities are still falling victim to the deficit model of thinking because they incorrectly believe the public are unaware of and unable to conceptualise uncertainty or unpredicted future consequences. As a consequence, authorities attempt to sanitise and control the message by eliminating uncertainty, hence they remove complexity and context. Wynne (2005) suggests science perceives such data will only serve to confuse or muddy the message they are trying to present.

Within this institutional science culture, "simplification" is not the abstraction of what is the essential kernel of meaning, which could be, very simply, "We do not think we know enough". It is instead, the systematic deletion of elements of knowledge or non-knowledge (ignorance) which are assumed by the interpreters to be troublesome to their relationship with their audiences. (Wynne, 2005, p.84)
Intellectual selection is thus systematically shaped by a background concern about social control and authority. By the time complexity comes into focus, it will always have been framed, translated and domesticated somehow, like everything else. (Wynne, 2005, p.87)

Uncertainty and trust along with concepts such as intuition or gut feel can also be considered heuristics. In certain contexts they become mental shortcuts to knowledge construction and decision making. For instance, in a complex decision-making environment with high levels of uncertainty, farmers will often resort to heuristics to make judgements and decisions (McGuckian, 2006; Menapace & Colson, 2012; Murray-Prior & Wright, 2001). In my research, heuristics emerged as an important influence on farmer decision making and I expand on this role next.

8.5 Heuristics and biases

Heuristics in the form of Availability, Affect, trust, values, worldviews and attitudes affected farmer and agronomist decision making in my research. This section examines the theory underpinning these heuristics and how they affect risk perception and decision making.

Overview.

Simon (1955, 1956) first suggested that humans are boundedly rational when making decisions (see also Kahneman, 2003; Wilke, 2012). This implies a human's ability to make rational decisions is constrained or limited by factors such as time, information, and cognitive capacity. Hence, we tend to rely on simple decision strategies or heuristics to find satisfying solutions rather than optimal ones (Wilke, 2012). This has led psychologists to consider humans as cognitive misers or "satisficers", which means we will use the least effort to process information we deem necessary to make a judgement or form an opinion that we are satisfied with (Scheufele, 2013). This is considered a principle reason why heuristics (experiential thinking) prevail over rationality (analytical thinking) because the former is less cognitively demanding (Chen, Duckworth, & Chaiken, 1999).

Amos Tversky and Daniel Kahneman in the 1970s used Simon's work as a starting point to expand on the concept of bounded rationality (Kahneman, 2003). They introduced the term cognitive bias to describe people’s systematic but often flawed judgment and decision-making (Wilke, 2012). Heuristics and biases are an integral part of the
experiential system of thinking. The heuristics we unconsciously employ to quickly evaluate risk and uncertainty are dominated by emotions and feeling and sometimes produce good estimates of risk (Slovic et al., 2004; Slovic, 2000). But heuristics are imperfect cues that can act as covert, systematic biases that lead to erroneous judgements (Finucane & Holup, 2006; Tversky & Kahneman, 1974).

Wilke (2012) contends that Tversky and Kahneman's heuristics and biases research is the most influential psychological research program to emerge in the last 40 years. Nevertheless some criticism emerged of the program. Tversky and Kahneman based their conclusions on a research method that presented participants with a laboratory-based reasoning problem that corresponded to a normative answer from probability theory or statistics. Participants’ responses were compared with the solution expected by these norms. Any systematic deviations (biases) between the responses and the normative solutions were claimed a consequence of heuristics (Tversky & Kahneman, 1974; Wilke, 2012). It is argued that the laboratory situations are too detached from the real-world situation to provide enough cues for people to base judgements on, hence it reduced their power to understand risk perception (Krimsky, 1992; Sjöberg, 2000a).

Regardless, heuristics have an effect and there are countless heuristics and biases with roles that will differ between individuals and contexts (Slimak & Dietz, 2006). For example, people’s personal values and beliefs (for example, religious beliefs) constitute heuristics and biases that can influence risk perception, especially risk and uncertainty associated with emerging technologies (Scheufele, 2013; Slimak & Dietz, 2006).

In chapter 2 I described intuition and gut feel as important heuristics in farmer decision making, but noted also that they normally operate in tandem with reason. There remains discussion about how the two systems of thinking interact and which dominates in different contexts. Nevertheless, understanding both thinking processes and how they integrate to influence judgment and decision-making is considered key to understanding risk (Finucane & Holup, 2006).

The various dual process theories often portray the two systems (experiential and analytical) as distinct with opposite tasks (Roeser, 2010). However, it is clear the two systems work in parallel and interact with one another to identify and prioritise experiences. The experiential system can influence (bias) and is influenced by the
analytic system, which directs behaviour on the basis of learning from past experience (Chen et al., 1999; Finucane & Holup, 2006). Together, the two systems of thinking comprehensively govern the valuation of risk information (Finucane & Holup, 2006).

Which system dominates is context-dependent, determined by differences in how people think and the degree to which individuals identify a situation that requires formal analysis (Epstein, 1994). Heuristic processing is often expected to prevail over analytical processing because the latter has higher cognitive demands (Chen et al., 1999). For instance, Epstein (1994) suggests emotions and past experience shift the balance of influence in the direction of the experiential system.

Slovic (2000) links these emotive, associative and experiential aspects of intuitive thinking to how we perceive risk. He suggests risk perception is highly dependent upon experiential thinking, which is guided largely by emotion and affect. Slovic et al. (2004) call it "Risk as feelings", which causes fast, instinctive and intuitive reactions to danger. If the activated feelings are pleasant, they motivate actions and thoughts anticipated to reproduce the feelings. If the feelings are unpleasant, they motivate actions and thoughts anticipated to avoid the feelings (Epstein, 1994).

In contrast to much of the above, Khatri and Ng (2000) separate intuition from any association with emotion and guess work. They describe intuition as a sophisticated form of reasoning that comes with years of experience specific to the job. They still characterise it as mostly subconscious as it draws on extensive experience; as complex and quick; and as part of all decisions. They also consider intuition highly accurate (Khatri & Ng, 2000). I contend, however, that the type and extent of experience will influence accuracy.

Roeser (2010) draws conclusions more reflective of how I interpret certain farmer decision making contexts in my research. Roeser considers emotion and conscious reflection as important elements, though she makes a distinction between ethical intuitions and gut feelings. Roeser argues that it is unclear whether certain emotions, such as moral emotions, are used strictly in the experiential system. For instance, moral emotions may be a source of reflection and practical rationality and such emotions may not be spontaneous but can be the result of a long process of reflection and intertwined with complex, long-lasting narratives, which are traits more characteristic of analytical
thinking. She concludes that decisions based on gut feelings are not irrational but moral
intuitions and emotions that are sources of ethical wisdom that come from ethical
reflection and deliberation (Roeser, 2010). Farmer 13’s philosophy about how we use
insecticide illustrate this. It is about feelings and emotions that have evolved over time
through new experiences, analysis and reflection.

F-13: The initial reason I said insecticides are no good is because in Moree in
the late 1980s—cotton country—on 1 October every year they start spraying
insecticide and they might do 10-12 sprays per crop each year. All you smelt
was insecticides every day. On 30 September you would be covered in flies.
Come 1 October there wouldn't be a fly in the sky. I said I do not want to go
down that path.

Tversky and Kahneman (1974) conceived three key heuristics that they use to explain a
dozen systematic biases in judgment under uncertainty. One of these, Availability, is a
key heuristic that emerged as an important influence on farmer decision making in my
research. In my data, two others, Affect and trust also emerged as important. I discuss
the research and theory behind these three heuristics next.

**Availability heuristic.**

Heuristic processing is constrained by the requirement that the heuristic needs to be first
stored in the memory and then be retrievable and applicable to the decision making
context (Chen et al., 1999). Availability is the mechanism that people use to retrieve
examples of readily accessible and salient memories of events or instances. It is
favoured by personal experience with, and the salience of the instance itself (Tversky &
Kahneman, 1974). For example, Farmer 23’s memory of crop failure means he will use
an insurance spray to control invertebrate pests in high risk crops.

F-23:...having seen earlier chemistry not work causing a very detrimental
economic outcome I take a low risk approach.

Availability is considered one of the more important heuristics for understanding risk
perception and assessing future risks (Sjöberg, 2000a). The idea that frequent media
exposure gives rise to a high level of perceived risk is one apparent example of the
availability heuristic (Sjöberg, 2000a). Use of the availability heuristic also results in
predictable systematic biases in judgement (Slovic, 2000). Instances that are recent, or
have greater familiarity or salience tend to be retrieved in preference and will influence
or bias judgments (Tversky & Kahneman, 1974). Nevertheless, the Availability
heuristic operates within a social and cultural context that generates varied cost-benefit analyses. So, instances or memories that are available to one group may be unavailable to another (Sunstein, 2006). For instance, farmers exposed to more recent or devastating droughts were more likely to be certain about climate change. When predicting the future climate these same farmers did so by extrapolating from their recent experience of drought years (Diggs, 1991).

**Affect heuristic.**

Affect is a subtle form of emotion, defined as feelings that are tagged as positive (like) or negative (dislike) (Slovic, 2000). These emotive evaluations occur rapidly and automatically and are experienced as a feeling state, with or without consciousness (Epstein, 1994; Loewenstein, & Weber, 2001; Slovic et al., 2004; Slovic, 2000). Such emotional reactions can guide responses when they first occur and through conditioning and memory at later points in time (Loewenstein, & Weber, 2001). People then consult or refer to this affective image pool to aid decision-making about risk. For example, Peters and Slovic (1996) argue that in the context of their research, Affect was a powerful predictor of support for nuclear power. They also suggest that Affect associated with images of nuclear power was linked to a person’s worldviews. How an individual feels about a risk such as nuclear power seems to be determined partly by how risk is managed by industry and government and how it aligns with that individual's worldview of how the world should operate. Even in non-risk situations, the emotions emerging at the moment of making a decision, which can be independent of the decision's consequences, can play a role in the choices people make (Loewenstein, & Weber, 2001).

Affect can be viewed as constructed via cognitive means or reactive in a Darwinian sense where it then influences the cognitive process itself, though there is debate over which comes first: do cognitive beliefs trigger the emotional response, or do emotional impulses act as heuristic strategies to develop an argument to support one's emotional stance (Peters & Slovic, 1996; Renn et al., 1992).

Peters, Burraston, and Mertz (2004) and others such as Loewenstein and Weber (2001) argue that risk perceptions are primarily emotional phenomena. Their research implies that people tend to base their judgments of a technology on what they think about it as well as how they feel about it. If they feel an activity is good, they judge any risk as low
and benefits as high; if they feel it is bad, they will judge any risk as high and benefits as low. In the Peters et al. (2004) model, at least, the Affect heuristic is coming prior to and guiding any judgement of the risk.

The following affective elements are considered to influence the emotional value of cognitive beliefs and drive risk perception: dread, fear, disgust and anger on the negative side and admiration, identification and immediacy on the positive side (Breakwell, 2007; Peters & Slovic, 1996). Dread is identified as an apparent major component of Affect and is defined by the extent of perceived lack of control, feelings of dread, perceived catastrophic potential, and the inequitable distribution of risks and benefits (Peters & Slovic, 1996).

Contrary to the above, Sjöberg (2003, 2004) presents a case that gives emotions only a minor role in risk perception. Sjöberg (2003) states, "People make finer distinctions than just a gross affective response of like–dislike" (p.122). Risk is only part of the picture and other dimensions are at work such as attitudes, ideologies and values (Sjöberg, 2003). For example, Sjöberg (2003, 2004) argues that many of the components of dread are not emotional and that evidence of any emotional significance is lacking. Instead, Sjöberg says that most of the dread items refer to severity of consequences rather than emotion and that in his research on opinions and attitudes to nuclear power, it was severity of consequences, such as perceptions relating to a risk involving fatal or non-fatal consequences, that carried the explanatory power of dread. This conclusion is demonstrated in research that Sjöberg (2003) conducted in four Swedish communities that pilot studies indicated might be suitable as host communities for the national Swedish High Level Nuclear Waste Repository. Random samples of residents in each community were mailed questionnaires with 260 questions about attitudes and perceived risk concerning nuclear waste. A sub-sample of non-respondents to the questionnaire were interviewed over the phone. Sjöberg split "dread" into two groups: one with explicit emotional items; the other with items denoting severity of consequences. Sjöberg found that public opinion of the repository was driven more by reason than emotion. Dread did appear as an important influence, but according to Sjöberg its power came mostly from the items measuring severity of consequences rather than emotional reactions. In chapter 7 I describe how for some farmers the potential of severe crop loss, and for agronomists a risk to their reputation is primarily
driven by the severity of consequences rather than emotion. I discuss this further in chapter 9.

**Trust heuristic.**

Trust was an important concept in my research and its use as a heuristic was dependent on whether the people in a farmer's relationship were part of the community (community trust) and had a continuity of association. I discuss the relevant theory here.

In chapter 2 I describe three forms of trust: Public, Institutional and Specific. All three are forms of social trust (see Breakwell, 2007; Siegrist & Cvetkovich, 2000). Trust has been implicated as a heuristic in a number of contexts. For instance, it is argued that trust can function to negate the need for knowledge and reason to make complex decisions. As Siegrist and Cvetkovich (2000) contend people instead employ trust in experts or institutions who share similar values to short cut the need for such thinking.

The function of trust is to reduce the complexity people are faced with. In other words, instead of making rational judgments based on knowledge, social trust is employed to select experts who are trustworthy and whose opinions can be believed as being accurate. (Siegrist & Cvetkovich, 2000, p.714)

For example, using structural equation modelling, Siegrist (1999) predicted acceptance of genetic technology from separate measures of perceived benefit, perceived risk, and trust, and proposed that trust in institutions such as industry or science might function as a heuristic in contexts where the public are unable to evaluate opposing evidence. Siegrist (1999) found the causal influence of trust on perceived risk was strong and significant. Additionally, he found a significant close relationship between trust and perceived benefit demonstrating that trust has an indirect influence on the acceptance of gene technology making trust in this technology a key variable (Siegrist, 1999).

Similar to Siegrist (1999), Sjöberg (2001) found trust can replace the experience of uncertainty or ignorance and can be negative or positive (see also Renn, 2008). However, Sjoberg argues trust has only a weak relationship with risk perception, and only in the context of specific trust, not public trust. A more important predictor of perceived risk was beliefs about the likelihood of unknown effects (uncertainty) associated with the risks, though with nuclear waste, at least, this was mostly restricted to the non-experts as opposed to the experts. Thus scientific institutions trying to
communicate positive messages about a technology may find it difficult where the public judge there are limits to scientific knowledge (Sjöberg, 2001). For example, in examining mistrust of science, Wynne (2001) says that in its self-anointed sovereignty, science and its institutions that develop or regulate GM food frame the associated risk and trust around the delusion that science is capable of testing for all risks and uncertainties. Thus when people respond, they are responding to this state of denial about uncertainties and risk, and the power and cultural structures of institutional science rather than to any risk. This form of mistrust is an ethical and intellectual judgement about the exaggerated claims of scientific institutions or experts and the discourse they construct about the risks surrounding GM food rather than an emotional, heuristic-based response toward the institution involved or the risk itself (Wynne, 2001).

The above highlights how the function and influence of trust can differ in different contexts. Attitudes, values and worldviews affect any correlation between trust and risk, the source of that risk, its messenger and how that message is communicated, though how the message is communicated is thought to have less influence than prior attitudes and trust in the institution or organisation (see Eiser et al., 2002).

Cognitive psychology portrays values and general beliefs as heuristics and biases that can influence stated risk perceptions (Slimak & Dietz, 2006). Although their importance too will vary with context, they can directly influence knowledge construction and decision making, which indeed was the case with farmers and agronomists in my research. Hence, the role of worldviews, values, attitudes and beliefs is the focus of the next section.

Values, beliefs, worldviews, attitudes.

There can be no doubt that the values, norms and beliefs associated with farming differentiate farm life from other lifestyles. They also provide the tools with which farmers make, or do not make, choices about adoption of farm practices. (Dunn et al., 2000, p.21)

This section defines values, beliefs, worldviews and attitudes and examines their role in farmer decision-making.
Defining values, worldviews, beliefs, attitudes.

Values.
Definitions of values vary, but Schwartz and Bilsky (1987) identify the following five features common to most: Values are concepts or beliefs; they are about desirable end states or behaviours; they transcend specific situations; they guide selection or evaluation of behaviour and events; and they are ordered by relative importance. Schwartz (1994) adds that, "Values are desirable trans-situational goals, varying in importance, that serve as guiding principles in the life of a person or other social entity" (p.20).

Values are thought to be relatively stable throughout life, they motivate action, and give it direction and emotional intensity (Schwartz, 1994). Our values are thought to act as filters or amplifiers with regard to information about threats to objects of value (Slimak & Dietz, 2006). They tend to be deeply embedded within a specific cultural context of beliefs, norms and moral convictions (Renn, 2008) and despite their relative stability they do undergo change along an ordered rank of importance. Making one value, such as freedom, higher in importance than say friendship, might change the emphasis on another causing a reorganisation of one's value hierarchy (Grube et al., 1994).

Reflecting this, Wynne (1992b) argues that individuals are not discrete beings with completely separate and fully finished values and beliefs. The form and quality of our social interactions work endlessly to shape our identities, beliefs and values. Beliefs and values are functions of our social relationships and patterns of moral and social identification. To achieve value change though is a long-term process and there remains a need to debate values because we are unlikely to resolve disagreements by better information about facts alone. To think otherwise is a comfortable form of bias (Dietz, 2013).

Worldviews.
Worldviews represent our general attitudes toward the world and its social organisation; they orient and guide our responses in complex situations and are instrumental in determining risk attitudes and perceptions (Dake, 1992). We each have a different view of what we consider to be reality, a reality that is filtered and shaped by past experiences, personal beliefs and values that help construct our worldview (Nettle & Lamb, 2010).
Whereas values are thought to form earlier in life during the socialisation process with family and peers, worldviews develop later through broader experience with the social and political world (Stern et al., 1995). Worldviews are constructed and mediated by these social relations (Dake, 1992). They too act as cognitive filters screening information that leads to particular appraisals of negative emotion and stigma responses (Peters et al., 2004).

**Farmer values.**

There is considerable research that examines the role of values and worldviews in farmer decision making. The purpose of this section is to give an overview of some of the arguments and what this means for extension.

Kerridge (1978) presents four value clusters attached to family farming. Kerridge adapted and expanded on the clusters from Gasson (1973) (cited in Kerridge, 1978). See also Holmes and Day (1995). Most people demonstrate a mix of all these value clusters depending upon context and social relations (Renn, 2008; Stern & Dietz, 1994). All of them are apparent among the farmers participating in my research (see chapters 5–7). Kerridge's four value clusters are

- instrumental values where farming is viewed as a means of obtaining income and security (F-23: the farm has got to return [financially] the equivalent what I could get elsewhere. If it does not I do not want to be there [on farm]);
- expressive values where farming is seen as a means of self-expression or personal fulfilment that includes feeling pride of ownership and the self-respect gained from doing a worthwhile job;
- intrinsic values where farming is valued as an activity in its own right and includes enjoyment of farming and farming life, independence and freedom; and
- social values that place importance on farming for the sake of the inter-personal relationships and involves a sense of belonging to a farming community and continuing a family tradition.

Kerridge's intrinsic and social value clusters reflect the strong connection a farmer can feel toward their land and farming. Because it emerged as important to many of the farmers and their decision making in my research, I explore this in more detail next.
Attachment to place.

F-22: I value the farm as something that has been in my family for years and as something I would like to carry on for a while yet.

F-2: It has been in the family a long time and other bits have been bought recently. It forms a bit of our identity. A lot of us feel a close connection to our land, whether that is because we have been here a long time or because we have worked hard to buy it. It is not something you are likely to easily give up.

Attachment to place (home, farm, community) and occupation as expressed by Farmers 22 and 2 above can exert a powerful influence on risk perception and resilience to change (Marshall, Park, Adger, Brown, & Howden, 2012; Marshall, 2010; Milne, Stenekes, & Russell, 2008).

For example, Kane, King, and Brien (2009) report that different perceptions of risk environments that included attachment to place dictated the varied decisions farmers in their research made, especially on their forward planning and management practices. Their research investigated dairy farmers' motivations to grow different types of forage plants to complement more traditional perennial and annual rye grass feed bases for dryland dairy farms. The following comment from a farmer in Kane et al.'s project concerns his farm and his concept of farming:

Yeah. Like, it means more to me than just "I'll get up in the morning and I'll milk the cows". It's not, you know...It's a family farm; especially this one, it's been in the family since day one: we've always owned it. It's where I live, it's my work: it's my life... It's everything, and if I was to lose the farm, for whatever reason, I'd be lost. (Kane et al., 2009, p.62)

Kane et al.'s interpretation of this comment was that this farmer saw his farm as a part of his family's identity and as something that he held in trust, with his family and its future generations. This affected how he perceived risk relative to his farm and any decisions he made. Other dairy farmers, through economic necessity, regard their properties as assets which facilitate their business enterprises. This farmer viewed his farm as an expression of the family's shared history. Consequently, he was prepared to accept, to some extent, a reduction in lifestyle options to ensure the security of the farm (Kane et al., 2009).

Further, Rogers et al. (2012) examined farmer responses to climate change and the factors influencing their decisions. To adapt to climate variability, one conclusion
Rogers et al. draw is that farmers' attachment to place can increase their desire to improve their local environment and build a more resilient farm business so that farmers and their families can remain on the farm.

The theory discussed in this chapter underpins the meaning and significance of my data (chapters 5-7). It also provides context to my research aim and questions. In the next chapter I discuss what the data mean and draw conclusions that will help understand how empowerment affects farmer decision making about weed and pest management, and what this means for engaging with farmers on the topics of IWM and IPM and similar complex concepts.
9. Engaging the empowered farmer, understanding their learning journey

Overview

As empowerment emerged as a core concept in my data it began to direct the focus of my research, and helped form my research aim, which is to understand the effect of empowerment on farmers' knowledge construction and decision making. From this emerged my core research question, how does empowerment affect farmer decision making about weeds and invertebrate pest management? Empowerment ultimately became the keystone to most of the principal findings in my research.

I divide this chapter into four broad points of discussion to examine and discuss my research question and its implications for extension. The four points are Empowerment; Power-knowledge relations; Ambiguity (where science interpreted risk and uncertainty for IWM and IPM differently from non-scientists); and the IPM story.

Within these four points, I discuss how empowerment affects the dynamics of farmers' power-knowledge relationships; how farmers' autonomy, control and discretion help determine with whom they form a relationship and on what conditions; and the role of trust and how or whether it is earned.

I discuss the different aspects of ambiguity that manifest themselves under two broad headings: uncertainty, and the difference in concern between farmers, and science and industry about the danger of HR and IR to farm viability and productivity. The IPM story discusses the challenge to engage farmers about IPM. I argue for both an objectivist and constructivist approach to overcome the knowledge deficit, but with a focus on the use of on-farm trials as a constructivist way for farmers to construct meaning and knowledge and make decisions about IPM. The IPM story is also indicative of how empowerment facilitates and supports a farmer's learning journey and the constructivist way farmers think and learn, construct knowledge and make decisions about complex problems.
Table 6 presents an overview of these ambiguities in the form of similarities and differences in farmer attitudes and management strategies that affected their knowledge construction and decision making about weed and invertebrate management.

**Table 6 Differences and similarities in farmer attitudes and management strategies toward managing weeds and invertebrate pests**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Similarities</th>
<th>Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term versus short-term</td>
<td>Farmers took what is considered by proponents of IWM and IPM as a short-term view to manage weeds and invertebrates.</td>
<td>Farmers acknowledged they typically only managed invertebrates from year-to-year (short-term). In contrast, if farmers perceived they had a weed problem, they considered that a 3-5 year management strategy was long-term. The agricultural research and industry groups argued, however, that a 10-20 years outlook is required to manage HR and weed seed bank.</td>
</tr>
<tr>
<td>Value for natural systems</td>
<td>Some farmers ranked their value for natural systems higher the others but it was present in all farmers and affected their long-term objectives for the farm, and their attitudes toward weed and invertebrate management in that they all appreciated the need to move away from chemicals as the dominant management tool.</td>
<td></td>
</tr>
<tr>
<td>Chemical use</td>
<td>Farmers acknowledged the need to move away from chemical-dominant management.</td>
<td>Farmers followed their agronomist's advice for herbicide use. They were less inclined to follow such advice for insecticide.</td>
</tr>
<tr>
<td>Plant versus invertebrates</td>
<td></td>
<td>Farmers typically had a moral aversion to killing invertebrates, which contributed to their greater inclination and desire to avoid insecticide use. There existed no such aversion to killing weeds. Invertebrates are given a different moral status to weeds.</td>
</tr>
<tr>
<td>Latent versus inherent uncertainty</td>
<td>Latent uncertainty about the climate and similar physical factors (frost, drought) affected decision making for invertebrates and weeds, but this was the limit of similarities.</td>
<td>Latent uncertainty affected farmers' knowledge construction and decision making about invertebrates more so than with weeds (for example, are the pest invertebrates present or not). Uncertainty about weeds was predominantly inherent. For instance, any uncertainty about weed identification or control strategies could be easily solved by a quick chat with the agronomist, neighbour or a look in the weed identification book or chemical use manual. The knowledge deficit</td>
</tr>
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</table>
make this harder to achieve for invertebrates.

| Knowledge deficit | 
|-------------------|---|
| Farmers could identify most weeds and understand their ecological effect in the paddock. Farmers typically lacked this knowledge about invertebrates. Compared to weed science, farmers perceived a lack of scientific evidence about invertebrates to help manage them using IPM. | 

| On-farm trials | Conducted by all farmers for weed management. It was rare for invertebrate management. |

| Thinking, learning about weeds and invertebrates | Constructivist, social, contextual, iterative, incremental |

| Adoption of IWM, IPM | Use of IWM tactics was motivated by the HR threat. With exception of stored grain pests, IR appeared to have minimal motivation on the implementation of IPM tactics. |

| Risk of HR, IR | Farmers perceived the risk of HR and IR as high. |
| Concern about HR, IR | Farmers' concern for HR was low. Their concern about IR was unclear. Farmers were confident that, with minimal disruption, they could introduce new IWM tactics to manage HR. They appeared less confident or motivated to introduce IPM tactics to manage IR, at least in the field. This may have had more to do with lower prevalence of IR compared to HR in broadacre contexts. |

| Affect, Availability | Both heuristics typically had a powerful influence on farmers' management decisions for invertebrates. By comparison, the same fears and salient memories operating on invertebrate management decisions had minimal effect on weed management decisions. |

In two further sections, I outline a set of core recommendations to help improve extension's engagement with farmers on complex problems such as weed and invertebrate management, and acknowledge the limitations of my research and where there is potential for further research opportunities.
9.1 Empowerment

Although still relevant in certain contexts, it is widely acknowledged, especially where problems are technically and socially complex, that the linear transfer of technology model is often inadequate (see chapters 2 and 8). A proposed alternative was greater farmer participation in research projects initiated to solve these complex problems (see GRDC, 2014). Despite the greater inclusion of farmers in research, their contribution can still be restricted to objectives and the research project parameters defined by others (see Black, 2000; Ingram, 2014). Knowledge may also come with fixed and imposed meanings (Bartlett, 2008). This is considered an objectivist approach and one that can constrain farmers' agency and control (see Bartlett, 2008; Llewellyn, 2007). Further, the objective for many such projects, including many of those funded by the GRDC, is to deliver skills and knowledge to empower farmers (see Bartlett, 2008; Chambers, 1997; Dunn et al., 2000).

In certain contexts farmers may indeed lack or need empowerment, but this was rarely apparent or made explicit in the majority of the research data I examined for this thesis. It was an assumption only (See chapter 2 and 8). For instance, the GRDC research projects examined in chapter 8 have the objective of empowering farmers, often through acceleration of technology or knowledge transfer. There appears to be no attempt to understand whether farmers are already empowered or if they seek to be empowered.

When constructing knowledge and making decisions about weed and invertebrate management, the farmers in my research are already empowered. Although my research did not directly test for this, my research is at least indicative that this empowerment extends to most agronomic decisions and also to many long-term planning decisions such as those involving family (for example, legacy) and the farm business (for example, empire building). This understanding is important as I argue throughout this chapter that the empowered status affects how extension should engage with farmers.

The status of the empowered farmer is the keystone to nearly all the other principal findings from this research. Empowerment affects the dynamics of farmers' power-knowledge relationships. It affects how farmers interpret information, what meaning it has for them, how they construct their knowledge and make decisions. It affects how they interpret and manage risk and uncertainty. Empowerment facilitates and supports a
farmer’s learning journey and the constructivist way farmers think and learn. This section discusses the way empowerment affects these factors and its implications for extension.

**Engaging the empowered farmer.**

Farmer empowerment and its implications for farmer decision making needs to be understood if extension is to establish an effective relationship with farmers.

Nettle et al. (2015) for instance, consider the empowered farmer as critical for RD&E. Without empowered farmers, most technology-push options fail (Nettle et al., 2015). Nettle et al. also argue that collaborative research designs need to avoid the objective of information as the sole output. They argue instead that extension needs to understand how the research process contributes to farmer empowerment and adaptability (see also Ayre, Nettle, & Love, 2012). Farmers still need access to support and expertise, but the emphasis needs to be on ways to aid reflection and learning, and create and facilitate knowledge networks (Dowd et al., 2014; Nettle et al., 2015).

This supports what emerged in my research data: that we need not only to understand how farmers learn, think and interpret knowledge, and then construct their own, but to enable and facilitate the empowered farmer to do so creatively. My research data indicates that the empowered farmer proactively seeks research knowledge to strengthen agency and control. This does not mean change will occur or decisions will be made. Farmers in my research analysed and reflected on the value of any knowledge; they interpreted and created meaning from that knowledge. Their experiences, values, worldviews and objectives for their farm also affected their analysis, reflection, interpretation and meaning to construct knowledge, which they then used at their discretion. It ensures as Farmer 2 says, "You are not just at the bottom of the food chain waiting for all these so called experts to hand out info saying you need this or that”.

These are also traits characteristic of constructivist thinking and learning, something that I argue develops naturally for farmers because of the complex and dynamic farm systems they operate in, a system that requires adaptability and flexibility. Constructivist thinking and learning enables adaptive behaviour; it is a way to help solve complex problems; it helps innovative ideas to emerge and be tested because it is more than learning or extracting facts. It is a process that I argue farmers engage in to
interpret and give meaning to an experience. It is an interpretation and meaning that will evolve with each new experience. Empowerment is a key component that supports and, in some ways, enables constructivist thinking and learning.

I argue therefore as Bartlett (2008) does, that engagement with empowered farmers requires a constructivist approach as it enables farmers to act as autonomous agents, think critically, analyse, experiment, reflect and from these experiences construct meaning and knowledge unique to each farmer. This does not mean that an objectivist approach is inappropriate. Sometimes simple problems or introductory knowledge are better supported by more objectivistic approaches, for example introductory biology and identification of invertebrates. Most times though with complex concepts such as IWM and IPM the objectivist approach is incompatible with how farmers learn and think.

9.2 Power-knowledge relations

Understanding relationships.

In Weber’s resource-based power model (Gerth & Wright Mills, 2009), relationships are a means or resource base for power and used to achieve an objective (see also Uphoff, 1989). Power is also either authoritative or coercive. For Foucault (in Foucault & Gordon, 1980), authority does not exist. Power instead exists through the network of relations. Some agronomists in my research seem to perceive they have authoritative power in the form of their agronomic expertise. As I discuss below, the bigger picture tells a different story.

Farmers in my research actively seek their agronomists for their expertise, and often just as a sounding board for their own ideas. This seemed especially evident for weed and invertebrate pest management. But as noted, some agronomists appear to perceive their expertise gives them an authoritative role. This role is to instruct farmers and deliver information. In doing so, they attempt to control and manage the knowledge, define the objectives and direct behaviour (see Jonassen, 1991). It is also an objectivist approach to extension. While this may be how the agronomists in question perceive their position, I argue that farmers have a different perspective. For instance, Wood et al. (2014) talk about farmers being the principal facilitators of any knowledge exchange. Although I did not assess this directly, my data is indicative that it is an empowered, autonomous
The farmer who actively seeks and initiates relationships, and exercises choice and discretion about who to engage with.

As Snowden (2003) argues it is these relations, through which the power and knowledge circulate, that need to be understood rather than attempts to manage the knowledge (see also Foucault & Gordon, 1980; Schirato et al., 2012). Wood et al. (2014) make a similar argument. They say that rather than focus on attempts to theorise about new ways to develop specialist facilitation between experts and non-experts (where farmers are considered non-experts), the effort should focus on finding and understanding the existing farmer-facilitated knowledge networks and how they sustain agricultural innovation. I too argue that regardless of the agronomist's perspective and attempts to manage knowledge, any power exists not as a resource in the form of expertise, but through the farmer-agronomist relationship where the agronomist's knowledge circulates with other competing knowledges. Farmers analyse and create meaning from this varied knowledge, and construct their own, but it is the relationship itself that is the crucible for knowledge construction.

Farmer 23 exemplifies this in a more concrete way.

F-23: So how do I do this [make good decisions], I mix with good people, mix with who I think are the best operators and I refine that in my own mind.

Hence, I also argue that extension needs to focus on understanding these relationship dynamics to improve farmer engagement in solving complex problems. This does not mean that the farmers' objectives, interpretation, knowledge and decisions that emerge from power-knowledge relations are sound or rational, but in an effective relation they are at least subject to arbitration, as are those of others in the relationship (see Dunn et al., 2000).

In a further reflection of Foucault's concept of power, the farmers in my research will observe, investigate, then interpret and create meaning for an event such as the scientific data about the risk of chemical resistance, or the message urging farmers to adopt IWM and IPM and the long-term benefits of doing so. Similar to Foucault's description (in Foucault & Gordon, 1980), it is through farmers' use of instruments such as observation, interpretation and investigation that power evolves and knowledge is constructed. The
fact that farmers' interpretation and meaning of an event is often different from that intended by science or the extension effort is further evidence of their constructivist thinking and learning (Ertmer & Newby, 2013; Hein, 1991).

Although I emphasise the importance of the farmer-agronomist relationship for knowledge construction, my evidence is largely from the perspective of the farmer. Further research is needed to understand the significance of the relationship to a farmer's interpretation of events and their knowledge construction. This will mean getting a better understanding of the agronomist's perspective and influence, and observing the actual farmer and agronomist together to understand the dynamics of the relationship itself. This should include also how this relationship interacts with others within a farmer's interconnected network (see Woods et al., 2014).

While the relationship is the crucible for power and knowledge construction there are different ways of thinking that affect how a farmer constructs knowledge and makes decisions.

**Knowledge construction: thinking, reflecting fast and slow.**

I have argued that Foucault's conceptualisation of power-knowledge is one of the better conceptualisations to help explain how I interpret the concepts empowerment, power and knowledge construction that emerged in my data. What also emerged as factors in farmer decision making were the roles of intuition, emotion and reason.

Farmers' knowledge construction about weeds and invertebrate management is often to help make decisions to manage risk and uncertainty. Slovic (2000) links the emotive, associative and experiential aspects of intuitive thinking to how we perceive risk, suggesting risk perception is highly dependent upon experiential thinking, rather than reason and analytical thinking (see also Epstein, 1994). Supporting this, there is evidence that in complex decision-making contexts, hence where uncertainty exists, farmers will often rely less on reason and analysis of scientific facts and more on intuitive-based heuristics (see Darnhofer et al., 2010; McGuckian, 2006; Menapace & Colson, 2012; Murray-Prior & Wright, 2001).

For the farmers in my research, the form of thinking used and which had greater influence was context dependent. The more heuristic-based and emotive (intuitive)
response was evident and predominant for farmers and agronomists who experienced crop failure because of a missed insecticide application. To some extent it was evident also in the context of the thresholds used to manage invertebrates. But in nearly any other situation, emotion as a heuristic was not a dominant influence. Experience or gut feel (intuition) are evident, and indeed important in many farmer decisions, but farmers reflected on their experience and weighed it against other competing knowledges. They also weighed it up against their values, and worldviews. Their intuition was an integral part of a reasoned analysis. This was especially evident where farmers' value of natural systems and moral values on invertebrates influenced decision making (chapter 7). These farmers were influenced by varied emotions (heuristics) that influenced the decision making process. For instance Farmer 13 experienced his own silent spring and Farmer 8 has a moral opposition to the kill all approach. These experiences are emotive, but they do not act as mental shortcuts to decisions about the use of broad spectrum insecticides. These emotive experiences are weighed up against multiple factors: the risk and uncertainty of crop loss, new experiences such as the appearance of different pests, their agronomist's advice, their perception of risk to family health, new management approaches or technologies, and so on. Many of these factors involve reason and they are integrated with the emotive experiences where together critical thinking and reflection occur. As cumulative experiences they continually shape farmers' knowledge and meaning (see Ertmer & Newby, 2013; Schultze & Stabell, 2004). They are part of what Roeser (2010) describes as complex, on-going narratives. Thus from one perspective a farmer's intuition in these contexts is a slow and reasoned form of thinking.

For this reason, Nuthall (2012) argues that finding ways to facilitate and enhance farmers' intuition may improve their decision making. Although untested, he suggests one way may be to encourage farmers to share and critically review their decisions and experience through mentor groups made up of trusted farmers. Given farmers' constructivist approach to thinking and learning where the social nature of dialogue, analysis and reflection are important to their knowledge construction this is an important idea to test. Having said that, most farmers in my research also seek quantitative data. Experience and intuition are still important, but if reliable quantitative data is available they want it. As farmer 14 says, "We need to use more data". One way of getting that data is through on-farm or farmer-led trials.
Trialling.

The literature notes that farmers' use of on-farm trials is important to reduce risk and uncertainty, and to facilitate learning. It helps farmers determine whether or not to adopt an innovation (see Abadi Ghadim et al., 2005). Roling and van de Fliert (1994), however, place greater emphasis on on-farm trials as part of a farmer's learning process and one that we need to understand. Adoption is secondary.

Trialling did emerge in my research as important for farmers to assess risk and uncertainty, yet, as Roling and van de Fliert observed, it was not necessarily a step in the adoption process. As I discuss in more detail below (section 9.4), it became apparent that trialling is an integral part of a farmer's learning journey, yet I extend this to argue that trialling is part of a complex narrative about farmer empowerment. I argue that the knowledge constructed from the process of trialling and experiment enables further analysis, critique and reflection. Importantly, in the context of this argument, it stimulates agency (see Bartlett, 2008), enables control and hence empowerment. Empowerment, or the need to maintain agency and control, is a powerful motivator for on-farm trialling that, along with facilitating knowledge construction, ensures farmers are not passive recipients of information. Farmer 18 is explicit in this.

F-18: You have to be careful you do not get wound up with all the hype...You have to know what works...just because you have been told something does not mean it is right. If I think it has merit I might trial it internally.

As an experiential form of learning, experimenting and on-farm trialling reflect a constructivist approach. Farmers do this out of necessity and as a natural way of learning and thinking about a problem, and to construct meaning and knowledge. For farmers in my research it was also social and operated as part of, or through their knowledge-relationships. Coughenour (2003) observed similar behaviour within no-till cropping networks and described trialling as a never-ending process of social construction of new techniques that require their shared cultural knowledge. He too, describes a learning journey.

As part of research projects, farmer groups such as BCG and SFS conduct on-farm trials with farmers. Collaborative trials between farmers and research groups also occurs in relevant GRDC projects. I did not directly assess the extent of, nor the dynamics of the
relationships between the farmer groups, researchers and farmers as part of my research, but as all farmers in my research, in some way, conduct on-farm trials and they share these stories with other farmers and their agronomists, I argue there is capacity to use farmer-led trials to generate more data and knowledge that could be of use and made accessible to farmers, agronomists and researchers. A key issue to overcome, however, is that many of the farmer-led trials in this research, lack scientific rigour. As Farmer 4 illustrates, most data resembles anecdote rather than robust scientific data.

F-4: We work around the edges. Using trial and error, we'll have a go, test it, tweak it.

Thompson and Scoones (1994) had a similar experience, though their research was done with farmers in developing nations with different agricultural systems, levels of education and access to resources.

Understanding how to get greater involvement from farmers and generate more meaningful data from farmer-led trials is beyond the scope of this thesis. But my research does highlight its potential. For instance, all the farmers in my research appreciate the science relevant to their industry, and indeed science generally. While some farmers are time constrained or do not see conducting rigorous science as their role, a number work closely with farmer groups in running scientifically robust paddock trials. Others acknowledge the need for more robust data and some at least are now seeking ways to achieve it in their own trials (see chapter 7.3). Greater willingness of farmers to participate in research was also noted by Dunn et al. (2000). Further research is required to understand the level of support for this concept, and to assess its feasibility and ways to make that data accessible to others.

I have alluded to the importance of building social capital. Relationships and trust are key to achieving this.

Focus on the relations.

The farmers in my research acquire and build up social capital through investment in relationships and the subsequent connection of those relationships into interconnected networks. Similar to Wynne's (1992a) observation, their beliefs, the knowledge they
construct, and their perception of the credibility and trustworthiness of the people in those relations, are functions of these networks.

Other research has found that the more extensive and connected farmers' networks are, the stronger the community connections and greater the opportunity to learn about innovations and to possess adaptive behaviours (Howden et al., 2007; Nelson et al., 2007; Sligo & Massey, 2007). Although my data supports the importance of farmers' relationships and their connections and that investment in social capital is crucial to resolve complex problems, I did not research in any depth the extent or connectedness of farmers' networks and the implications for IWM and IPM. This is something that could be better understood through network analysis methods (see Wood et al., 2014) and Actor-Network Theory (see Coughenour, 2003). Instead my research expands on this existing knowledge by revealing social capital's role in farmers' empowerment and how it affects their knowledge construction and decision making.

The role and significance of empowerment becomes apparent in the context of relationships and trust. Empowerment affects the dynamics of these relations through farmers' exhibition of choice, discretion and self-direction. It affects who a farmer forms a relationship with and on what conditions, and it affects the nature of trust and how or whether it is earned.

**Trust.**

The influence of trust on risk perception and decision making is context dependent, though it is considered influential in helping develop and maintain a relationship. Without trust a relationship will struggle or fail (see Milne, Steneke, & Russell, 2008; Smith et al., 2012). Certainly, Porter et al. (2007) observed farmers had a high level of trust in agronomists, as well as other farmers. While my data supports this, Porter et al. do not investigate the rationale for this trust, nor the context in which it is relied upon. They speculate that trust in agronomists is influenced by a tendency to place a value on services that are paid for. To an extent, this may be so for some farmers with independent or fee for service agronomists, but there was no indication this was the case with the farmers in my research. Farmers in my research exhibited a high level of trust in their agronomist whether they were sales agronomists or fee for service, but this trust had to be first earned. It was not automatically granted.
Trust is also considered a heuristic in many contexts, acting to negate the need for knowledge and reason. People instead employ trust in select people or organisations to short cut the need for complex decisions or where knowledge lacks (Siegrist & Cvetkovich, 2000; Sjöberg, 2001). Again, there was no indication this occurred with farmers in my research except in certain contexts such as where farmers needed to make decisions quickly, and relied on the advice of their agronomist and then again only if that trust had been earned.

In my research, trust functioned as a glue to help form and then keep intact the social processes, and hence farmer relations within farming communities and between farmers themselves. McGuckian (2006) observed that a shared context between the information source and the farmer is critical. My research expands this notion and defines a component of this shared context as three trust filters that a farmer uses, consciously or unconsciously, to test out a person's credibility and the value of their expertise to ensure that trust is earned. These are community trust, continuity of association and owning/managing a farm. These filters underpin farmers' trust in their agronomists and are important considerations for any person or organisation that wants to engage with and establish a relationship with farmers, especially where farmers are urged to change and adapt farm practices.

This does not mean that where any of the three filters have yet to be established, the information or knowledge is rejected. Instead, greater scrutiny and oversight occurs. Information may be treated with greater skepticism and as such require longer to filter through the knowledge construction system. Trust in this sense, is an enabler of knowledge construction, and of adaptability and change.

*Making it work.*

It could be argued that a relationship between science (scientists and their organisations) and farmers, or science and farmer groups is a business relationship and therefore cannot be considered social capital. Indeed, a scientific organisation is unlikely to have the same connection to a farmer's community and community process that an agronomist does. My own experience suggests the scientists themselves are also less likely than agronomists to be farmers or be part of a family farm. As Fleming et al. (2014) argue, however, knowledge exchange and knowledge construction through participatory extension methods fail unless there are established, long-term and personal
relationships built on trust, and where farmers’ power is recognised. Without this, engagement methods almost always revert to traditional knowledge transfer approaches and the problems of opposing objectives and different interpretation of the knowledge remain (Fleming et al., 2014). Further, as farming becomes more complex, good networks with a depth and variety of skills are increasingly important. With complex, multi-disciplinary problems such as invertebrate management an individual is unlikely to have the skills to manage it alone. Farmers, scientists and professionals will need to become more adept at forming and working in teams to resolve such problems (Nettle et al., 2015).

Thus I argue that, especially with complex problems such as weed and invertebrate management, an effective relationship has to be built with farmers that is based on continuity of association and community trust. And I argue as Wood et al. (2014) do, that farmers’ relationships, for example those with agronomists, seed merchants, vets and other farmers, and especially the long-term relationships, are strengthened though informal and social interaction. Such relationships became multi-dimensional and personal. This is social capital. Further, as Nettle et al. (2015) also argue, extension will need to consider in any such relationship the potential of farmer empowerment, for example their self defined objectives and agency. Thus extension will need to invest in social capital and build knowledge networks (interconnected relationships) that enable dialogue, analysis and reflection within a learning environment that will facilitate and support farmers’ constructivist learning processes.

The following section discusses the implications of the following research sub-questions where ambiguity is a consequence: how do farmers interpret the science and messages about IWM and IPM? How does interpretation of these messages affect farmer behaviour? How do the concepts of complexity, risk and uncertainty affect farmer decision making? And what role do heuristics play in decision making?

9. 3 Two tribes

Ambiguity, where science will interpret risk and uncertainty and construct a meaning that is different to non-scientists, is well documented in the literature (see Beck, 1992; Renn, 2003, 2005; Wynne, 1992a). In my research also, farmers, researchers and extension each have different frames of reference about the weed and invertebrate problem that results in different interpretation of IWM and IPM and therefore different
management objectives, priorities and risk perception. In my data, ambiguity manifested itself in different ways and was exacerbated by mixed messages from science and extension. This section discusses the different aspects of ambiguity that emerged in my data and its implications for farmer decision making and extension.

The different aspects manifest themselves under two broad headings. The first is uncertainty, which underpinned and motivated much of the ambiguity. The second is a difference in concern between farmers, and science and industry about the danger of HR and IR to farm viability and productivity. Science perceives a problem; the farmer typically does not.

**Uncertainty.**

The concept of uncertainty as an influence on farmer decision making pervades much of my research data and its influence is more significant than risk or complexity. Uncertainty is most apparent in the perception of IPM efficacy and the different concepts of long-term, which are discussed below. The role of uncertainty in the perception of IPM is discussed further in section 9.4.

**IPM efficacy.**

In the farmer-targeted literature, IPM is often framed as an effective strategy to manage invertebrates, reduce costs and farm more sustainably. The scientific literature acknowledges uncertainties and limits of scientific knowledge for some aspects of invertebrate biology and the efficacy of certain IPM tactics, but I failed to find an extensive discussion of these uncertainties in the farmer-targeted literature.

Regardless, the scientific proponents of IPM typically see these uncertainties as quantifiable, and known or at least manageable in the context of IPM's efficacy. The science is considered sound and sufficient to implement IPM, and IPM is communicated to farmers as a viable and necessary management strategy. In contrast, farmers and, to some extent, agronomists consider there is insufficient science and too many uncertainties. They have a different perception of the risk and attach a different meaning to these uncertainties, which they consider unknowable or unquantifiable.

Scientists' different perception of the uncertainties leads them to frame their argument around the long-term consequences of not adopting IPM. In contrast, farmers and
agronomists fear the consequences of adopting IPM. The unknown uncertainties make any consequences unpredictable. They therefore take what science perceives is a short-term view to manage invertebrates. This is underpinned by cultural and societal factors that include fear of reputation damage and crop loss that mean they tend to manage invertebrates year-to-year. As examined in chapter 7 and discussed further in section 9.4, this is underpinned by a knowledge deficit.

**Taking complexity and uncertainty in their stride.**

Complexity may delay a decision because of the longer process of analysis and reflection, but it does not prevent change. Complexity, and therefore uncertainty, is part of farming and farmers can and do make complex decisions involving uncertainty every day (see Gianatti & Carmody, 2007; Jackson et al., 2009; Kingwell, 2011; Pannell & Zilberman, 2000; Wynne, 1992a). My data certainly supports this.

The ambiguity associated with complexity and uncertainty manifests itself to some extent in differences in perceived need. My data illustrate varied instances where extension strives to remove complexity. In some instances, this may be because farmers are perceived as unable to cognitively cope with it. Certainly Ag-I-01 thought this, at least for some farmers:

Ag-I-01: There is a lot of people [farmers] who cannot deal with the complexity of farming, that is part of the problem. They do not have the cognitive skills.

Given the evidence that emerged in my research, I argue that farmers want the complex detail; they need the uncertainties and implications openly discussed. The farmers in my research indicate they require this context to judge the veracity of assertions or data about weeds and invertebrate management. It is crucial to their empowerment, their knowledge construction and decision making.

My research also indicates that, for IWM at least, the perceived complexity does not prevent its adoption by farmers. Affecting adoption of IWM are the different frames of reference about HR and the concept of long-term, and mixed messages from science, which is discussed in the following sections. With IPM, I argue it is uncertainty rather than its complexity that impedes the learning and knowledge construction relevant to IPM. As noted, this is driven by the knowledge deficit and is discussed later in this chapter.
One instance where I did observe complexity and uncertainty openly discussed was at a farmer-targeted IPM workshop, but it failed to attract its target audience, the farmers. In this workshop, the scientists appeared to recognise the limits of scientific knowledge regarding IPM and did not deny or obfuscate the uncertainties. This is important because if farmers perceive there is denial and obfuscation of uncertainty, trust and the integrity of a relationship will likely be affected (see Beck, 1992; Frewer, Miles, Brennan, et al., 2002). But there were few farmers in attendance, which highlights the potential need to rethink how extension engages with farmers about IPM, especially the uncertainties and their implications.

Although I am aware that the scientists presenting at this workshop have talked at other events that farmers attended, I did not attend these events and therefore lack knowledge of the scientists’ presentations, and farmer interaction with the workshop content and presenters. Further research is required to understand how science and extension engage directly with farmers about the uncertainties of IPM, and how farmers interpret and use the data to construct meaning and knowledge.

**Long and short-term.**

Scientists and industry typically have a different perspective to farmers and agronomists about what is long-term weed and invertebrate management. Again, uncertainties underpin these differences, which manifests itself in further differences in how farmers, science and agronomists interpret the scientific message about chemical resistance and how to manage it.

Here too, science frames its argument around the knowable uncertainties associated with HR and IR that should be managed for the long-term, which for IWM is 10-20 years; for IPM it is up to 10 years. The 20-year period for IWM is linked to the time needed to get a return on investment. With IPM, it is more about the time needed to establish a functional ecosystem to manage pest invertebrates with minimal chemical input.

In contrast, farmers consider a long-term weed management strategy is about five years. For invertebrates, it is only one or two years. Farmers perceive there exist unknowable uncertainties for IWM and IPM that make it difficult for them to think beyond these timeframes. These uncertainties place doubt on the value of investment in IWM. For
IPM, the consequence of uncertainties is fear of crop loss, a fear based on experience and emotion that results in risk averse decisions that typically culminate in the use of insecticide. These uncertainties are facilitated and potentially exacerbated by mixed messages.

For instance, in the context of rising levels of HR, the farmer-targeted literature as well as some academic literature emphasise that new herbicides are a long way from commercialisation and we need to conserve the ones we have. Contradicting this are messages from scientists at farmer-targeted events, such as GRDC crop updates and webinars, that claim we are developing new herbicides, and some are close to commercialisation.

There are also mixed messages about the economics of the long-term outlook of IWM. The 20-year outlook for IWM, which is also based on the need to conserve the efficacy of the existing herbicides, is contradicted by economic modelling that says in many situations farmers are economically better off to continue using two of the more common broadacre MOA herbicides until they no longer function rather than trying to conserve their efficacy for the long-term. This modelling data is published in the academic literature, but it is also being presented and discussed at the same or similar farmer-targeted events as the new herbicide research (see chapter 7.2).

This made farmers in my research ask, how long have I got until the herbicide fails and I am forced into alternative action? How effective is my existing weed management strategy? Will my existing weed management be effective until new herbicides or technology arrives, which many farmers anticipate will happen? Do I invest time and resources now and implement more IWM tactics to extend the longevity of the existing herbicides? The mixed messages raise further uncertainties and one consequence of this is that an empowered farmer with their own objectives will, as Farmer 12 says, do what works for them.

F-12: Even BCG were [saying] no sheep [in the cropping system] and now all of a sudden sheep are back in. Mixed messages. I just do what works.

This rationale typically underpins farmers' shorter-term thinking about weed and invertebrate management. For instance, the difference between the messages for IWM's
long-term outlook and that of the economic modelling is that the latter message more readily aligns with farmers’ interpretation of HR and how to manage it. The economic models also tell farmers that their existing management strategy is economically sound. Even if farmers are unaware of the economic modelling data, IWM framed around a 20-year outlook is incompatible with how farmers plan and think about weed management. One potential solution is to reframe the message to align better with where and how farmers think long-term.

**Reframing long-term.**

Farmers' emotional attachment to their land influences their perception of risk and resilience to change (Marshall, Park, Adger, Brown, & Howden, 2012; Marshall, 2010; Milne, Stenekes, & Russell, 2008). This attachment to the land and farming embeds them into the cultural matrix of farming (see Porter et al., 2007; Vanclay, 2004), and it underpins their objective to build a resilient and sustainable business for themselves, their family and future generations (Frost, 2000; Rogers et al., 2012). Attachment to land, along with Empire building and Legacy, are concepts that motivate the farmers in my research to think in timeframes beyond 20 years.

I argue that science and farmers have incompatible concepts of long-term and a farmer's concept has some effect on how the IWM and IPM messages are interpreted. Farmers' objectives and values that affect how farmers do think long-term, such as those I identify, could be used to help re-frame engagement messages about IWM and IPM.

For instance, although I did not test this, messages and dialogue could be framed around a need to implement IWM and IPM because it builds value in the farm as an asset, or builds a more resilient and sustainable farm system for future generations. This may resonate more with farmers than return on investment and time to establish a functional ecosystem. It may also change how they perceive the associated risks and uncertainties because the risks are no longer confined to the health and value of the crop for the next 1-5 years, but spread over 10-20 years and in the context of family, the land and value of the farm as an asset.

One potential advantage of aligning the objectives of IWM and IPM with a farmers' objective to build a resilient, sustainable and valued farm business and asset for themselves, their family and future generations is that these objectives and the values
that underpin them appear stable compared to the dynamic and uncertain year–by–year environment in which many farmers manage weeds and invertebrates.

The final ambiguity of note is different perceptions of the problem of HR and IR.

**Problem, what problem?**

Science and extension often frame chemical resistance (HR and IR) around an urgent need to adopt IWM and IPM because of a high risk to farm productivity and viability. Science and industry also exhibit a high concern. This means they interpret the risk as real and the danger imminent should farmers fail to adopt these strategies. Farmers in my research agree the risk is high, but most have a different perception about the dangers to their farm viability and productivity because they have a different interpretation of the hazard (HR and IR). This affects farmer decision making about IWM and IPM and has implications for how to engage with farmers about IWM and IPM.

Farmers place HR and IR low in the hierarchy of risks to be concerned about because they are confident in their ability to manage it with their existing strategies. With IWM, at least, use of a new IWM tactic may require a learning period that includes on-farm trials, but farmers are confident in their ability to access knowledge and implement different tactics if they need. Farmer 11 sums up the attitude below.

**F-11:** It [HR] is an issue there is no doubt about it...it does not really concern me because I have crop competition.

Facilitating this attitude, a number of farmers revealed an optimism bias where farmers perceived that a new technology, likely a new chemical, would be developed before chemical resistance became unmanageable. Their experience, so far, justifies this optimism. Again, the engagement implications are a need for an effective long-term relationship that facilitates dialogue, analysis and reflection. The nature of the dialogue and construction of meaning and knowledge will likely vary depending on the farmer and others in the interconnected networks, the farm systems and farmers’ objectives for them. I argue, however, that extension needs to accept the potential for different interpretation of the science as part of the relationship with farmers. An effective relationship enables these differences to be understood and become part of a constructive dialogue rather than a divisive force.
This section emphasised the importance of framing and the need to understand how a farmer interprets problems such as HR and IR to ensure messages are those that a farmer can relate to. It emphasised the need to consider how extension communicates uncertainty and risk. Invertebrate management and IPM feature also, but as examined in chapter 7, there are notable differences between IPM and IWM that means farmers interpret the science differently, there are different values and heuristics involved that affect risk perception and knowledge construction. The rest of the IPM story is discussed next.

9.4 IPM story

The concepts of empowerment, power, knowledge construction, trust, uncertainty and complexity are also significant to the IPM story. This section examines the implications of these concepts. The first section is an overview of the broadacre farmer and their perception of IPM. The second examines the challenge to engage farmers about IPM compared to IWM. In the third section I argue that to overcome the farmers' and agronomists' IPM knowledge deficit requires both an objectivist and constructivist approach. Finally, I argue that trialling is a natural way for farmers to not only understand uncertainty and risk, but is a constructivist way to think and learn that can enable farmers to construct meaning and knowledge, and make decisions about IPM.

IPM and the broadacre farmer today.

The objective of IPM is to reduce the use of insecticides and create a more sustainable and resilient farm system. All farmers and agronomists in my research have moved beyond the prophylactic use of broad spectrum insecticide, or the 'insurance spray', as standard practice. The exception is on high risk crops such as canola where residual bare earth sprays are common and part of nearly any agronomist recommendation.

To some extent the motivation to avoid the insurance spray comes from farmers' values for natural systems and a position that considers invertebrates as a form of life with a higher value than weeds. These values appeared to help motivate all farmers in my research to question their existing reliance on insecticides and ensure a baseline reluctance to use insecticide. For a handful of farmers, however, these values featured higher up their value hierarchy (see Grube et al., 1994) and resulted in a greater reluctance to spray insecticide. All farmers and agronomists in my research also
understand the risk insecticides pose to human health, the environment and the long-term viability of farms. They acknowledge the risk of IR, even if this risk, in most circumstances, fails to influence decision making at the moment. Despite these motivations, no farmer in my research fits the definition of someone using true IPM. Uncertainty that stems from a knowledge deficit means insecticides typically remain as the dominant management tool for most farmers and agronomists.

**Weeds versus invertebrates.**

Most agronomists and farmers in my research have a similar management approach to weeds. As complex as the problem is, they have a good understanding of weeds, HR, and the associated risks and uncertainties. The uncertainties are largely perceived as knowable and predictable. If deemed necessary, farmers are confident about using IWM tactics, even if they do not always adopt them the way science advocates. A different interpretation and meaning attached to the severity of the HR problem, their confidence in managing HR with existing tools, and optimism about the timely development of new technologies means farmers typically fail to perceive a need to use IWM unless necessary. Thus, to a large extent, decisions to implement IWM tactics are motivated by the actual presence on their farm of HR unmanageable by any other means.

This does not apply to invertebrate management, although IR may have a greater influence on farmer behaviour as its prevalence increases. With IPM, farmers and agronomists have a knowledge deficit that manifests itself in a perceived uncertainty about the efficacy of IPM in their farm system. As noted already, many of the uncertainties associated with IPM are perceived as unknowable and therefore the consequences are unpredictable. In this instance, the heuristics, Affect and Availability, become powerful influences compared to the risks farmers and agronomists associate with IWM, such as resistance. Agronomists fear damage to their reputation and farmers' salient memory of crop losses result in a tendency to resort to the use of insecticides.

This presents a different challenge to how you engage with farmers and agronomists about IPM. I argue, however, that while the knowledge deficit and the consequent uncertainties affect their decision making, my evidence indicates that because farmers try to avoid insecticide use if they can, when they are confronted with invertebrate management problems, they still analyse and reflect; they still have self-defined objectives; they still have control; they still operate within and rely on knowledge
relations to construct knowledge and make management decisions. The knowledge deficit does mean they have less data on which to base their decisions; it means heuristics, their experience and values have a relatively greater influence in certain contexts, but they remain empowered.

**The knowledge deficit.**

From an objectivist approach, a knowledge deficit implies a solution where you give farmers knowledge and teach them about IPM. This linear transfer of information may be appropriate in some instances. But even when appropriate, transferring knowledge to farmers and agronomists will not by itself lead to use of a wider variety of IPM tactics. As Llewellyn et al. (2004) found, adopters and non-adopters of IWM had similar knowledge levels about HR and weeds. As I argue above, to improve farmers’ knowledge and understanding of invertebrates, extension, in its relationship with farmers, needs to consider the empowered farmer who will filter any knowledge through their social system, their own experience, values, worldviews and objectives for their farm. Extension needs to acknowledge and facilitate agency and control. It also needs to consider farmers' constructivist approach to thinking and learning, especially in complex contexts such as IPM. It means there may be different interpretations of the science and messages.

To support farmer learning and knowledge construction—to overcome the knowledge deficit—requires both an objectivist and constructivist approach. Invertebrate management and IPM may be complex but farmers and agronomists lack basic field and taxonomic skills. Improving these skills requires knowledge of objective facts. Learning these may be best achieved through the structured environment of an objectivist approach. Such structured, objectivist-based courses exist already and many agronomists in my research have done these. I argue they are less accessible and appropriate for farmers. Although its objective was less about structured teaching and more about an opportunity to present and discuss recent IPM-based research, the IPM workshop examined in chapter 7 was still a formal structured form of professional development. Its failure to attract farmers is possibly indicative of this. Less formal and more social learning environments that operate within farmers’ knowledge relations may have greater success. These could include IPM-focused crop walks and similar inspections of local trials, or hands-on workshops that occur at field days organised by
farmer groups such as those run by BCG and SFS. Further research is required to understand the most effective way to make this work for IPM.

The constructivist approach requires finding ways to engage farmers over the long-term with the more complex aspects of IPM, for example the ecology of the predator-prey interaction unique to a farm system, and the more socio-cultural factors such as the fear and uncertainties that farmers and agronomists perceive. It is in this context that the expertise of science and extension is considered alongside that of the farmer and others in the relationship. It is where all knowledge is subject to scrutiny and integrated into constructive dialogue, where problems and objectives are defined as part of the relationships, which in turn facilitate constructivist learning and thinking.

As the focus of my research was mainly on farmer decision making, I am unable to argue whether agronomists think and learn in a similar way to farmers, though given the nature of the farmer-agronomist relationship, I argue that they have a crucial role to support farmers' learning. The role itself will be dependent on the dynamics of the farmer-agronomist relationship.

Uncertainty has a significant effect on farmer decision making about IPM, and trialling is one way that farmers manage uncertainty. The next section discusses how trialling, as a constructivist thinking and learning process, might help farmers understand the more complex aspects of IPM and invertebrate management.

Use trialling to engage with uncertainty.

Farmers and agronomists regularly conduct weed management-related field trials. But in invertebrate management, the knowledge deficit and the consequent uncertainties mean that farmers and agronomists are less willing to conduct trials. A lack of skill in how to conduct them may be a contributing factor, but for many agronomists in my research they lack faith in IPM-based trials, perceiving them to be too difficult because of too many uncertainties and the extended time required to achieve potentially meaningful results. Even with sufficient time, one agronomist was skeptical about any IPM trial producing useful results.

As for farmers, in addition to their own trials, they will examine and assess professionally conducted trials, especially those conducted locally by farmer groups,
agronomy professionals and government departments. For example, Farmer 18 uses these trials as a starting point to assess and discuss the implications with others before deciding whether to trial something similar on his place.

F-18: You have got to have the science and they might eliminate a heap of different things...They [SFS trials] are good, but you have to be able to replicate them at farm scale...What worked on a trial plot and treated with kid gloves might not work on a farm scale. What Vic NoTill and SFS do is a starting point for doing larger stuff internally.

The lack of professional IPM-based trials compared to other agronomic problems, such as weeds and disease, means there is minimal baseline data for farmers to begin dialogue, think and reflect about the potential for trials on their own farm. This lack of, at least readily accessible baseline data is also reflected in farmers' and agronomists' perceived lack of evidence (scientific or anecdote) to support IPM.

But, trialling is what farmers do. It is a natural way for them to not only understand uncertainty and risk, but a constructivist way to think and learn that enables them to then construct meaning and knowledge, and make decisions. Trialling could be a principal initiative to help farmers overcome their knowledge deficit as well as help them understand IPM's risks and uncertainties and how IPM could operate in their farm system.

As I argue above, trialling is an integral part of a farmer's learning journey. The concept of a learning journey and its implications for understanding farmer decision making and improving engagement between science, extension and farmers is discussed next.

9.5 Understand, participate in the learning journey

Communication with farmers about IWM and IPM often concerns the urgent need for farmers to adopt IPM or IWM. I argue for a shift away from a focus on adoption to understanding a farmer's learning journey and process of knowledge construction. The journey encapsulates the role of empowerment and power-knowledge relations that together influence, support and facilitate farmers’ constructivist way to think and learn.
Adoption as a concept and a goal is incompatible with the constructivist way farmers think and learn about complex concepts such IWM and IPM, hence my argument to put greater emphasis on the learning journey and process of knowledge construction. This emphasis includes understanding the knowledge relations and the concept of empowerment that are a strong influence on the experiences, learning and knowledge construction that continually occur as part of the journey. The following outlines my justification for this and how it is important to understand this learning journey to enable effective engagement with farmers.

Constructivist learning is open to change as it evolves with each new experience and exposure to continually emerging knowledge. It is a learning journey, one with a route of a farmer's own creation. It is a journey with an indeterminate destination defined by their values, worldviews, experience, their objectives for their farm, and the natural environment including the dynamic nature of the farm system itself.

For instance, all farmers in my research were at least aware of IWM and IPM, yet they or the concept of their adoption were rarely mentioned unless I raised it. What they did talk about when discussing weeds and invertebrates was the problems they faced and had to manage; their conversations about weeds and invertebrates with others, especially agronomists and other farmers; what they read and listened to and how they interpreted that; trials they had viewed on other farms or through their local farmer group; their own trials and how they assessed the value of that test, how well it worked (or didn't), how they tweaked the design or tried it a different way; they discussed their relevant experiences through the years and the implications of this for how they interpreted events and constructed knowledge. They talked about their journey, one that was unique to each farmer and still continues in incremental steps. They expressed no explicit or implied intention to adopt IWM or IPM. As noted already, farmers managed weeds and invertebrate problems as they arose, and that includes chemical resistance.

The incremental nature of the learning journey means adoption cannot be recorded as a point in time as there is no end point to a farmer's learning journey or knowledge construction. Managing weeds and invertebrates is an on-going, continually evolving part of broadacre management. This is a limitation to Kogan's adoption curve as it
implies that IPM, a complex innovation, has an endpoint defined by farmers' effective adoption of sufficient IPM tactics. This is not to deny that at some point a farmer will successfully implement sufficient IPM tactics and have a functional biological system that fits the existing criteria of 'true' IPM. Kogan's adoption curve is a useful guide, but similar to adoption generally, its focus is on defined and measurable objectives that are points in time. For weeds and invertebrates, the learning journey of farmers in my research lacked such objectives. The focus therefore should switch to understanding the journey and the components that determine the nature of that journey. The two key components that emerged in my data are empowerment and power-knowledge relations.

**Empowerment, relationships and the journey.**

Empowerment helps facilitate and support the constructivist way farmers think and learn about complex problems. It is the ability to analyse, think critically and reflect on these problems; to construct meaning and knowledge from new experiences, and adapt accordingly.

Thus, I argue that engagement with farmers on complex concepts such as IWM and IPM requires an emphasis on the constructivist approach. A farmer's power-knowledge relations are integral to this as it is through these relations that knowledge (and power) circulate and farmers create knowledge and meaning. To build long-term relationships with farmers means being part of their learning journey in a way that facilitates and supports their empowerment and their constructivist approach to thinking and learning. Trialling, in its varied forms, is a principal example that should be supported as part of extension-farmer relations. It is a form of constructivist thinking and learning and it acts to facilitate and strengthen agency and control. This is especially relevant to IPM where there exists a relative dearth of local on-farm trials.

In this and previous chapters, I have expanded our understanding of how farmers think, learn, construct knowledge and make decisions about IPM and IWM. I argue that empowerment facilitates and supports this process, and does so through farmers' knowledge relations. To apply this understanding I have developed the following core recommendations to improve engagement between science, agronomists and farmers on not only IPM and IWM, but similar complex concepts in agriculture.
9.6 Core Recommendations

To engage effectively with empowered farmers on complex problems such as weed and invertebrate management I argue the following recommendations are important for extension to consider.

The empowered farmer.

If extension is going to encourage farmer participation in research, and it should, then they need to acknowledge the potential for empowered farmers who will have control and agency, and who will analyse, critique and reflect on information. Extension needs to create an environment within the relationship to facilitate and support this. This means farmers will help define the problem and a project's boundaries and objectives. Dialogue will be a key tool. Most farmers need to understand the risks, uncertainties and their implications. This should be part of any open dialogue involving complex concepts. The integrity of the relationship depends on this and therefore knowledge construction and informed decision making.

Knowledge relations.

To encourage farmer participation in research, extension will need to build effective and interconnected relationships that are long-term and built on community trust. Extension has to focus less on the knowledge it wishes to impart and more on understanding the people with whom it needs to engage, the dynamics of that relationship and those with whom it interconnects. It is the relationship that generates new understanding and knowledge of a problem. Through this, extension will understand farmers' motivations, experiences, values, worldviews and how they think, learn, construct meaning, interpret and construct knowledge, and make decisions. There is no authoritative power. Expertise is not a resource to wield; it is added to the pool of competing knowledge and skills, and incorporated into the dialogue where it is subject to analysis, critique, testing and reflection.

Constructivist learning.

Farmers' constructivist way to think and learn must be facilitated and supported. This will require extension to create a social and contextual environment. One such environment, and a constructivist form of learning, is the on-farm and farmer-led trial. Extension also needs to understand the motivation for such trials, how farmers use the trial data to interpret the science and scientific messages, construct meaning and
knowledge, and apply it to the farm system. This is one way to measure agency and should of a higher priority than measuring adoption. It is also knowledge that will help build effective relationships with farmers.

**The learning journey.**

In complex contexts, such as IPM and IWM, extension should put a greater effort into being an integral part of a farmer's learning journey rather than focused on an objective to accelerate and achieve farmer adoption. Greater insight into how farmers understand a problem, their motivations and process of knowledge construction and decision making will help build an effective, long-term relation and enable participation in a farmer's learning journey. In turn, this will facilitate dialogue, knowledge construction and effective decision making for farmers and extension.

**9.7 Further limitations of research, future research opportunities**

My research is a snapshot in time. In effect it assumes time is frozen and my analysis timeless. But innovations, knowledge and socio-cultural factors continue to evolve and affect farmers' meaning and interpretation of information, and the course of their learning journey. For IPM especially, it would be valuable to track the journey of different farmers to understand how learning evolves, how they interpret and apply emerging IPM knowledge, and so on. (See Rogers, 2003, p. 127.)

IPM offers a wealth of other research opportunities that emerged from my research. These include investigating the potential to generate more meaningful data from farmer-led trials, though this is also applicable to IWM and other agronomic problems. But for IPM especially, there is an opportunity to investigate how to support farmers to use on-farm trials as a constructivist way to begin to understand and implement IPM, and to make that data accessible to others.

I note also there needs to be further research to understand how science engages and communicates with farmers about the uncertainties of IPM, and how farmers interpret and use the data to construct meaning and knowledge. I have argued that farmers in this context will more effectively learn and think in a constructivist way. Thus further research needs to assess appropriate learning and knowledge construction environments and how to build effective relationships to achieve this. This includes the farmer-
agronomist relationship and how it interacts with others within a farmer’s interconnected network.
References


Owen, M., Preston, C., & Walker, S. (2013). Making herbicides last The need to learn to love the herbicides we have. *Ground Cover*, (May-June).


Paterson, J. (2013). Glyphosate lost to the US. *Ground Cover, 4*.


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Appendices

Appendix A

Farmer recruitment survey

Appendix A outlines the survey used to help guide the direction of my research and recruit participants to interview. The survey accompanied a participant information letter that described my research, my ethical obligations and the purpose of the research.

The survey was put online and advertised through a letter in selected farmer group newsletters. It was also handed out as a hard copy at professional development events such as farmer group field days. The primary purpose of the survey was to recruit farmers and agronomists to interview. The questions served to guide interview questions and refine my literature search. All survey participants were also supplied with an ethics information sheet. Note the participant information letter mentions that the research explores decision making about nitrogen use efficiency. This survey was used before the direction of my research changed to instead explore IPM. Indeed, the answers to the nitrogen-based questions were partly responsible for this change in direction.

Survey and explanatory letter

My name is Jason Major. I am a PhD candidate from the Australian National University (ANU). I should like your help in completing a short (5 minute) online survey exploring how farmers make decisions about Integrated Weed Management and Nitrogen Use Efficiency strategies. It is not a knowledge test. The survey is part of my PhD research supported by an ANU research scholarship and the Grains Research and Development Corporation.

The next step in this research involves conversation-based, in-depth interviews with farmers and extension professionals. The last survey question asks if you would like to participate in an interview to explore this topic further. There is no obligation to participate but it will be greatly appreciated. The interview is done face-to-face at a place convenient to the farmer - usually on your property.
To complete the survey go to https://www.surveymonkey.com/s/77ZS8KK

Purpose of project: If we can better understand what influences farmers' decisions on these issues it should improve engagement between farmers and others such as scientists and extension officers. It that will also lead to a better understanding of the problems farmers face and better ways to solve them.

If you have any queries contact Jason Major
email: jason.major@anu.edu.au
phone: 0455 288 309

Survey
Two of the bigger emerging agronomic problems in Australia are herbicide resistance and inefficient use of nitrogen fertiliser. Potential solutions exist, but there is concern that farmers are not adequately adopting them.

My name is Jason Major. I am a PhD candidate from the Australian National University (ANU). I should like your help in completing a short (5 minute) online survey exploring how farmers make decisions about Integrated Weed Management and Nitrogen Use Efficiency programs. It is not a knowledge test. The survey is part of my PhD research supported by an ANU research scholarship and the Grains Research and Development Corporation (GRDC).

Online survey: https://www.surveymonkey.com/s/77ZS8KK

The last survey question asks if you would like also to participate in a conversation-based interview. There is no obligation to participate but it will be greatly appreciated. Alternatively, if you are interested in participating in an interview, you can contact me directly and we can arrange a suitable interview time. The interview is preferably done face-to-face and in a location convenient to the farmer. I am based in Melbourne, so a short drive to the country is considered a bonus.

If you should like to participate in an interview or need more information
email: jason.major@anu.edu.au. Phone: 0455 288 309
How do farmers make decisions about Integrated Weed Management and Nitrogen Use Efficiency?

Survey questions

1. What type of farm do you run (circle most appropriate)
   - Cropping only
   - Mixed farming (cropping and livestock or other)

2. What is the region of your main farming operation? (Circle most appropriate)
   - Western Districts (Vic); Wimmera; Mallee; North Central (Vic);
   - Western Plains (NSW); Riverina

3. What are key agronomic problems you face as a farmer, both today and in next 5-10 years?

4. To any extent, are you aware of
   - Integrated Weed Management (IWM) Yes
   - Nitrogen Use Efficiency (NUE) Yes
   - No

5. Describe how you understand the purpose of IWM?

6. Describe how you understand the purpose of NUE?

7. Would you be interested in participating in a face-to-face interview?
   This survey is part of a larger PhD research project exploring what motivates or influences a farmer's decisions associated with adopting technologies and strategies in Integrated Weed Management and Nitrogen Use Efficiency programs. I am seeking farmers who have cropping as part of their operation to participate in a conversation-based interview to get a deeper understanding of this question.

   How to participate: If you are willing to participate in the interview please enter your name and contact details (phone and/or email) I will contact you soon after to further discuss the research and interview process. Participation is voluntary and there is no obligation to continue following our initial discussion.

   Name:............................................................................................................
   Email:............................................................................................................
   Phone:............................................................................................................

Completed surveys can also be posted to Jason Major, 3/262 Poath Road, Hughesdale, 3166
Survey participant information Sheet

Each survey participant was given the following participant information sheet that outlines the purpose of the research, the survey and my ethical obligations to the survey participants.

Thank you for participating in my survey. It should take about 5 minutes to complete. My name is Jason Major. I am a PhD candidate from the Australian National University. The following are questions for a research project exploring how farmers make decisions about Integrated Weed Management and Nitrogen Use Efficiency programs. It is not a knowledge test. The survey is part of my PhD research supported by an ANU research scholarship and the Grains Research and Development Corporation. The next step in this research involves in-depth interviews with farmers and extension professionals. The last question asks if you would like to participate in a conversation-based interview to explore this topic further. There is no obligation to participate but it will be greatly appreciated.

Purpose of project: If we can better understand what influences farmers' decisions on these issues it should improve engagement between farmers and others such as scientists and extension officers. It will also lead to a better understanding of the problems farmers face and better ways to solve them.

Participation in this online survey is voluntary. You are free to stop completing the survey at any time. I will only receive surveys that are submitted by selecting "Done" on the last question. Your submission is considered to be your consent to participate. Once you submit your data it cannot be withdrawn.

The survey results will be used to refine the interview process and will ultimately be part of the published PhD thesis. Some of the research may also be published in peer-reviewed journals.

I will not collect any information that can identify individuals in anything we produce or publish unless you choose to participate in the interview where the following applies: All attempts will be made to ensure your personal information is completely confidential as far as the law allows. All data and personal details will be kept securely and not used for any purpose other than that outlined above. No details will be used that will enable you to be identified in any publication or presentation.

Queries and Concerns:

If participants have any queries about the research or their participation in it they can contact the primary investigator, Jason Major, by phone or email email: jason.major@anu.edu.au; phone: 0455 288 309. Or Dr Will Grant will.grant@anu.edu.au.
The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee. If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.OFFicer@anu.edu.au
Appendix B.

Research participant consent form

Appendix B contains the consent form and participant information form given to all participants interviewed as part of this research. The consent form signified their consent to be interviewed and to have the interview recorded. The form also allowed participants to choose their level of anonymity. The participation form outlined the nature of my research and my ethical obligations. Note that the consent form contains the original project title before the research focus switched from NUE to IPM. This was explained to participants interviewed after the change in research direction and before they signed the form.

WRITTEN CONSENT for Participants in research project, "Farmers assessment of risk and uncertainty associated with decisions to adopt Integrated Weed Management (IWM) and Nitrogen Use Efficiency (NUE) programs".

I have read and understood the Information sheet you have given me about the research project and I agree to participate in the project.

Signature:..................................................

YES ☐ NO ☐ I agree to this interview being audio taped

I agree to be identified in the following way

YES ☐ NO ☐ Full name
YES ☐ NO ☐ Pseudonym
YES ☐ NO ☐ Complete confidentiality

Signature:..................................................
Appendix C

Research participant participation form

Appendix C contains the participant information form given to all participants interviewed as part of this research. The participation form outlines the nature of my research and my ethical obligations.

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Participant Information Sheet

Hi, my name is Jason Major. I am a PhD candidate from the Australian National University's Australian National Centre for the Public Awareness of Science (CPAS). I am the primary investigator on the following project.

**Project Title:** How farmers assess risk and uncertainty associated with decisions to adopt technologies and strategies in Integrated Weed Management (IWM) and Nitrogen Use Efficiency (NUE) programs.

**General Outline of the Project:**
This research will explore the motivations behind farmers' decision to adopt or not adopt two programs, Integrated Weed Management (IWM) and Nitrogen Use Efficiency (NUE).

If we can better understand what influences farmers' decisions on these issues it should improve engagement between farmers and others such as scientists and extension officers. It that will also lead to a better understanding of the problems farmers face and better ways to solve them.

**Your involvement:**
Participation in this research project is voluntary.
You will be interviewed by the primary researcher to discuss issues of concern for themselves as farmers, and how they perceive IWM and NUE and the issues associated with them. The interview will last up to one hour and be done in a location convenient to you.

The interview data will be used as part of my PhD thesis and potentially papers for peer-reviewed journals. I will also present results to seminars or conferences relevant to agriculture and science communication. You are welcome to read or be sent any published material from this research or call the primary researcher with questions or for feedback on the interview. Interview transcripts and field notes will be sent to participants to ensure they are happy with what they said and to elaborate on or reassess parts of their contribution.

This is an in-depth, conversation-based interview. There is no requirement to divulge information you deem private or personal, or to answer any questions asked as part of the conversation.

The interview will be audio taped only with your consent. There may be a need for a follow up interview or questions, though this may be done via email or phone. You can request at anytime to have your interview withdrawn from the data. All recordings, notes and transcripts will then be destroyed.

The research is funded through an ANU PhD scholarship and a top-up scholarship from the Grains Research and Development Corporation (GRDC).

Confidentiality:
All attempts will be made to ensure your personal information is completely confidential as far as the law allows. All data and personal details will be kept securely and not used for any purpose other than that outlined above. No details will be used that will enable you to be identified in any publication or presentation.

Data Storage:
All data that can be stored electronically, such as audio, notes and any personal details will be stored on a password-protected computer kept at my home and backed up on secure ANU server. Hard copy notes will be stored on file at my home.
It is a requirement that all data be kept for a period of five years following publication. De-identified data may be kept for longer if deemed useful for future research, though only with permission of the participants. Otherwise data will be destroyed - hard copy field notes shredded and electronic files deleted.

**Queries and Concerns:**
If participants have any queries about the research or their participation in it they can contact the primary investigator, Jason Major, by phone or email
email: jason.major@anu.edu.au
phone: 0455 288 309

Alternatively, the participant may contact Dr Will Grant the primary investigator's PhD supervisor at ANU. Email: will.grant@anu.edu.au

**Ethics Committee Clearance:**
The ethical aspects of this research have been approved by the ANU Human Research Ethics Committee. If you have any concerns or complaints about how this research has been conducted, please contact:

Ethics Manager
The ANU Human Research Ethics Committee
The Australian National University
Telephone: +61 2 6125 3427
Email: Human.Ethics.Officer@anu.edu.au
Appendix D.
Coding for interviewee type, their districts and position

Table D1. Abbreviation codes for Interviewees and their position (Farmer, Research Agronomist, Agronomist, Scientist)

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Abbreviation code</th>
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<tbody>
<tr>
<td>Research Agronomist</td>
<td>ResAg</td>
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<tr>
<td>Agronomist</td>
<td>Ag</td>
</tr>
<tr>
<td>Scientist</td>
<td>Sci</td>
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<tr>
<td>Farmer</td>
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**District**

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<tbody>
<tr>
<td>Western District</td>
<td>WD</td>
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<tr>
<td>Northern Irrigation Country</td>
<td>NIC</td>
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<tr>
<td>Mallee</td>
<td>MAL</td>
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<tr>
<td>Northern Wimmera</td>
<td>NW</td>
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<tr>
<td>Northern Western Australia</td>
<td>NWA</td>
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<tr>
<td>New South Wales</td>
<td>NSW</td>
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**Position**

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<th>Position</th>
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<tr>
<td>Agronomist Sales</td>
<td>S</td>
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<tr>
<td>Farmer Continual Cropping</td>
<td>CC</td>
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<tr>
<td>Farmer Mixed</td>
<td>MF</td>
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<tr>
<td>Farmer's wives</td>
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<td>Grains Research and Development Corporation</td>
<td>GRDC</td>
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</tbody>
</table>

Table D2. Farming district for each agronomist and research agronomist

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td>ResAg-1</td>
<td>WD</td>
</tr>
<tr>
<td>ResAg-2</td>
<td>WD</td>
</tr>
<tr>
<td>ResAg-3</td>
<td>WD</td>
</tr>
<tr>
<td>ResAg-4</td>
<td>WD</td>
</tr>
<tr>
<td>ResAg-5</td>
<td>WD</td>
</tr>
<tr>
<td>ResAg-6</td>
<td>WD</td>
</tr>
<tr>
<td>ResAg-7</td>
<td>NIC</td>
</tr>
<tr>
<td>ResAg-8</td>
<td>WD</td>
</tr>
<tr>
<td>Ag-I-01</td>
<td>Western Australia</td>
</tr>
<tr>
<td>Ag-I-2</td>
<td>South Australia</td>
</tr>
<tr>
<td>Ag-S-4</td>
<td>NIC</td>
</tr>
<tr>
<td>Ag-S-7</td>
<td>NW</td>
</tr>
<tr>
<td>Ag-S-8</td>
<td>NW</td>
</tr>
<tr>
<td>Ag-S-9</td>
<td>NW</td>
</tr>
<tr>
<td>Ag-S-10</td>
<td>MAL</td>
</tr>
<tr>
<td>Ag-S-11</td>
<td>MAL</td>
</tr>
<tr>
<td>Ag-I-12</td>
<td>MAL</td>
</tr>
<tr>
<td>Ag-S-13</td>
<td>WD</td>
</tr>
<tr>
<td>Ag-S-14</td>
<td>WD</td>
</tr>
</tbody>
</table>

*Note: Ag-3, 5 and 6 are not included because they were either redesignated as a research agronomist or not used in the analysis*

**Table D3. Farmer interviewees, their farm type and farm district**

<table>
<thead>
<tr>
<th>Farmer</th>
<th>Type</th>
<th>District</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>CC</td>
<td>NWA</td>
</tr>
<tr>
<td>2</td>
<td>MF</td>
<td>NW</td>
</tr>
<tr>
<td>3</td>
<td>CC</td>
<td>NW</td>
</tr>
<tr>
<td>4</td>
<td>MF</td>
<td>NW</td>
</tr>
<tr>
<td>5</td>
<td>MF</td>
<td>NIC</td>
</tr>
<tr>
<td>6</td>
<td>MF</td>
<td>NIC</td>
</tr>
<tr>
<td>7 (1=husband, 2=wife)</td>
<td>CC</td>
<td>MAL</td>
</tr>
<tr>
<td>8</td>
<td>MF</td>
<td>NIC</td>
</tr>
<tr>
<td>9</td>
<td>CC</td>
<td>MAL</td>
</tr>
<tr>
<td>10</td>
<td>MF</td>
<td>WD</td>
</tr>
<tr>
<td>11</td>
<td>CC</td>
<td>WD</td>
</tr>
<tr>
<td>12</td>
<td>MF</td>
<td>WD</td>
</tr>
<tr>
<td>13</td>
<td>CC</td>
<td>WD</td>
</tr>
<tr>
<td>14</td>
<td>CC</td>
<td>WD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>15</td>
<td>MF</td>
<td>WD</td>
</tr>
<tr>
<td>16</td>
<td>MF</td>
<td>WD</td>
</tr>
<tr>
<td>17</td>
<td>MF</td>
<td>WD</td>
</tr>
<tr>
<td>18</td>
<td>CC</td>
<td>WD</td>
</tr>
<tr>
<td>19 (1=husband, 2=wife)</td>
<td>CC</td>
<td>WD</td>
</tr>
<tr>
<td>20</td>
<td>CC</td>
<td>WD</td>
</tr>
<tr>
<td>21</td>
<td>MF</td>
<td>WD</td>
</tr>
<tr>
<td>22(1=son, 2=father)</td>
<td>MF</td>
<td>NW</td>
</tr>
<tr>
<td>23</td>
<td>CC</td>
<td>NW</td>
</tr>
<tr>
<td>24</td>
<td>CC</td>
<td>NW</td>
</tr>
<tr>
<td>25</td>
<td>CC</td>
<td>NSW</td>
</tr>
<tr>
<td>26</td>
<td>CC</td>
<td>NIC</td>
</tr>
</tbody>
</table>

\[a\] Both the husband and wife are considered farmers. I did not make a distinction between the two except when discussing women farmers and women on the farm in chapter 5. Elsewhere in the thesis, unless otherwise indicated, they are considered as one farmer — F-7 or F-19.

\[b\] Most of the conversation occurred between farmer 22(1)—the son—and myself. Thus, all quotes from Farmer 22 refer to the son.
**Appendix E**

*Expansion of empowerment codes.*

Table E contains an expanded list of comments that were coded under the core concept, empowerment. Empowerment here encompasses the concept of power-knowledge. The comments in Table E are those not used in the main body of the thesis.

**Table E. Selected farmer comments that were coded under, empowerment and used to help determine the role of empowerment in farmer decision making.**

<table>
<thead>
<tr>
<th>Empowerment</th>
<th>Farmer</th>
<th>Comment/conversation [Other empowerment/power elements]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency: analysis, reflection</td>
<td>F-10</td>
<td>F-10: I want some knowledge of the issue/problem myself.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ME: So why not go straight to the agro?</td>
</tr>
<tr>
<td></td>
<td>F-18</td>
<td>F-10: So I have some questions to ask them.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>They will have their spiel and then I can ask them my questions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Well by default I will be talking to my agro...I will have talked to a couple of mates and they will tell me they have done this or that. You talk to your agro and he will say you need to do this or that...and might point out any problems and say this is why we do this way instead...I might say fair enough we will do it your way</td>
</tr>
<tr>
<td></td>
<td>F-01</td>
<td>But I trust the research. I tend to become quite good friends with our agronomist and I trust what he says, but if I get a new bloke in I will question his advice with greater scrutiny in that I will want to know why he is suggesting a certain tactic or chemical strategy. He will need to justify his advice. I will do the same for the regular agronomist, but it is more</td>
</tr>
</tbody>
</table>
| Agency: Self direction | F-14 | ME: So are you suggesting the resellers and linked agros are still operating only on finding the best way to sell you more chemical.'  
F-14: Yes, give me a drum of herbicide and that fixes that problem, but whether you spray it on time, that is your decision. So we have to re-educate ourselves. That is why we need these [moisture] probes in the area to be working for us... But it is exciting; it is |
|-----------------------|------|---|
| F-19 | because I want to learn more about all this. [Control]  
I have mates that won't go to SFS stuff and I think this is the biggest let down in their operation. They are reasonable farmers, but they won't source additional information other than what they get from their reseller [agronomist]. So how can you critique if you have no background from which to do it. |
| F-20 | It was when I first got home and didn't know too much and I was doing what I was told which is fair enough, but learning, learning...getting told to put chemicals on that we had used in the three years previous and I started saying do you think we should mix it up a bit. I was told no, this is the new best chemical out, we need to use it. I suppose it was a difference of opinion on that and they were saying you are paying us good money, do you want us to recommend or not. Yes, but we need to discuss it not you tell me what to do. [Autonomy, Control] |
challenging and I am really opening my eyes up. You've got to do your own thinking.

He [agronomist] is not the one trying to run the business. I am the one writing the cheques. I am the one that has to try and pay the couple of million bucks back, not him. And what works, works...you know, got to get down to the bottom line...all these experts. [Control]

<table>
<thead>
<tr>
<th>Power-knowledge relations</th>
<th>Farmer</th>
<th>Comment/conversation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomy/Knowledge construction</td>
<td>F-15</td>
<td>It is not what he [agronomist] says is gospel and I have my knowledge, and things chop and change. [Agency]</td>
</tr>
<tr>
<td>F-4</td>
<td>ME: So how do you back your knowledge or weigh up your knowledge against the agronomist's? F-4: I put them together. The agro will suggest something and I will ask why am I doing that and not this. He will give me an explanation - he is usually right - but every now and then I will suggest something different and he might go that isn't a bad idea...you are pooling the information to get the right result.</td>
<td></td>
</tr>
<tr>
<td>F-5</td>
<td>They [agronomists] might recommend a heap of stuff and you'll go...hang on, I'm not set up for that, or I can't do that, or that is going to cost me too much money and I need to look for another option...So you get the best advice then you make a decision on that advice. You</td>
<td></td>
</tr>
<tr>
<td></td>
<td>will select the bits that work for me and find ways around other things. [Control, Agency]</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>F-13</td>
<td>I certainly value his [agronomist] opinion and we mix my thoughts and his opinion to come up with something</td>
<td></td>
</tr>
<tr>
<td>F-7</td>
<td>[Agro] has been keen for us to burn windrows, but I have been resisting that...because I don't want to. It is a lot of mucking around and lighting fires is not a desirable thing re: the effort of lighting the fires and the consequences of the fires themselves. [Self direction]</td>
<td></td>
</tr>
</tbody>
</table>
Appendix F.

Farmer networking, trust codes

Knowledge relations and the inherent trust within them are an important foundation for farmer empowerment. Table F contains select and edited farmer comments that were coded for networking and trust and not included in the main analysis from chapter 6.1. They are indicative of the social nature of farmer learning and the extent of knowledge sharing. Of the 26 farmers interviewed 19 had comments coded to networking with 61 references. See Appendix D. for translation of farmer identification codes.

Table F Selected farmer comments assigned to the different codes under the concept of networking and trust.

<table>
<thead>
<tr>
<th>Farmer</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-8</td>
<td>I have a good relationship with [agronomist - different from his own] in Kerang, so I rang him and asked him what his approach was on this and he said he hadn't advised any of his clients to spray. It was hold and wait. My bloke was saying spray...That is where you trust your agro or you don't. He was being informed by what he saw what the Hopetoun fellas had. [Kerang agro] was being informed by the local area and his assessment of it. You look at a mix of things, what the mallee and other farmers are doing, what the agronomist says...I talk to them about what is going on. It is not specific prescriptions a lot of the time with. You are just having a yarn in the ute as you are driving along.</td>
</tr>
<tr>
<td>F-2</td>
<td>I always listen to the Rural Report on ABC radio in morning, and Country Hour. I am a member of BCG. I get their publications and technical bulletins. I go to their field days and similar events - eg the GRDC grower update. I try to find out the latest things the GRDC are working on - reading their Ground Cover magazine. You talk to other farmers and other agronomists. You pick up whatever you can from whatever source.</td>
</tr>
<tr>
<td>F-10</td>
<td>Yes the Internet... I do have a look at it. I will often ask other farmers I know if they know anything. If there are none locally</td>
</tr>
</tbody>
</table>
that know I will ask a few further North. My third option is to go to the agronomist and hopefully I have some background before I go to speak to them.

Community committees - kid's sport, local hall or the CFA. And within these committees there are farmers you keep in touch with. This is probably the best way of seeing people - seeing a different group of people. You don't see your neighbour there, you see people from the other side of town.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>F-11</td>
<td>I am not paying for an independent agro. I speak to many an independent agro. I go to seminars, field days. I am always speaking to different people.</td>
</tr>
<tr>
<td>F-9</td>
<td>It is more a local research...The BCG, I guess they are spreading themselves around more, but we are in a different area. The Normanville Cropping Group, in different forms, has been going for 20-30 years. You might see someone doing it. Our agronomist has a different group that gets us all together and a lot of ideas are talked about there, so this info comes from different sources and you talk about it with different groups.</td>
</tr>
<tr>
<td>F-6</td>
<td>Yes, if you go to a field day you get a lot of information just talking to other farmers, but everybody is busy.</td>
</tr>
<tr>
<td>F-18</td>
<td>I ring them up and say this has gone wrong, what are you doing about it., and that could be about anything, insects, weeds, grain marketing, machinery, technology issues, computers...you ring your mates, have a chat and see how they have coped with it. Then you go back to the science side of it - you go to your agronomist, a tech support person or whatever it may be. BBQs, pub, telephone, funerals, fires. Wherever you bump into people. Or you turn around at a Field Day and you say that was a F...up, what did you do wrong? They will tell you what they have done wrong and you think well I won't do that.</td>
</tr>
<tr>
<td>F-22</td>
<td>We have the bloke who spreads our lime and gypsum, we are good friends with, so we have a yarn to him. I have a neighbour who has been putting out lime for a long time, he grows lucerne and he is swearing by the lime and he's big on it. We are sort of looking over the fence at him.</td>
</tr>
<tr>
<td>F-13</td>
<td>You certainly do catch up with neighbours now and again, but nowhere near as much as we used to physically, but with mobile phones you do.</td>
</tr>
<tr>
<td>F-14</td>
<td>Look I have learnt so much off [2 local farmers]. I have a mate up past Ararat who I have learnt so much off - he is purely a sheep guy. He did a farm tour down here and I did a farm tour around his joint. You hear this from farmers, you observe what they are doing. I am personally travelling around trying to have a look within a 20km radius from home on a Sunday morning and you can tell what is going on.</td>
</tr>
<tr>
<td>F-4</td>
<td>You talk to your neighbours - the problem isn't just on my farm. You have mates who live around the district and you chat about how they might be dealing with this or that. Some will have some good ideas, others will say I am doing this and I'll think...hmm I don't like that idea.</td>
</tr>
<tr>
<td>F-20</td>
<td>Phone, neighbours - old and young neighbours... and asking if you have this weird plant in your paddock as well, then you might Google it, then GRDC, Facebook or Twitter. I only got Twitter happening in the last couple of days.</td>
</tr>
<tr>
<td>F-23</td>
<td>And then they've [his agronomist's company] got informal or formal networks, whether its GRDC advisor updates; if they are part of it... they've got their mates that they talk to; and they've also got their chemical manufacturers information — well it might be skewed info — but its providing them with info. But they've got their whole network that is independent of what I am doing that they are drawing information on and making decisions.</td>
</tr>
<tr>
<td>F-25</td>
<td>Decisions sometimes have to be made quickly and you have to have either experience with them or you do some research...like, OK this has just happened, we will research it, use social media, contacts, and try to identify the problem, the outcomes and how to fix it.</td>
</tr>
</tbody>
</table>