UNDERSTANDING THE ADOPTION OF PRECISION AGRICULTURE TECHNOLOGIES IN AUSTRALIA

by

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Thesis

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ABSTRACT

Even though precision agriculture (PA) technologies are available to farmers in Australia, the adoption rate in agricultural industries is lower than desired by government and industry leaders, and the potential business productivity and profitability improvements, as well as environmental benefits, from PA technologies adoption are not fully realised. In particular, the potential for PA technologies to generate significant international competitiveness gains as well as reductions in environmental impacts caused by agricultural activities is yet to be fully understood. To date, there is a paucity of literature examining the multifaceted interactions between different components/determinants in the adoption process of PA technologies in Australia. Whilst there are various adoption tools, and this thesis examines many of them, one comprehensive theoretical model, the model of determinants of diffusion, dissemination and implementation of innovations (MDDDII), offers a strong conceptual framework to explore multiple components/determinants that are likely to influence PA technologies adoption. This research utilised MDDDII, which consists of nine components and several determinants to explore the presence and interactions of the model's components within the PA technologies adoption literature.

Through examining the presence or absence of the components/determinants of MDDDII in PA technologies adoption literature, and the case studies and the reports, and the strategic plans of the RDCs (the Australian grey literature), this thesis offers insights into why poor adoption rates are being experienced in Australia . First, a systematic review of 58 PA technologies adoption literature was conducted, second, thematic analysis was carried out to identify the themes of 43 Australian grey literature, and third, the themes were then examined through the lens of MDDDII.

After conducting the systematic review of PA technologies adoption literature, it was found that PA technologies adoption literature covered five components of MDDDII: the innovation, communication and influence, outer context, adopter, system antecedents for innovation and linkage. Thus, none of the publications covered the other four components of MDDDII: system antecedents for innovation, system readiness for innovation, assimilation and implementation process. Likewise, thematic analysis found that the Australian grey literature included only four components of MDDDII: the innovation, communication and influence, outer context, and adopter. Thus, in the case of the grey literature, five components of MDDDII were absent: system antecedents for innovation, system readiness for innovation, linkage, assimilation, and implementation process.

Analysis of both the PA technologies adoption and the Australian grey literature on PA technologies adoption revealed that only a few studies encompassed a broad range of components/determinants recognised in the broader PA technologies adoption literature, and none covered all components of MDDDII. As a result, it was concluded that the relationship between poor adoption rates of PA technologies in Australian agricultural industry and the systematic absence of several components/determinants of MDDDII within academic and the Australian grey literature needs further investigation.

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CANDIDATE'S STATEMENT

By submitting this thesis for formal examination at CQUniversity Australia, I declare that it meets all requirements as outlined in the Research Higher Degree Theses Policy and Procedure.

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June 2020

STATEMENT AUTHORSHIP AND ORIGINALITY

By submitting this thesis for formal examination at CQUniversity Australia, I declare that all of the research and discussion presented in this thesis is original work performed by the author. No content of this thesis has been submitted or considered either in whole or in part, at any tertiary institute or university for a degree or any other category of award. I also declare that any material presented in this thesis performed by another person or institute has been referenced and listed in the reference section.

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In conducting the study, I was responsible for all research relevant tasks. This publication was written by me. I formed the research question, collated the literature, analysed the data and interpreted the results. [100% contribution].

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My co-author, [Professor Philip Brown and Associate Professor Talitha Best], performed proof reading and some enhancement of sentence structure. [0% of co-authors' contribution].

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Abbreviations

AECL	Australian Egg Corporation Limited
ALECL	Australian Livestock Export Corporation Limited
AMPC	Australian Meat Processor Corporation
APL	Australian Pork Limited
AWIL	Australian Wool Innovation Limited
CRDC	Cotton Research and Development Corporation
CTF	Controlled Traffic Farming
DAL	Dairy Australia Limited
FRDC	Fisheries Research and Development Corporation
FWPA	Forest and Wood Products Australia
GRDC	Grains Research and Development Corporation
HIAL	Horticulture Innovation Australia Limited
HRSC	House of Representatives Standing Committee
MDDDII	Model of Determinants of Diffusion, Dissemination, and Implementation of Innovations
MLA	Meat and Livestock Australia
PA	Precision agriculture
PF	Precision farming
RDCs	Rural Research Development Corporations
R&D	Research and development
RD&E	Research, Development, and Extension
RIRDC	Rural Industries Research and Development Corporation

SRA	Sugar Research Australia Limited
VRT	Variable Rate Technologies
WA	Wine Australia

CHAPTER ONE: INTRODUCTION

Precision agriculture (PA) is the application of data acquisition technologies and data processing systems to enhance decision-making and the profitability of farming operations. Global positioning system (GPS) and remote sensing are currently allowing the development of a suite of PA technologies, and these technologies have the potential to drive a new wave of increased agricultural productivity (Yazdanifar 2014) as well as to contribute to the ecological sustainability of farming systems. PA technologies such as autosteer and satellites use sensors, and provide valuable information in farming systems. These devices and machinery provide the capacity for decision-making on a much finer spatial and temporal scale and support more efficient resource management on farms and reduce the risk of on- and off-farm natural resource degradation.

PA technologies can, for example, ensure the right amount of agrochemicals are used in the field to provide both economic and environmental benefits (Lencses, Takacs & Takacs-Gyorgy 2014). The adoption of PA technologies, including variable rate technologies (VRT) and controlled traffic farming (CTF) provide many benefits to farmers. For example, a survey conducted by Robertson et al. (2012) shows that variable rate fertilizer application increased the economic benefits of wheat production in Australia by $5-50/hectare. Variable rate fertilizer application uses agrochemical at different rates across a field based on data collected by sensors, maps, and GPS. Therefore, it saves on the cost of agrochemical. Likewise, Kingwell and Fuchsbichler (2011) highlighted that CTF generated an increased profit of $46.8/ hectare of crop. This benefit occurred due to avoiding unnecessary use of agrochemicals (reduced overlap) and labour and materials cost. Further, research conducted by Tullberg et al. (2018) revealed that controlled traffic farming might be anticipated to decrease the global warming potential of soil emissions of N_2O and CH_4 by 30%-50%. While the adoption of these technologies is occurring, an acceleration of the adoption rate is desirable.

Much of the research undertaken in Australia has demonstrated that PA technologies can provide many benefits to farmers, including reduced input costs, higher productivity, and reduced soil and water degradation. Despite the demonstrated advantages, PA technologies, for example, VRT and remote sensing, have not been widely adopted in Australia (Williams 2014). To realise the potential benefits that may be gained by Australian agriculture from PA technologies, it is significant to re-examine how technology adoption is theorised and acted upon so as to explore opportunities for improving the way we implement strategies that support the optimal rates of adoption of those technologies.

Agriculture is a significant contributor to commercial, social, and ecological sustainability (National Farmers' Federation 2012), and supports around 3% of Australia's GDP (National Farmers' Federation 2018). It is also a leading employer in rural and regional areas (Batt 2015), and generated a gross value of $60 billion in 2016-2017 in which the agricultural industry earned $44.8 billion from the export of the farm products in international markets (National Farmers' Federation 2019). Likewise, the export income from farm products was predicted to be $47 billion in 2018-19 (ABARES 2018). Therefore, strengthening the agricultural sector through greater PA technologies adoption would have benefits for the whole of the Australian community. Many PA technologies adoption studies show a large number of factors influence PA technologies adoption, for example, age of farmers, size of the farm, cost and complexity of technology along with available sources of agricultural information, and conservation payments (Lambert, Paudel & Larson 2015), level of educational attainment of farmers, access to irrigation infrastructure, and farm location (Larson et al. 2008), usefulness, government pressure, and IT knowledge (Lima et al. 2018). Similarly, PA technologies adoption literature also considers agricultural contractor, farming experience and farm size (Paustian & Theuvsen 2017), optimal use of fertigation and environmental regulation (Lopus et al. 2010), complexity, trialability, crop consultant and education (Robertson et al. 2012) as influencing factors in PA technologies adoption. Based on these and other studies that demonstrate multiple elements that may impact the decision of farmers to adopt or discard PA technologies, strategies to promote adoption must consider the complexity of this decision-making process.

Given the widespread interest in the agricultural industry, and the demonstrated benefits of PA technologies, it is not surprising that the Australian Government has been funding programs to develop and promote these technologies. Government agencies, including the Rural Research and Development Corporations (RDCs), and private agencies such as Society of Precision Agriculture Australia (SPAA), Precision Agriculture, and the Research and Innovation Network for Precision Agriculture Systems (RINPAS) are engaged in the promotion of PA technologies in Australia. While the resources and the level of interest provide an environment in which adoption of PA technologies can occur, the documented limited rate of adoption of many new technologies suggests that a re-evaluation of our understanding of the adoption process would be valuable in guiding the development of the most effective strategies to promote adoption.

1.1 Background of the study

Agricultural extension is the activities associated with the transfer of new knowledge, idea, or technology in farming practices. Components such as educational programs, training, meetings, social networking and demonstrations provide new information which may increase farmers' farming knowledge and skills and eventually motivate them to change their behaviour. Extension officers, private companies, growers' groups, research centres, and universities deliver extension services.

Agricultural extension programs in most countries are associated with agricultural research programs, with many research projects having extension activities built into the project. For example, the Australian Government provided $2,600,000 to Dairy Australia Limited for the Virtual Herding project (Department of Agriculture and Water Resources 2018). In Australia, growers' levies and government contributions support research, development, and extension (RD&E).

The outputs of agricultural extension, including the transfer of knowledge and capacity building of farmers, are essential aspects of technology adoption. Capacity building programs help farmers to take advantage of PA technologies, such as variable rate technology, yield monitoring, crop sensors, satellite images, and many more. Likewise, extension services increase farmers' knowledge (Velandia et al. 2010), and then that increased knowledge may change farmers' behaviours to that of using PA technologies.

A large body of literature (Adekunle 2013; Adrian, Norwood & Mask 2005; Eastwood et al. 2017; Fountas et al. 2015; Konrad et al. 2019; Koutsos & Menexes 2019; Larson et al. 2008; Monfared 2015; Schimmelpfennig & Ebel 2016; Silva, De Moraes & Molin 2011; Tamirat, Pedersen & Lind 2018; Thompson et al. 2019; Watcharaanantapong et al. 2014) has revealed several factors that affect PA technologies adoption. Some of these factors include age, farm size and soil nutrient concern (Konrad et al. 2019), economic and environmental benefits, social network, change agents, government assistance and education (Nganje et al. 2007), capacity building of farmers and service providers, supportive technical advisory groups and private companies, and aligned research and development projects (Eastwood et al. 2017).

The literature has highlighted that some technologies, such as yield monitors in the United States agriculture (Erickson, Lowenberg-DeBoer & Bradford 2017; Griffin et al. 2017; Schimmelpfennig & Ebel 2016) and controlled traffic farming in Australian agriculture, have been adopted rapidly. On the contrary, the adoption of variable rate technologies was sluggish in both the United States (Erickson, Lowenberg-DeBoer & Bradford 2017; Griffin et al. 2017; Schimmelpfennig & Ebel 2016) and Australia (Bramley & Ouzman 2018). While PA technologies adoption literature have broadly covered the potential advantages of PA technologies, the relatively low rate of adoption of PA technologies (Bramley 2009) suggests that their potential remains largely unrealized. Thus, the examination of what influencing factors are being considered, and equally not considered, by PA adoption researchers and practitioners could be a critical step in determining how adoption strategies could be revised to ensure increased use of these tools in agriculture.

The published PA technologies adoption literature covers only a small quantity of the total volume of agricultural literature (Pierpaoli et al. 2013). In other industries, technology adoption is a significant part of the innovation process, and so has been extensively studied. Therefore, the broader literature relating to technology innovation adoption provides a wealth of research insights to support and extend the material published in the traditional agricultural extension area.

Public sector innovation is high on the program of public managers and politicians, in addition to corporations, societal organisations and people (Bekkers & Tummers 2018). The scope of the public sector is more extensive than the agricultural sector, and researcher and scholars have developed more models and theories to increase the productivity and profitability of public sector organisations rather than agriculture. Thus, models/theories of innovation/ technology adoption from the public organisations' scholarship provide better perspectives than the models and theories from agricultural innovation systems scholarship.

This study examines the ideas, development, and application of technology adoption models/ theories, with the emphasis on potential application for PA technologies. The literature presents several models/theories that explain users' acceptance of new technology and their intention to practice the technology. These include, but are not limited to, the diffusion of innovations theory (Rogers 2010), the technology acceptance model (Davis 1986), the technology acceptance model 2 (Venkatesh & Davis 2000)**,** the technology acceptance model 3 (Venkatesh & Bala 2008), the theory of planned behaviour (Ajzen 1991), the adoption and diffusion outcome prediction tool (CSIRO 2018), and the model of determinants of diffusion, dissemination and implementation of innovations (Greenhalgh et al. 2004). An examination of these models/theories reveals concepts that have relevance to the adoption of PA technologies, and Chapter 2 critically analyses these models/theories of innovation/ technology adoption.

1.2 Problem statement

The Australian Government has invested in PA technologies related RD&E projects through RDCs. For example, the Australian Government provided $601,150 for the project 'Demonstrating the benefits of no-till permanent bed vegetable production' (Department of Agriculture and Water Resources 2015a). Similarly, PA technologies adoption stakeholders, for example, the Society of Precision Agriculture Australia (SPAA), and the Western Australian No-Tillage Farmers Association (WANTFA) are also contributing to promoting PA technologies adoption in Australia (Grains Research and Development Corporation 2013). However, the adoption rate of PA technologies in Australia has not been as fast as desired (Umbers, Watson & Watson 2015), despite the environmental and economic benefits that PA technologies delivers (Grains Research and Development Corporation 2014) and technologies being available to farmers. VRT and remote sensing are a well-known suite of PA technologies with limited adoption in Australia (Williams 2014). An agriculture technology survey conducted by GrainGrowers Limited in 2017 showed that the adoption rate of variable rate application and NDVI crop sensors were 20.85% and 5.35%, respectively (GrainGrowers Limited 2017). These studies showed that farmers have not taken up PA technologies as quickly as that expected by PA technologies adoption promoters. So, this raises a question around why there is such a gap between the expectations of PA technologies adoption stakeholders (such as researchers, research funders, and policymakers) and actual adoption rates.

This thesis conducts a systematic review and qualitative research to understand how adoption is theorised and recognised to understand better the known and potentially unexplored factors in PA technologies adoption that could be important. The systematic review examines the PA technologies adoption literature (academic literature), and qualitative research analyses the Australian grey literature (the case studies and the reports, and the strategic plans of the RDCs). The model of determinants of diffusion, dissemination and implementation of innovations (MDDDII) is a comprehensive summary of the factors, referred to as components/determinants in the model, that affect innovation/technology adoption. Therefore, MDDDII is used as a tool in Chapters four and five to understand PA technologies adoption process. MDDDII demonstrates that addressing an individual component/determinant in a process to promote adoption is unlikely to increase the rate of adoption of technology because a complex interplay between the various components and specific determinants is involved in innovation adoption situations. Chapter 2 includes the reasons for choosing MDDDII as a tool to understand the PA technologies adoption process.

1.3 Research aim and objectives

This thesis aims to examine (1) PA technologies adoption literature (academic literature), and (2) the case studies and the reports, and the strategic plans of the RDCs (the Australian grey literature) through the lens of the MDDDII to identify which aspects of the innovation adoption process are being considered, and equally not considered, by Australian PA adoption researchers and practitioners as influential in the adoption process, and therefore potentially put on display opportunities to improve how PA adoption strategies are designed and developed in Australia. Thus, this thesis has the following objectives:

1. To determine the presence/absence of components/determinants of MDDDII in the PA technologies adoption literature (academic literature).

2. To determine the presence/absence of components/determinants of MDDDII in the case studies and the reports, and the strategic plans of the RDCs (the Australian grey literature).

The published PA technologies adoption literature is peer-reviewed academic literature and is based on scientific inquiry, which provides a big picture of complex technology adoption processes in a worldwide. In contrast, the examination of the Australian grey literature helps to understand how the knowledge provided by the PA technologies adoption literature is applied in the agricultural industry to promote PA technologies adoption. Therefore, the examination of PA technologies adoption literature could be a useful source for understanding the PA technologies adoption process in the Australian agricultural industry.

1.4 Scope and limitation of the thesis

The MDDDII has covered a wide range of components/determinants of innovation adoption (Greenhalgh et al. 2004), and this thesis applies MDDDII as a conceptual framework to examine both PA technologies adoption literature, and the case studies and the reports, and the strategic plans of the RDCs. These documents contain reliable information for analysis, contributing to the validity of the research outcomes. The outcomes of this thesis could be a valuable source of information for government, extension personnel, PA technologies manufactures, dealers, and research centres promoting PA technologies.

This thesis has not collected primary data from agricultural enterprises to assess if the nine components of MDDDII and interactions between them were involved in the decision to adopt or discard PA technologies in Australia, which limits the scope for interpretation of outcomes but provides a foundation upon which further research can be conducted. This thesis includes a proposed survey design in appendix C.

The findings of any systematic review rely on data from other studies, and therefore the outcomes of a systematic review are only valid when the analysis process is free from bias (Drucker, Fleming & Chan 2016). This thesis includes 58 publications in its systematic review and evaluate each publication very carefully to minimise bias: thesis supervisors cross-checked the selection criteria of the publications and the process to ensure the systematic review process was valid; rigorous selection criteria were used to minimise the selection bias of publications (Pannucci & Wilkins 2010), and the PA technologies adoption literature, case studies and the reports, and the strategic plans of the RDCs were selected using PA technologies related keywords, such as precision agriculture, precision farming, adoption, and agricultural extension. Chapter 3 includes further details of the bias handling techniques.

1.5 Outline of the thesis

This thesis consists of six chapters, and the contents of each chapter are as follows.

The current chapter introduces PA technologies adoption and its potential benefits with examples and also adds a brief discussion of agricultural extension. Further, this chapter includes a problem statement, research aim and objectives along with a short discussion of the scope and limitations of the thesis.

Chapter two is a literature review of the adoption of PA technologies. It critically analyses the diffusion of innovations theory' (Rogers 2010), the technology acceptance model (Davis 1986), the technology acceptance model 2 (Venkatesh & Davis 2000), the technology acceptance model 3 (Venkatesh & Bala 2008), the theory of planned behaviour (Ajzen 1991), the adoption and diffusion outcome prediction tool (CSIRO 2018), and the model of determinants of diffusion, dissemination and implementation of innovations (Greenhalgh et al. 2004).

Chapter three outlines the methodology used across this research more broadly. This chapter is organised into two parts to show the rationale and process of the research design. Part one outlines the methodology related to the procedural steps for a systematic literature review regarding PA technologies adoption literature, and part two presents the main methods and scholarship behind the thematic analysis of the case studies and the reports, and the strategic plans of RDCs around PA technologies adoption.

Chapter four outlines the data analysis and results of the systematic review. It includes the background of the selected 58 publications such as year and location of publications, types of PA technologies and agricultural industries at the beginning. Then, using MDDDII as a framework, this thesis identifies the components/determinants of PA technologies adoption included within the 58 selected publications.

Chapter five covers the data analysis and outcomes of the case studies and the reports, and the strategic plans of the RDCs around PA technologies adoption. The frequencies of three parameters, such as year of publication, agricultural industries and tools of PA technologies, are measured at the beginning. Likewise, this thesis identifies the main themes of the selected Australian grey literature using thematic analysis and compares these themes with MDDDII to determine the presence/absence of components/determinants of MDDDII in the selected Australian grey literature.

Chapter six includes the research outcomes and provides strengths and limitations of the thesis. Besides, this chapter contains conclusions and recommendations designed to enhance the understanding of the PA technologies adoption process in Australia.

2 CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter examines PA technologies adoption literature to understand the PA technologies adoption process and the factors that influence the adoption process. Similarly, this chapter also examines commonly used innovation/technology adoption models/theories because innovation/technology adoption models/theories provide a more useful theoretical basis for understanding the innovation/technology adoption process. The following innovation/ technology adoption models/theories are examined: 1) the diffusion of innovation theory (Rogers 1962), 2) the technology acceptance model (Davis 1986), 3) the technology acceptance model 2 (Venkatesh & Davis 2000), 4) the technology acceptance model 3 (Venkatesh & Bala 2008), 5) the theory of planned behaviour (Ajzen 1991), 6) the adoption and diffusion outcome prediction tool (CSIRO 2018), and 7) the model of determinants of diffusion, dissemination and implementation of innovations (Greenhalgh et al. 2004).

Technology adoption is a series of activities that lead to an individual using new technology (Rogers 2010). This thesis examines the technology adoption process through an understanding of the steps and influencing factors in each of these steps. The adoption process is not unique to agriculture, and a significant body of theoretical knowledge exists in the published literature (e.g. Davis 1986; Ajzen 1991; Venkatesh & Davis 2000; Greenhalgh et al. 2004; Venkatesh & Bala 2008; Rogers 2010, Kuehne et al. 2017). Technology adoption is not a simple acceptance or rejection of an object or machine, but it is the acceptance, integration, and use of new technology, which crosses a series of processes and steps.

The technology adoption pathway then involves the following path: first, becoming aware of new technology; next; obtaining more information, especially ease of use and usefulness of technology; and then deciding whether to use or reject the technology. Finally, the user accepts the innovation/technology for continuous use. Thus, the individual adopter passes a series of processes and steps in technology adoption.

Diffusion of innovation (DOI) theory developed by Rogers (2010) included five stages in the innovation adoption process (knowledge, persuasion, decision, implementation, and confirmation), and represents stages through which an individual or organisation evaluates a new idea and decides whether to accept or reject the ideas (Rogers 2010). Likewise, Davis, Bogozzi and Warshaw (1989) included four stages of technology adoption, namely the perception of a user towards the technology, attitude, behavioural intention and actual system use to describe the process or steps an individual or organisation goes through. In agriculture, this has been explored in terms of understanding a farmer's attitude towards technology and whether it is easy to use (positive attitude) or difficult to use (negative attitude). This attitude, in turn, creates an intention, and finally the farmer decides whether to accept or reject the technology. While potentially over-simplified, the model of technology adoption typically involves the description and definition of steps or processes in which an individual moves towards utilising and adopting a process or product. Consequently, many theories/models highlight several stages in achieving the results of technology adoption.

One aspect of technology adoption is how innovation/technology is discussed and diffused. Consequently, there is a diversity in the number of stages and steps in the adoption pathway and a diversity of components/determinants that can influence each stage of technology adoption. For example, a survey conducted by Daberkow and McBride (2003) showed that education level, computer literacy, and farm size influenced awareness of PA technologies in the United States. Consequently, the identification of critical factors influencing the stages of technology adoption is the logical first step in understanding the pathway to the adoption of PA technologies.

PA technologies have brought significant changes in farming systems. It increases the productivity and profitability of the farm and may also improve working conditions and deliver environmental benefits (Yazdanifar 2014). A survey conducted by Maheswari, Ashok and Prahadeeswaran (2008) revealed that the adoption of PA technologies increased production of tomatoes by 80% and brinjal by 34% in India. Further, robotic milking improves the quality of the dairy farmers' life due to the decreased labour demands and better time tractability (Driessen & Heutinck 2014). PA technologies provide monetary, environmental, and social benefits.

Some PA technologies are adopted rapidly in agriculture, while others are yet to find widespread adoption. PA technologies, such as yield monitoring systems, soil monitoring technologies, and controlled traffic farming, are commonly adopted in farming, but crop sensors and variable rate technologies have been adopted slowly. Evidence from several researchers (Erickson, Lowenberg-DeBoer & Bradford 2017; Griffin et al. 2017; Schimmelpfennig & Ebel 2016) showed that yield monitoring systems were adopted rapidly in the United States agriculture, but the adoption rate of variable rate technology was slow. A survey of grain growers conducted by Bramley and Ouzman (2018) identified that 84% of the respondents adopted controlled traffic farming or machine guidance technologies in Australia. In contrast, the Grains Research and Development Corporation (GRDC) conducted a survey in 2014 in Australia and identified that only 9% of the respondents had adopted variable rate technology (Umbers, Watson & Watson 2015). This data shows a changing trend in PA technologies adoption. Therefore, it is essential to identify what factors contribute to the adoption or rejection of PA technologies.

Many studies (Asare & Segarra 2018; Barnes et al. 2019; Boyer et al. 2016; Keskin & Sekerli 2016; Kountios et al. 2018; Koutsos & Menexes 2019; Lambert et al. 2014; Lambert, Paudel & Larson 2015; Lencses, Takacs & Takacs-Gyorgy 2014; Lima et al. 2018; Medrano-Galarza et al. 2018; Paustian & Theuvsen 2017; Tamirat, Pedersen & Lind 2018; Thompson et al. 2019; Weber & McCann 2015) have considered numerous drivers and barriers that influence PA technologies adoption. Therefore, the next section examines factors that are associated with PA technologies adoption.

2.2 PA technologies adoption influencing factors

There are many research studies regarding PA technologies adoption across a broad range of agricultural industries, for example, grain (Schimmelpfennig & Ebel 2016), vegetable (McPhee & Aird 2013), livestock (Neves & LeBlanc 2015), and industrial crops (Watcharaanantapong et al. 2014). A variety of drivers and barriers influence the adoption of PA technologies in different agricultural industries, including economic benefit, size of farm, income of farmer, attitude, subsidy, taxation, skill of staff, management and investment cost (Barnes et al. 2019; Koutsos & Menexes 2019), age, education and benefits of PA technologies (Kountios et al. 2018), perceived features of PA technologies, government pressure and skill of farmers (Lima et al. 2018), crop consultant, farm size, education and perceived features of PA technologies (Robertson et al. 2012). PA technologies adoption factors are dispersed within the literature. Therefore, this thesis collates PA technologies adoption influencing factors mentioned in PA adoption literature into five groups: 1) farmer and farm attributes, 2) external support, 3) information sources, 4) perceived features of PA technologies, and 5) behavioural factors.

2.2.1 Farmer and farm attributes

Farmer attributes are a category that relates to the knowledge and background features of the farmer that might impact the adoption of PA technologies. To date, many studies suggest determinants like age, education, experience, income, and computer knowledge influence PA technologies adoption. For example, a survey of 739 cotton growers in the United States showed that the age of a farmer was negatively correlated with the probability to adopt PA technologies, and this relationship was statistically significant. Each additional year in the age of the farmer decreased the adoption propensity of PA technologies by 3.45% (Lambert, Paudel & Larson 2015). Thus, increasing age could be a barrier to PA technologies adoption.

Farm attributes includes many determinants which play a significant role in PA technologies adoption. These determinants include farm size, irrigation, yield variability, and soil quality. For example, a survey of 1,507 corn growers in the United States showed that farm size was positively related to PA technologies adoption (Schimmelpfennig & Ebel 2016). The expenditure per unit area of land or quantity of production associated with the technology is lower when it is spread over a large farm, and thus an economy of a scale is achieved. Therefore, the size of a farm has the potential to be an essential determinant influencing the adoption of PA technologies.

2.2.2 External support

External support also plays a very strong role in promoting PA technologies adoption. External support, such as availability of subsidies, conservation payments or disaster relief payments provided by the government, influence the PA technologies adoption. A survey of 743 cotton farmers in the United States found that subsidies influence the adoption of PA technologies (Marra et al. 2010). The financial incentive of subsidy, then, it could motivate farmers to use PA technologies.

2.2.3 Information sources

Information sources are another determinant that increases the awareness of farmers and helps in the decision-making process, and therefore could influence the adoption of PA technologies. Consultants, contractors, dealers, extension workers, university, agricultural exhibitions, agricultural technology firms, field trips, workshops, demonstrations, press media, and electronic media provide information to farmers.

Some studies highlighted that crop consultant services were the most effective source of information for PA technologies adoption (Lambert et al. 2014; Larson et al. 2008; Robertson et al. 2012; Weber & McCann 2015). For example, a survey of 1723 cotton growers in the United States found that access to a fertilizer-management recommendation by a crop consultant was likely to increase PA technologies adoption by 40%-42% (Lambert et al. 2014). Beside consultant services, a small number of studies (Kutter et al. 2011; Reichardt & Jurgens 2009) found the agricultural press to be an essential source of information, and a survey of 6,183 farmers in Germany showed the agricultural press was the vital to spread precision farming information (Reichardt & Jurgens 2009).

2.2.4 Perceived features of PA technologies

PA technologies have several features such as relative advantage, complexity, compatibility, trialability, observability (Rogers 1962), technical support, risk, and reinvention (Greenhalgh et al. 2004), which influence PA technologies adoption. For example, a survey conducted by Lencses, Takacs and Takacs-Gyorgy (2014) in Hungary showed that the perceived economic benefit (relative advantage) of PA technologies positively influences the adoption of a new practice. Rogers' diffusion of innovation theory (see Figure 2.1 and explanation on page 17) includes a detailed explanation of how the perceived features of PA technologies influence the adoption process.

2.2.5 Behavioural factors

The attitude of farmers, subjective norms and perceived behavioural control are the various factors of behaviour that influence PA technologies adoption. Some studies showed that attitude, subjective norms, and perceived behavioural control influence the intention of the potential user to use PA technologies (Borges et al. 2019; Despotovic, Rodic & Caracciolo 2019; Senger, Borges & Machado 2017). Therefore, farmers will have more intention to adopt PA technologies if they have a favourable attitude, subjective norms, and perceived behavioural control.

2.3 Agricultural extension

Agricultural extension is the activities of transferring of new knowledge, ideas, or technology to farming practices (Altalb, Filipek & Skowron 2015) which improve agricultural productivity and profitability (Danso-Abbeam, Ehiakpor & Aidoo 2018). Many studies (Adekunle 2013; Alvarez & Nuthall 2006; Jenkins et al. 2011; Russell & Bewley 2013; Stuart, Schewe & McDermott 2014) demonstrate that agricultural extension is an essential factor and process that can support PA technologies adoption. A survey conducted by Velandia et al. (2010) showed that 66% of farmers used extension services to increase their knowledge about PA technologies. As new knowledge could change the behaviour of farmers (Aremu et al. 2015) and also supports the uptake of new technology (Bagheri & Bordbar 2014), agricultural extension is a valuable service and strategy for PA technologies adoption.

Agricultural extension links with government/public sector services. However, it is also associated with public-private co-investment, a private or third party, such as a community organisation, and industry support networks that provide agricultural information to farmers. Based on the service scope, Australian agricultural extension has been categorized into five groups: 1) public extension, 2) public-private extension, 3) private- commercial extension, 4) private extension and 5) third sector/NGO extension (The University of Melbourne 2018).

Public extension is predominately owned by the Commonwealth Government, state agriculture and environment departments, local government and catchment (regional) organisations (Nettle et al. 2018). Many RD&E projects focus on the extension of PA technologies in Australia. For example, the Australian Government provided $2,600,000 to Dairy Australia Limited for the Virtual Herding project (Department of Agriculture and Water Resources 2018). Similarly, the Cotton Research and Development Corporation received $1,397,561 for the project 'Accelerating Precision Agriculture to Decision Agriculture' in order to design a solution for the use of big data in agriculture and to increase profitability and improve farming strategies (Department of Agriculture and Water Resources 2018). In addition to, large projects explicitly focussed on the extension of PA technologies, and many other RD&E projects, such as the 'Precision and Digital Systems Underpin Future Farm 2' project (Grains Research and Development Corporation 2019), also contain elements that relate to the extension of PA technologies.

Some models of the agricultural extension have been studied to identify whether they are useful in PA technologies adoption. Black (2000) examined four significant models of agricultural extension: 1) linear 'top-down' transfer of technologies; 2) participatory 'bottom-up'; 3) one-to-one advice or information exchange; and 4) formal or structured education and training.

In linear 'top-down' transfer of technologies model, scientists develop and validate technologies and knowledge, and extension agencies promote the adoption by farmers to increase farm production. Field days, meetings, print media (rural magazines, books, leaflets, newspapers), radio, television, computer applications, the internet, and information centres are the means of communication in this model (Black 2000). Many farmers are communicated at one go and at low cost in a linear 'top-down' transfer of technologies model due to the use of mass media. This theory of extension highlights that once farmers adopt the new technologies, their example will lead to its adoption by others.

In the participatory ‘bottom-up’ model, farmers define their problems and then develop the solutions and disseminate technologies. Extension workers motivate farmers to share knowledge and experience in this model (Baloch & Thapa 2018). This model of extension identifies and appreciates local knowledge and delivers capacity building chances for farming societies. Community development workshops, landcare groups, and catchment groups are users of this extension model (Black 2000).

Extension agents meet the farmers individually and discuss problems and provide information and guidance in the one-to-one advice or information exchange model (Black 2000). The nature of the meeting is usually informal and relaxed. Farm management consultancy, technical advisory services, diagnostic services, and rural financial counselling are the various means of communication of this extension model (Black 2000), and the adoption of technology could potentially be quicker due to meeting directly with farmers.

Formal or structured education and training is another model of agricultural extension (Black 2000). Farmers participate in training events and acquire information and knowledge to bring about changes in their farming practice. Similarly, universities and TAFEs provide formal education programs to farmers, and due to the educational programs, farmers acquire opportunities to increase their skills.

While the section above highlights many specific factors within several models of agricultural extension that affect PA technologies adoption, the following section examines innovation/technology adoption models/theories to understand the technology adoption process. Models/theories that allow the specific factors to be viewed within the context of a more holistic view of the adoption process present a more useful theoretical basis for understanding the process.

2.4 Rogers’ diffusion of innovation theory

The perception of a potential user towards the technology is one of the most significant elements that influences the adoption of PA technologies (Fanigliulo et al. 2020; Gonzalez-Gonzalez et al. 2020; Hay & Pearce 2014; Kingwell & Fuchsbichler 2011; Popescu et al. 2020; Robertson et al. 2012). Therefore, it is appropriate to examine models/theories that help the understanding of how the perception of a potential user influences PA technologies adoption.

One well-accepted and established theory evident in the agricultural extension and innovation/ technology adoption literature is the diffusion of innovation theory developed by Rogers (1962), in the field of social science, which describes how the perception of the potential user influences technology adoption. Therefore, the DOI theory is relevant to examine in this thesis.

DOI theory highlights that the innovation/technology adoption process covers a series of steps such as knowledge, persuasion, decision, implementation, and confirmation(Rogers 2010) through which an individual or organisation assesses the innovations/technologies and decides whether to accept or reject those innovations/technologies. Broadly captured in Figure 2.1 below, this model highlights that the individual adopter has a series of internal processes and pathways in technology adoption.

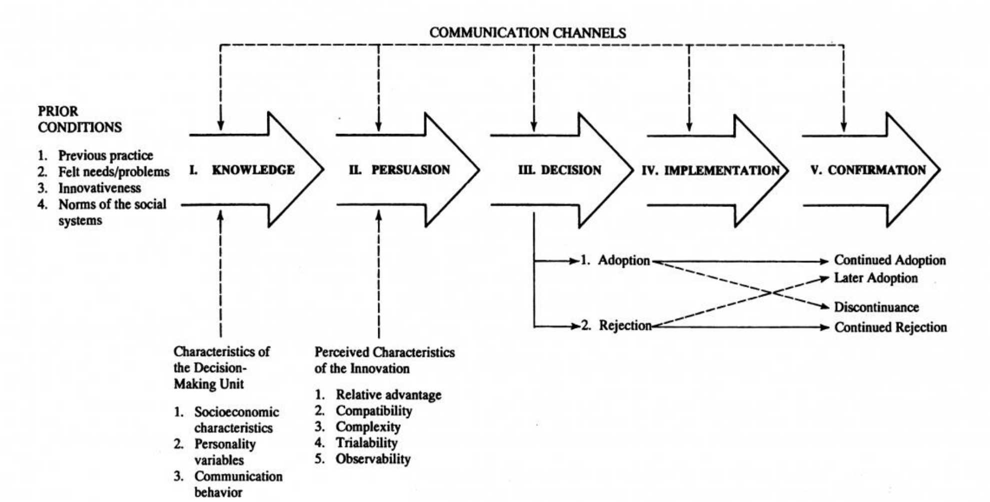

Figure 2.1: A model of stages in the innovation/technology decision process

Source: Rogers (2010)

According to DOI theory, knowledge gain is the first step of technology adoption. In this step, prospective users or farmers acquire information such as required skills, rate of adoption in a community, and the basic structure of the technology. Many factors, for example, socio-economic (income, education, experience), personality variables (optimistic, short tempered, wise, quiet, peaceful and irritable), and communication behaviour influence the knowledge gain step of the technology adoption process.

Having become aware of the innovation, the decision-maker such as a farmer will gain sufficient information especially the features of the technology, and he/she develops a positive or negative feeling towards the technology in the persuasion stage. The perceived features of the technology, for example, relative advantage, complexity, compatibility, trialability, and observability, have a strong influence on this step (Rogers 2010). Adopter features, including education level, resource availability, and risk appetite, also influence this process with innovators and early adopters showing a higher propensity to have a favourable opinion of technologies. According to DOI theory, the perceived features of the technology drive the adoption decision. Therefore, this thesis explains the perceived features of the technology in detail.

Relative advantage is the extent to which an innovation/technology is alleged to be better than the idea it supersedes (Rogers 2010). DOI theory highlighted that the adoption rate of innovation would be more rapid if the user perceives that the technology provides relative advantages. Many studies (Fanigliulo et al. 2020; Gonzalez-Gonzalez et al. 2020; Kingwell & Fuchsbichler 2011; Kountios et al. 2018; Lima et al. 2018; Pathak, Brown & Best 2019; Popescu et al. 2020) have highlighted that relative advantage is a vital determinant in PA technologies adoption. Thus, it is not surprising given the demand and economic drive of growers to utilise technology in on-farm practices to maximise yield and profits.

PA technologies provide many benefits to farmers, such as cost reduction, an increase in production, field variability information, and livestock identification. A study conducted by Kingwell and Fuchsbichler (2011) in Australia showed that PA technologies such as controlled traffic farming (CTF), increased farm profit by around 50%. In CTF, machines run on permanent wheeled tracks where lanes for machines and crop zones are permanently separated. Therefore, CTF reduces soil compaction so that the plants grow very well. Likewise, the accuracy of CTF systems enables agrochemicals to be applied precisely. All these benefits of CTF increase profit. Therefore, the relative advantage is a unique determinant that influences PA technologies adoption in a wide range of agricultural industries.

Compatibility is the extent to which an innovation is alleged to be consistent with the current values, experience, and requirements of potential adopters, influences the technology adoption (Rogers 2010). The more compatible PA technologies result in fewer changes of behaviour for a farmer, therefore, allowing for quicker adoption.

Many studies (Reimer, Weinkauf & Prokopy 2012; Takacs-Gyorgy, Lencses & Takacs 2013; Warner, Lamm & Silvert 2020; Yazdanifar 2014) found that compatibility is an essential aspect of PA technologies adoption. If PA technologies fit in with the existing farming equipment and operation, farmers may perceive PA technologies as valuable and then they may be more likely to adopt the new practice. For example, Reimer, Weinkauf and Prokopy (2012) conducted an interview survey with 45 farmers in the United States and found that conservation tillage was compatible with existing farming practices, such as no-till soybean. Therefore, farmers perceived conservation tillage was beneficial and were more likely to adopt it.

Complexity is the extent to which an innovation is alleged as challenging to understand and use (Rogers 2010). Some studies found that complexity was negatively related to the rate of PA technologies adoption (Aubert, Schroeder & Grimaudo 2012; Eastwood et al. 2016; Hay & Pearce 2014; Lambert, Paudel & Larson 2015; Robertson et al. 2012). The adoption of complicated technology, such as variable rate technology, requires changing several components of the farming system (Robertson et al. 2012), which has potentially low consistency with current farm practices, and this causes a slow rate of adoption. For example, a study conducted by Lambert, Paudel and Larson (2015) in the United States identified that cotton growers perceiving PA technologies were too complicated were 5.6% less likely to adopt the bundle of PA technologies, such as yield monitor and grid soil sampling. Therefore, complexity reduces the rate of PA technologies adoption. Consequently, the higher level of complexity of PA technologies results in the lower rate of adoption because complicated technology does not meet the expectations of the farmer. If technology becomes incompatible with existing farming activities, farmers may feel it is difficult to use the technology, and their attitude is influenced negatively towards technology.

Complexity can also be the result of limited knowledge by the end-user. Therefore, increasing end-user skill and knowledge on how to use the technology is required to promote the adoption of PA technologies (Eastwood et al. 2016). The literature highlights training programs for improving farmers knowledge and skills as potential ways to address and reduce the complexity of PA technologies in order to promote adoption (Reichardt & Jurgens 2009). Much agricultural research has shown that training develops farmers' knowledge, skills and ability in specific farming operations, which enables farmers to perform much more efficiently (Sharma et al. 2017). Agricultural experts, consultants, agronomists, PA technologies suppliers, and manufacturers arrange training and extension program to build farmers' knowledge about PA technologies (Robertson et al. 2012). PA technologies with higher complexity could face higher risks of adoption failure than other agricultural technologies because PA technologies with higher complexity need the greater competency of a farmer.

Also, potential adopters may like to trial technology on a limited basis before they adopt it. After trialling PA technologies, farmers will have formed a view about the required ability to practice the technology. If they perceive that they have the essential skills and also perceive that the technology is valuable, then they might adopt it. Research that has examined this link has clearly shown a strong relationship between value, and adoption pathways. For example, a study conducted by Bowman, Denny and Stone (2020) in the United States found that trialability had a positive influence in the adoption of on-farm bacteriologic culturing (OFBC) in dairy farms. The possible reasons of trialling of OFBC is that dairy farmers acquired many benefits, such as reduced antibiotic expenses, faster results than from a lab test (Bowman, Denny & Stone 2020), and lower cost. After trialing PA technologies, farmers will be able to identify whether the technology is helpful and how it fits with their farming operations. Further, they also acquire an opportunity to learn the required skills of technology use. Hence, trialling of technology could change potential adopters' behaviours towards the technology. So, trialling of the technology is essential because it can augment the likelihood of the PA technologies adoption (Aubert, Schroeder & Grimaudo 2012; Khan & Khan 2016; Rezaei-Moghaddam & Salehi 2010; Robertson et al. 2012).

In addition, if a farmer is unable to trial the technology for themselves, seeing and observing other farmers and the results are a key to adoption pathways. Consequently, observability, as another determinant in adoption pathways and is also influential in PA technologies adoption. Importantly, research in PA technologies adoption have shown that observation, and demonstration sites for farmers are critical to providing the knowledge. For example, research conducted by Sattler and Nagel (2010) in Germany showed that observability profoundly influenced the intention of farmers to adopt PA technologies, such as reduced tillage. As prospective users can see the benefits of reduced tillage, for example surface water pollution, and soil structure improvement, observability influences the adoption of reduced tillage technology.

Individual assessment of the features of the product leads to a decision on whether to adopt or discard the innovation (Franceschinis et al. 2017). In the decision stage, the decision-maker progresses from accessing and assessing information to the point of commitment to trial the innovation or reject it. Therefore, DOI theory highlights that communication channels are essential in this stage of the technology adoption process. So, DOI theory covers two channels of communication: 1) mass media, and 2) interpersonal communication. The following section describes how these channels of communication influence PA technologies adoption.

Mass media and interpersonal communication are the main channels of communication which increase awareness of farmers towards the PA technologies. Mass media plays a crucial role in spreading information to large groups of people quickly (Irfan et al. 2006) and informing and guiding farmers about PA technologies use. For example, Ani et al. (2015) surveyed 120 farmers in Nigeria and found that farmers perceived mass media as a useful source of communication for increasing their awareness of information about technology and training. Different channels of mass media, for example, agricultural programmes on the radio and television provide information to farmers which increase their knowledge. As a result, they become more comfortable to use technology such as PA technologies.

Champions, change agents and opinion leaders are forms of interpersonal communication by which individuals develop and distribute information between each other to accomplish shared understandings (Rogers 2010). Interpersonal communication increases the awareness of farmers and helps in the decision-making process, and therefore influences the adoption of PA technologies. Only a few studies have considered champions as an essential aspect of technology transfer (Howell & Boies 2004; Luz et al. 2018; Renken & Richard 2019). However, a large number of studies highlighted that change agents could bring changes in farmers' attitudes which influence PA technologies adoption (Adekunle 2013; Busse et al. 2014; Caplan et al. 2014; Lencses, Takacs & Takacs-Gyorgy 2014; Najafabadi, Hosseini & Bahramnejad 2011; Paustian & Theuvsen 2017; Torbett et al. 2008).

A champion is an innovative and smart farmer who uses new technology in the first instance and feels comfortable to use technology. Likewise, the champion trains and supports other farmers in agricultural development work. Thus, the social interaction between the champion and other farmers could increase the knowledge of farmers. As the champion uses new technology more quickly, other farmers in the society observe the outcomes of the technology. If the outcomes of the technology became valuable, then other farmers might be interested in using the new technology. Thus, the champion could be a valuable source of agricultural information to promote PA technologies adoption.

Change agents, such as contractors, deliver input services and information demanded by farmers. They also provide rental service of PA technologies to farmers. For example, Tata Kisan Kendra is a change agent in India which provides agrochemical, modern machinery and equipment for rent and also provides agricultural information and training to develop farmers' skills. Thus, these activities of Tata Kisan Kendra motivate farmers to use PA technologies.

Similarly, a survey conducted by Kutter et al. (2011) in Germany found that change agents such as contractors were essential promoters of PA technologies. Change agents share information, establish networks and develop credibility with farmers. Therefore, they can influence farmers' intentions positively to adopt PA technologies.

In a social system, local farmers could be opinion leaders and play a role model in technology adoption (Hameed & Sawicka 2017). As opinion leaders have a higher social status, are more innovative, and more exposed to all forms of external communication (Rogers 2010), they exert their influence on the adoption of innovation. Once opinion leaders agree and accept an innovation, it impacts others in the group who also accept the innovation to sustain a social and economic status among the social system (Oleas et al. 2010). For example, a qualitative study conducted by Oleas et al. (2010) showed that opinion leaders influence the adoption of agricultural technology in Guatemala. As opinion leaders are respected people in society, their decision could influence other farmers.

In the implementation stage, the decision-maker, that is, the farmer, tries the technology and evaluates whether the innovation meets their desire. The final stage in the adoption process is the confirmation, which occurs when the decision-maker likes the innovation and commits to its continued use.

Farmers might have different characteristics, such as being innovative, risk-averse, educated, young or old, which could influence PA technologies adoption. Therefore, this thesis examines adopter categories included in DOI theory in the following section.

2.4.1 Adopter categories

DOI theory categorises the potential users of innovation/technology into five groups based on their innovativeness: 1) innovators, 2) early adopters, 3) early majority, 4) late majority, and 5) laggards (Rogers 2010). These categories have been used in multiple explanations for technology adoption curves across business, finances, economics, commerce, technology, software, and also in precision agriculture. The innovativeness is the extent to which an individual is comparatively quicker in adopting new ideas than other members of the social system (Rogers 2010). The innovativeness of the adopter is significant to recognise the preferred and foremost behaviour in the innovation-decision process.

According to DOI theory, innovators tend to be young, educated and have a high-risk appetite. They possess substantial economic resources and represent 2.5% of the overall population. For PA technologies adoption, an interesting survey conducted by Watcharaanantapong et al.

(2014) in the United States in cotton farming presented that the adoption of PA technologies, such as grid soil sampling and yield monitoring, was related with innovators, those who were young and educated and willing to take a risk, earlier than other farmers. The data indicated that an additional year of age of farmers caused 0.07 and 0.04 years delay in the adoption of grid soil sampling and yield monitoring. Indeed, adoption pathways are quicker and more comfortable for those individuals who are considered innovators.

Early adopters tend to be educated, possess higher social status, and a robust financial circumstances. As they are most active and opinion leaders, they can influence other members in the community. Early adopters do not take as many risks as innovators and try to receive more information than innovators in the technology adoption process. On the other hand, early adopters represent 34% of the overall population and provide much essential feedback about how PA technologies are doing and in what ways these can be improved.

The next wave of adopters is considered the early majority, who accept new thoughts just before the usual members of the system, occasionally retaining a position of opinion leader, and are the most numerous adopter groupings, reaching up to one-third of the members of a system (Rogers 2010). They frequently interact with their peers and would like to see the benefits of an innovation before they adopt it. This group of adopters takes longer to adopt PA technologies compared to innovators and early adopters.

The late majority are considered characteristically risk-averse and sceptical, with little opinion leadership (Rogers 2010). Finally, the laggards tend to have a low education level and a limited peer network which is confined to contact with family and close friends only (Nieva 2015). They often made the decisions by looking at past results.

DOI theory includes several features of the innovation, for example, relative advantage, compatibility, complexity, observability, and trialability along with socio-economic factors (income, education, experience), personality variables (optimistic, short-tempered, wise, quiet, peaceful and irritable), and communication channels as influencing factors in various stages of the innovation/technology adoption process. The determinant, relative advantage, has been covered in a large number of studies (Asare & Segarra 2018; Bramley & Ouzman 2018; Keskin & Sekerli 2016; Lima et al. 2018; Silva, De Moraes & Molin 2011) as a PA technologies adoption influencing factors.

Many studies have applied DOI theory in different industries to understand the adoption process, including information technology (Kauffman & Techatassanasoontorn 2005), healthcare (Chew, Grant & Tote 2004; Helitzer et al. 2003; Lee, T-T 2004; Nath, Hu & Budge 2016; Ochieng & Hosoi 2006), agriculture (Peshin, Vasanthakumar & and Rajinder Kalra 2009; Robertson et al. 2012), tourism (Dibra 2015), banking (Al-Jabri & Sohail 2012), and education (Sasaki 2018; Tabata & Johnsrud 2008). Thus, the DOI theory is a useful framework to understand why farmers accept or reject PA technologies. In the next section, this thesis examines the technology acceptance model (TAM) to identify whether TAM provides new insight into the perception of the potential user in the acceptance of new technology.

2.5 Technology acceptance model (TAM)

Davis (1986) developed the technology acceptance model (TAM), which explains how two fundamental attitudinal components, perceived usefulness and perceived ease of use, influence technology adoption. The perceived usefulness component of TAM is the degree to which a potential user perceives that using a particular technology would increase his/her job performance (Davis 1989). Similarly, perceived ease of use is the degree to which the potential user perceives that using a specific system would be free from effort (Davis 1989). The concept of TAM is that the two key beliefs, perceived usefulness and perceived ease of use, influence the attitude of the user towards the new technology, and the attitude affects the intention to use the new technology (Davis 1986).

The perceived usefulness component and perceived ease of use component in TAM resemble the concepts of the relative advantage and complexity determinants in Rogers' DOI theory, respectively. However, both share some key elements, theoretically, the components of TAM (perceived usefulness and perceived ease of use) have no clear relation with the determinants of DOI theory.

Rogers (2010) defined relative advantage as the extent to which an innovation/technology is alleged to be better than the idea of it supersedes. In his definition of relative advantage, he compared two technologies, existing and new technologies and concluded that new technology needs to provide more benefits than the old one for the new technology to be adopted. However, DOI theory does not specify exactly which aspect of the technology is superior than the existing one. On the other hand, Davis (1989) defined perceived usefulness as the extent to which the potential user perceives that using a particular technology would enhance his or her job performance. In his definition of perceived usefulness, it is not clear whether new technology is compared with other technology, such as when the use of a computer is not compared with the use of a typewriter. Thus, his definition of perceived usefulness is concentrated on a single use of technology which focuses on valuable benefits relating to job performance.

Rogers' definitions of relative advantage and complexity are based on perceptions of the innovation itself, and not on perceptions of actually using the innovation (Moore & Benbasat 1991). Therefore, TAM seeks to explain these two key attitudinal components in technology adoption more thoroughly and then perhaps TAM does not try to address other aspects of the technology adoption process.

Many studies found that both perceived usefulness and perceived ease of use influence the adoption of PA technologies (Aubert, Schroeder & Grimaudo 2012; Flett et al. 2004; Monfared 2015; Salehi et al. 2012). For example, after surveying 985 New Zealand dairy farmers, Flett et al. (2004) found that the farmers realised soil testing technology was useful because it provided information regarding the level of nutrients in the soil. After identifying the level of nutrients in the soil, farmers can apply the optimum quantity of fertiliser, which provides not only economic benefit but also improves the plant growth rate and results in an increased adoption of PA technologies. Figure 2.2 below outlines the various components of TAM .

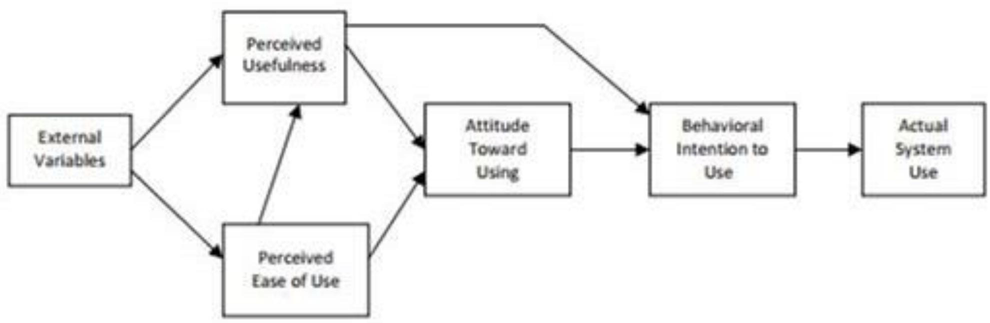

Figure 2.2: Technology acceptance model

Source: Davis, Bogozzi and Warshaw (1989)

TAM focuses on two attitudinal components: 1) perceived ease of use, and 2) perceived usefulness. Perceived ease of use is influenced by farmers' knowledge, compatibility of technology and availability of support, and perceived usefulness is influenced by relative advantage and information of technology (Aubert, Schroeder & Grimaudo 2012). TAM shows that perceived ease of use may influence perceived usefulness. TAM was updated into the technology acceptance model 2 (TAM 2) by Venkatesh and Davis (2000). Thus, this thesis now examines TAM 2 to understand the technology adoption process further.

TAM 2 also focuses on two constructs (perceived usefulness and perceived ease of use). The new information integrated into TAM 2 is that several factors such as subjective norm, image, job relevance, output quality, and result demonstrability influence perceived usefulness (Venkatesh & Davis 2000). Additionally, TAM 2 highlights that experience and voluntariness influence subjective norm. Therefore, TAM 2 was developed to explain and predict why users sometimes accept and sometimes reject technology. TAM 2 has been used more recently in PA technologies adoption literature. Figure 2.3 below outlines the various components of TAM 2.

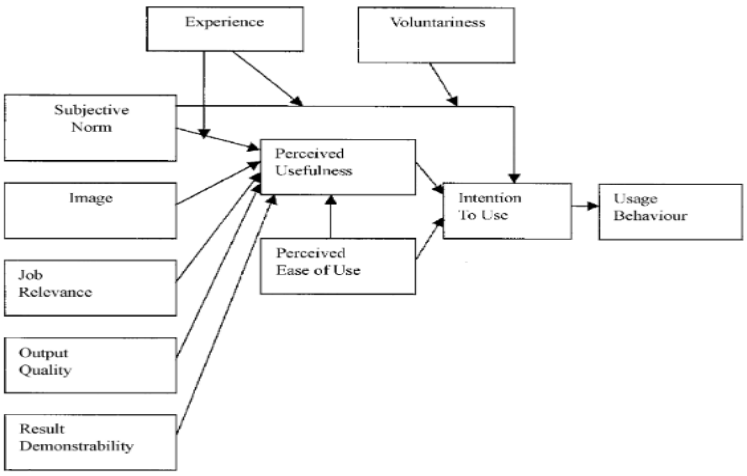

Figure 2.3: Technology acceptance model 2

Source: Legris, Ingham and Collerette (2003)

Subjective norm is perceived social pressure to accomplish or not accomplish the behaviour (Ajzen 1991). Experience and voluntariness affect subjective norm, and subjective norm influences the intention of a user to accept the technology. For example, a study conducted by Hou and Hou (2019) in China found that subjective norm directly influenced farmers' intentions to use low-carbon agriculture methods. The reasons behind the positive influence of subjective norm could be incentives from the government, encouragement from neighbours, and extension personnel. TAM 2 also focuses on perceived usefulness and perceived ease of use. The only difference between TAM and TAM 2 is the addition of elements that affect perceived usefulness and one extra element (subjective norm) in the model. In 2008, Venkatesh and Bala (2008) superseded TAM 2 with the technology acceptance model 3 (TAM 3) to explain and predict why users sometimes accept and sometimes reject technology.

TAM 3 highlights that a number of factors influence perceived ease of use. For example, computer self-efficacy, perception of external control, computer anxiety, and computer playfulness influence perceived ease of use (Venkatesh & Bala 2008). Similarly, perceived enjoyment and objective usability also influence the perceived ease of use (Venkatesh & Bala 2008). As a result, perceived ease of use influences the intention to use technology.

Computer self-efficacy, which is the users' ability to use their computer skills while practising technology, influences the users' perceived ease of use (Hasan 2007; Igbaria & Iivari 1995; Venkatesh & Davis 1996). PA technologies are computer-based technologies. Thus, computer knowledge is required to practice PA technologies. Farmers with computer self-efficacy would find PA technologies easier to practice than farmers who do not have this level of confidence.

Though there is a lack of analysis of several factors of TAM 3 in the context of agriculture, including computer anxiety on perceived ease of use, a study conducted in the educational context of a Canadian university by Saade and Kira (2009) found that computer anxiety had a significant effect on perceived ease of use. There could be several reasons for this. Students could feel uneasy while using the computer. Similarly, they might be scared that they could destroy a large amount of data due to hitting a wrong key. Further, they might think that they cannot make a correction if they made a mistake on the computer. Although the findings of this study are outside of agriculture research, it is relevant to PA technologies adoption because users could be students or farmers; both use computers and might have computer anxiety.

TAM, TAM 2 and TAM 3 are attitudinal-based models and offer potential use in PA technologies adoption research. However, there is limited research that has explored the constructs of TAM 2 and TAM 3 concerning PA technologies adoption. It is noted that TAM 3 also focuses on two constructs (perceived usefulness and perceived ease of use), including some external factors that influence the perceived ease of use. Figure 2.4 below outlines the various components of TAM 3.

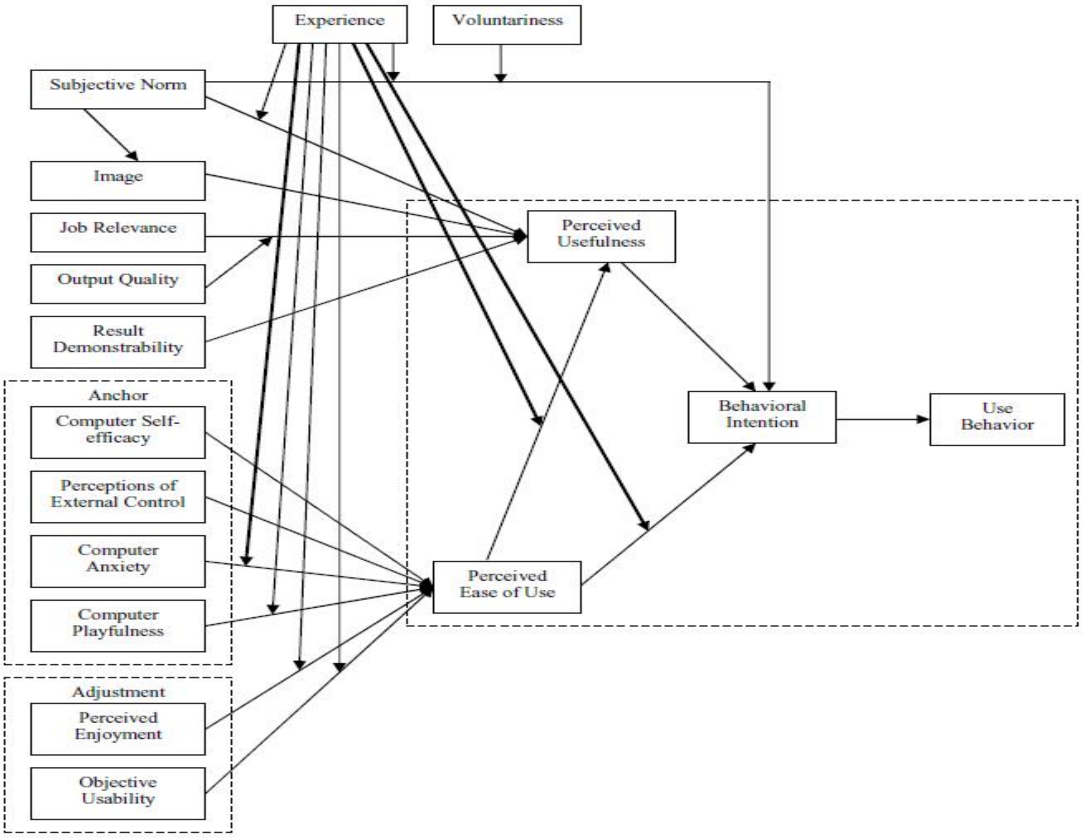

Figure 2.4: Technology acceptance model 3

Source: Venkatesh and Bala (2008)

As discussed above, the original TAM included two attitudinal factors: 1) perceived ease of use and 2) perceived usefulness; therefore, the model is simple and easy to use. Many studies have used TAM in a different sectors including dairy farming (Flett et al. 2004), education (Scherer, Siddiq & Tondeur 2019), and hospitality (Agag & El-Masry 2016). Also, TAM 3 has included computer self-efficacy, which is a novel feature of the model. The research shows that if potential users have high self-efficacy, they could be more likely to make a positive decision to change their behaviour (Locke & Latham 1990). Since, the computer system is a fundamental component of PA technologies, computer self-efficacy could be an essential determinant of PA technologies adoption.

However, many studies have also claimed that TAM is not a complete model of technology acceptance for predicting the adoption of new technology (Chung & Tan 2004; Morosan 2012; Yu et al. 2005). Therefore, they suggested adding some factors, such as perceived innovativeness (Morosan 2012), playfulness (Chung & Tan 2004), and trust (Yu et al. 2005) within the perceived usefulness and perceived ease of use constructs of TAM so as to understand the complicated situation of the technology adoption process.

The original TAM highlighted that perceived ease of use and perceived usefulness influence attitude and attitude influences intention. However, many studies showed that perceived ease of use and perceived usefulness directly influence intention to use technology (Aubert, Schroeder & Grimaudo 2012; Flett et al. 2004; Monfared 2015; Salehi et al. 2012). Therefore, it can be seen that attitude has a weak role as a moderator between constructs (perceived ease of use and perceived usefulness) and intention to use technology.

This thesis examines another theory (the theory of planned behaviour) in the next section to identify whether it provides more information about how psychological factors influence PA technologies adoption.

2.6 The theory of planned behaviour (TPB)

There is one commonly used theory, the theory of planned behaviour (TPB), which helps to understand how psychological factors, such as attitude, subjective norms and perceived behavioural control, influence technology adoption. Attitude is the positive or negative feeling or belief of an individual about a behaviour (Przepiorka, Blachnio & Sullman 2018) and the subjective norm is the perceived social pressure to accomplish or not to accomplish the behaviour (Ajzen 1991). Similarly, perceived behavioural control is the individual’s opinion of the comfort or difficulty of performing the desired behaviour (Ajzen 1991).

The attitude and perceived behavioural control components in TPB are not different from the concept of the perceived usefulness component and perceived ease of use component of the technology acceptance model (TAM). For example, a farmer might believe that PA technologies are useful in farming operations. So, this belief of the farmer is an attitude in TPB, and it is perceived usefulness in TAM. Similarly, the farmer might believe that PA technologies are not difficult to use in farming operations. So, this belief of the farmer is perceived behavioural control in TPB, whereas it is perceived ease of use in TAM. Both models/theories use different words, but the concept is the same because both TAM and TPB are based on the theory of reasoned action (TRA), developed by Fishbein and Ajzen (1975). The only difference is that TPB uses one different component, subjective norm, which provides more information about an individual’s intention to perform a behaviour.

According to TPB, attitude, subjective norms, and perceived behavioural control directly influence the intention of an individual, and that intention creates behaviour. If an individual possesses a more positive attitude and subjective norms, and better perceived behavioural control, the individual might have a more definite intention to perform the behaviour. For example, a study conducted by Sharifzadeh et al. (2012) in Iran showed that attitude, subjective norms, and perceived behavioural control influenced positively wheat growers' intentions to use agricultural climate information. Since wheat growers perceived use of agricultural climate information could improve agronomic decision making, they had a favourable evaluation towards it. Similarly, wheat growers who perceived social pressure to use agricultural climate information intended to use it. Further, the wheat growers perceived that it was easy to use agricultural climate information. Therefore, they had more intention to use it. Some other studies also showed that attitude, subjective norms, and perceived behavioural control influenced positively the intention of potential users to use agricultural technology (Borges et al. 2019; Despotovic, Rodic & Caracciolo 2019; Senger, Borges & Machado 2017). Indeed, the more favourable attitude, subjective norms and perceived behavioural control, the stronger the intention of farmers to use PA technologies. Figure 2.5 below outlines the different components of TPB.

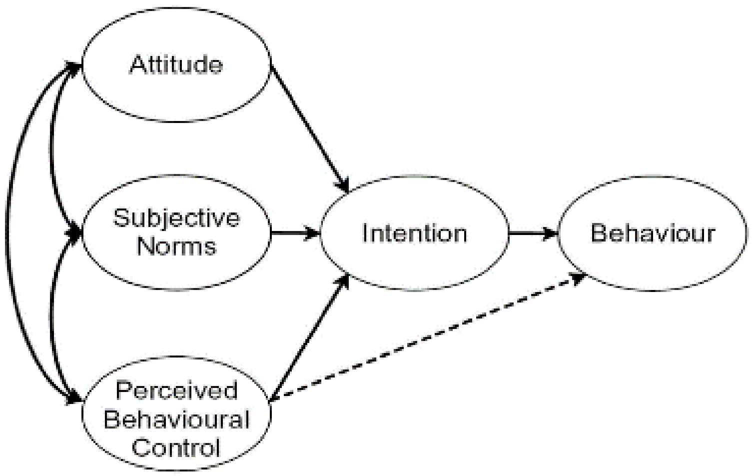

Figure 2.5: Theory of planned behaviour

Source: Ajzen (1991)

According to TPB, an individual intentionally assesses the effects of alternative behaviours and picks the one that leads to the most desirable outcome. In this theory, an attitude refers to farmers' optimistic or pessimistic assessments of accepting or rejecting the use of PA technologies. When farmers possess a more positive attitude, then their intention is more positive. Peers of farmers might encourage or discourage (creating subjective norms) them to use PA technologies. Likewise, farmers might perceive that use of PA technologies is either comfortable or sophisticated (perceived behavioural control). Thus, the combination of these determinants creates positive or negative intention towards the behaviour.

Sniehotta, Presseau and Araujo-Soares (2014) state that TPB is widely used amongst researchers. Similarly, studies conducted by Senger, Borges and Machado (2017) and Wauters et al. (2010) concluded that TPB contributes to developing strategies to improve agricultural production. This theory links attitude and perceived behaviour control. Therefore, TPB could be useful in forecasting the behaviour of PA technologies adopters.

TPB posits that people perform the desired behaviour when they receive opportunities and resources, regardless of the intention. It ignores factors such as fears and threats that also influence the intention to perform the behaviour. For example, farmers may have a fear of reducing crop production and quality. Likewise, they may have a fear of affecting the environment as a result of the application of agrochemicals in the farm, and farmers could have the intention to use PA technologies which provides both economic and environmental benefits. However, TPB does not consider how these factors (fear and threat) influence technology adoption.

The models/theories discussed above were developed in the field of social science/psychology to understand how potential users' perceptions influence technology adoption. Following on from this, the next section discusses a model developed in agriculture to understand the agricultural technology adoption process.

2.7 Adoption and diffusion outcome prediction tool (ADOPT)

A large number of studies have examined the adoption of agricultural technologies; however, only a few studies have utilised a model to make quantitative predictions of agricultural technology adoption. The adoption and diffusion outcome prediction tool (CSIRO 2018) could be a useful model to predict the likely peak adoption level and the likely time for reaching that peak of technology adoption. Both peak adoption level and time for reaching that peak are numeric outputs. For example, if an adoption level of new PA technologies is 27% in 4 years, it is predicted that the level of technologies adoption will be 64% in 7 years.

There are four critical aspects of ADOPT: 1) a relative advantage for the population, 2) learnability characteristics of the practice, 3) population-specific influences on the ability to learn about the practice, and 4) relative advantage of the practice (Forbes, Cullen & Grout 2013). Each key aspect of ADOPT has several factors (in total, 22 factors within four key aspects) which could influence the likely peak adoption level and the likely time for reaching that peak of technology adoption. Figure 2.6 below outlines the four key aspects and 22 factors of ADOPT.

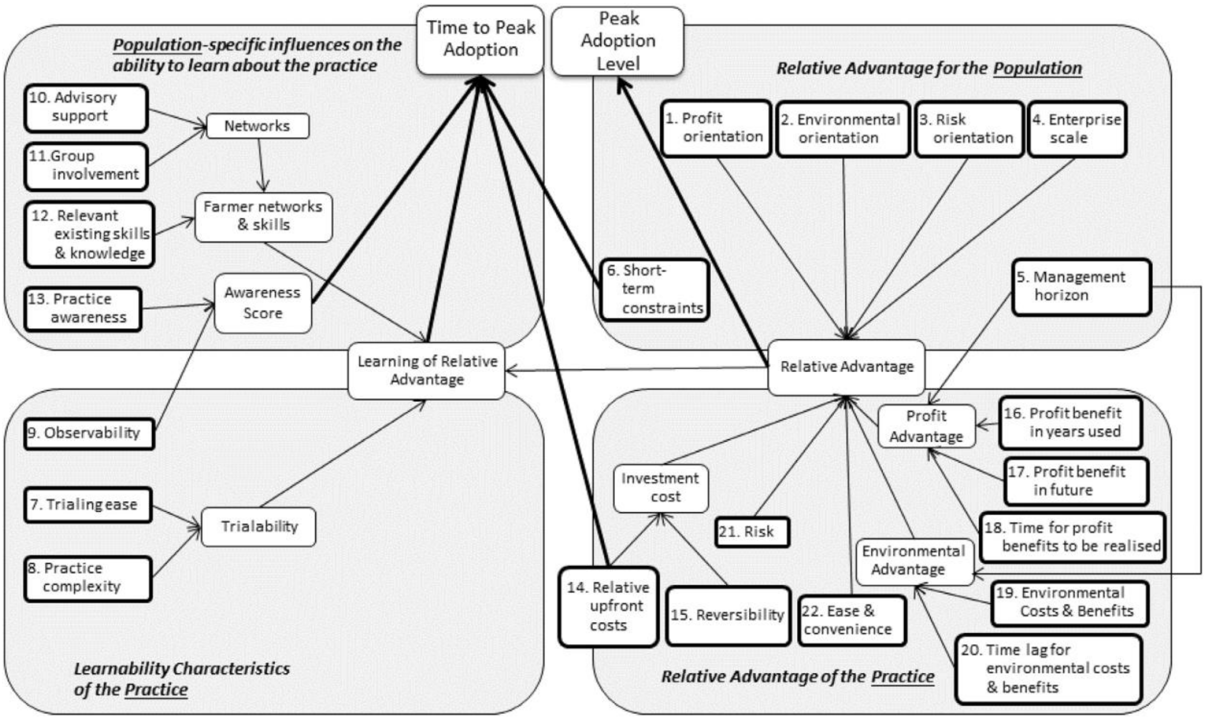

Figure 2.6: The conceptual framework of influences on peak adoption level and time to peak adoption

Source: CSIRO (2018)

A few studies have been conducted in PA technologies adoption by using ADOPT. For example, a study conducted by Kuehne et al. (2017) in Australia identified that predicted adoption level and time to peak adoption of PA technologies, such as new lupin (seed technology), were 72% and 14 years, respectively. Correspondingly, the actual peak adoption level and time to peak were 75% and 10 years, respectively. These results show that the actual time to peak adoption was less than that predicted, but the actual peak adoption level was 3% more than the predicted. The reason behind these outcomes could be an overestimated of time to peak adoption. The analysis might assume that farmers were not experienced with new varieties of lupins and had a lack of skills, which could increase the time to peak adoption. On the other hand, there could be an extension program to promote the uptake of new lupins, which could increase farmers knowledge of growing lupins. Kuehne et al. (2017) also highlighted that factors, such as short-term constraints, ease of trialling and practice complexity, influenced time to peak adoption whereas profit benefit in years used, profit benefit in future, and ease and convenience of the practice influenced peak adoption level.

ADOPT has a significant role in delivering information in agricultural research and development programs. The tool has been used in a number of industries and organisations, for instance, project evaluation (Grains Research and Development Corporation 2016) and use by teams of research scientists and project practitioners (James, Coutts & Gururajan 2015).

The forecast of ADOPT is based on a steady external environment, but price change, changes in legislation, and the availability of alternate technologies are not explicitly explained into the model (Kuehne et al. 2017). Most of the influencing factors (for example, profit orientation, environmental orientation, risk orientation, enterprise scale, ease and convenience) within ADOPT are relevant to the relative advantage of the technology. Although ADOPT has included 22 factors that influence the peak adoption level and time for reaching that peak, the influencing factors are similar to Rogers' DOI theory except for some communication channels. Therefore, this thesis looks to another model of innovation/technology adoption in the next section.

2.8 Model of determinants of diffusion, dissemination and implementation of innovations (MDDDII)

From examining several models/theories of adoption in the preceding sections, this thesis identifies that each of the models/theories provides a developed framework that seeks to explore/explain/understand the adoption processes from different perspectives. The adoption process across the models share a similar concept, but they emphasise different aspects. Rogers' DOI theory considers the perceived features of the innovation, such as relative advantage and complexity, as a significant component of technology adoption. Likewise, the perceived usefulness and perceived ease of use constructs of TAM are also pertinent to the perceived features of the technology. However, these factors emphasise the adoption process from a different angle, that is, perceived usefulness is influenced by external factors and perceived usefulness influences attitude, and then attitude influences intention to use technology, and, finally, intention changes into actual behaviour or technology adoption. Both TPB and ADOPT consider perceived features of the technology as influencing factors from a different angle. For example, TPB includes three psychological factors, such as attitude, subjective norms, and perceived behavioural control, but ADOPT includes 22 factors within four critical aspects of technologies that influence PA technologies adoption. Although these factors influence technology adoption from a different perspective, these factors are most relevant to the feature of the innovation, such as relative advantage.

The models/theories mentioned earlier explain varying aspects of the adoption process from different perspectives and purposes. Thus, while none of the models/theories is likely to explain the nuances of adoption and behavioural change completely, it could be helpful to consider multiple models/theories that can then take into account a diverse range of influencing contexts, in order to provide a large complex structure of the adoption process. Following on from this, one comprehensive theoretical model, the model of determinants of diffusion, dissemination and implementation of innovations (MDDDII), captures the multiple influencing components and determinants involved in the adoption of innovation process that has been presented in the literature, variously and partially covered by other models/theories of innovation/technologies adoption as mentioned above. MDDDII could be a uniquely strong model for understanding the diverse features of a multifaceted situation and their interactions in technology adoption.

MDDDII draws together a broad range of influencing factors of technologies adoption into a comprehensive theoretical model. It includes nine components (the innovation, communication and influence, outer context, adopter, system antecedents for innovation, system readiness for innovation, linkage, assimilation and implementation process) and considers 66 determinants. These components/determinants interact with each other and construct a relationship in the technology adoption process. For example, a farmer acquires more information of PA technologies (benefits, costs, and required skills) from the internet, media, consultants, friends, or extension personnel while deciding to accept or reject. In this example, the components of MDDDII, such as the innovation (benefits and costs are determinants within the innovation component), adopter (required skill is the determinant within adopter component), communication and influence (internet, media, consultants, friends, or extension personnel are determinants within the communication and influence component), interact with each other and build a relationship that influences a farmer's decision on whether to adopt or not to adopt PA technologies.

Many studies have used MDDDII in the healthcare industry to understand the technology adoption process and how different factors of MDDDII influence innovation/technology adoption in hospitals (Cook et al. 2012; Durlak & DuPre 2008; Fahey & Burbridge 2008; Makowsky et al. 2013). For example, a qualitative survey conducted by Makowsky et al. (2013) in Canada identified that MDDDII was helpful to understand the multifaceted nature of pharmacists' adoption of prescribing practices technology. Similarly, Emmons et al. (2012) tested how different features of the organisation, such as leadership and vision, managerial relationships, climate, and absorptive capacity, influence dissemination and implementation of technology in the healthcare industry. These features of the organisation are included as determinants of MDDDII within the system antecedents for innovation component. These are standard features of organisations, whether it is healthcare or agricultural enterprise. Therefore, the system-based determinants within the agricultural enterprise are essential factors of PA technologies adoption.

One of the distinguishing features of MDDDII is that Greenhalgh et al. (2004) developed MDDDII to understand the technology adoption process in service organisations. MDDDII considers the context of the organisation itself, and the readiness of a service or process. In terms of PA technologies adoption, an individual (a farmer) within the organisation (agricultural enterprise) might be ready to adopt a technology or a process. However, the context of the organisation (agricultural enterprise) may not be, and thus there can be different drivers and barriers for the potential technology adoption. For PA technologies adoption, therefore, the MDDDII could offer a lens to interpret the dissemination and diffusion of technologies because it considers many components/determinants and attempts to examine the interactions and their relationships in a complex technology adoption process. For example, MDDDII highlights that an organisation such as an agricultural enterprise where multiple individuals are involved in the technology adoption process, needs a robust background (system antecedents for innovation). A robust background to the organisation includes, but is not limited to, effective leadership, enough slack resources, new knowledge identification and sharing ability, and a clear vision of the organisation, which influences the new technology adoption, such as PA technologies. The literature also highlighted that if the organisation is a big, mature, functionally differentiated, and possesses slack resources, then the organisation will assimilate or adopt technology more readily (Dopson et al. 2002; Fitzgerald et al. 2002; Newton et al. 2003). Likewise, existing knowledge and skills base, ability to find, interpret, recodify, new knowledge integration and knowledge sharing also influence technology adoption (Ferlie et al. 2001). If the agricultural enterprise has enough cash on hand, it can afford new technology such as PA technologies, and also skilled employees uses technology efficiently, which in turn, fosters adoption. Indubitably, slack financial resources facilitate agricultural enterprises to invest in new technology and protect the agricultural enterprise from potential depletion of resources if such efforts are unsuccessful. Thus, system antecedents for innovation is an essential aspect of the technology adoption process. Further, MDDDII shows that system antecedents for innovation influences system readiness for innovation. Then, system readiness for innovation influences adoption. As a result, the user implements the technology for the short term or long term.

The structure of MDDDII is a novel way to understand how different components interact and build a relationships in PA technologies adoption. MDDDII has two phases: 1) examination of individual components of MDDDII, such as perceived features of the innovation/technology and characteristics of the adopter; and 2**)** their interaction within the background and readiness of organisations. For example, farmers may perceive that variable rate technology provides an economic benefit. As it is a sophisticated technology, a farmer needs skills, and he/she might use a consultant at the beginning of the technology use and also need to manage financial resources to purchase the technology. Thus, a combination of factors involve in technology adoption. Several components of MDDDII such as the innovation (economic benefit), adopter (skills), and system antecedents for innovation (slack financial resources) interact with each other in variable rate technology adoption. Therefore, MDDDII could be a useful framework for the stakeholders of PA technologies adoption, including extension personnel, policymakers, and PA technologies adoption researchers to design and develop extension strategies.

The distinct attribute of MDDDII is that it has expanded the features of the innovation component in Rogers' DOI theory by adding some other factors, such as technical support, the potential for reinvention, fuzzy boundaries, risk, task issues, and nature of knowledge required (tacit/explicit). MDDDII highlights that these extra features of the innovation influences technology adoption. For example, a survey conducted by Castro et al. (2015) in Spain shows that technical support motivated dairy farmers to use an automatic milking system because technical support helped the farmers to handle installation errors, and other technical problems. Subsequently, farmers felt it was easy to use the automatic milking system in their farming operations.

Further, MDDDII has expanded the communication channels of Rogers' DOI theory by adding some more determinants, such as marketing, homophily and crop consultants. These determinants influence technology adoption. For example, if prospective users have similar education, professions, and socioeconomic and cultural backgrounds (homophily), the technology is more likely to be adopted (Fitzgerald et al. 2002; West et al. 1999). However, outer context, system antecedents for innovation, system readiness for innovation and linkage components of MDDDII are different from other models/theories, as mentioned above, and provide information of how these components influence technology adoption.

The component outer context describes how the external factors, such as the socio-political climate, incentives and mandates, inter-organisational norm-setting and networks, and environmental stability (Greenhalgh et al. 2004) influence technology adoption. The combination of social factors (level of education, wealth, religion, family size and structure, buying habits, knowledge, and lifestyle) and political factors (tax policy, environmental law, and labour law) is equally essential while promoting PA technologies. Environmental resources, such as air, land, and water, need to be protected and maintained for future generations. For example, excessive use of agrochemicals in the farm could be poisoning birds and aquatic animals and causing environmental contamination of groundwater and waterways. Thus, it is a matter of environmental conservation, which is affected by both the social and political climate. In this case, governments can make a flexible tax policy or provide a monetary incentive to farmers while purchasing PA technologies, such as variable rate technologies which control the excessive use of agrochemicals.

Incentives and mandates, such as land conservation programs and regulations, influence PA technologies adoption. For example, after surveying of 739 cotton growers in the United States, Lambert, Paudel and Larson (2015) identified that farmers who were involved in federal sponsored working land conservation programs were 201% more likely to adopt PA technologies. This survey showed that land conservation program is the most crucial factor in the adoption of PA technologies. The land conservation programs provided cost-share payments to develop and implement soil nutrient management plans; therefore, this factor had a more considerable influence on the adoption of PA technologies.

The adopter component of MDDDII is similar to the adopter's categories, for example, the innovators, early adopters, and early majority (Rogers 2010) mentioned by Rogers in his DOI theory. MDDDII mentioned that the characteristics of farmers, such as skills, motivation, needs, values and goals, learning style, and social networks, are important determinants that influence technology adoption. Similarly, Rogers' DOI theory believed that innovators and early adopters are educated, possess higher social status, and have a robust financial situations which motivates him/her to trial new technology. Thus, both of the models have the same insight into how the adopter component influences technology adoption. Similarly, the motivation determinant within the adopter component is not very different from the computer self-efficacy (belief that he/she can use a computer) and image (using technology will increase someone's status in society) determinants in TAM 3.

System antecedents for innovation, which is the attribute of an organisation, is a distinct feature of MDDDII. This component of MDDDII highlights that organisations/agricultural enterprises require a robust background, for example, enough resources which are financial and human, effective leadership, new knowledge identification and sharing ability, and the clear vision to adopt new practices such as PA technologies. Similarly, organisations require the ability to find, interpret, and recodify, new knowledge integration and knowledge sharing to adopt the technology (Ferlie et al. 2001). Besides, organisations need the ability to take a risk in using technology along with clear goals, high-quality data capture, and good managerial relations because these determinants influence the adoption of technology (Dopson et al. 2002).

System readiness for innovation is another essential component of MDDDII. The farming business may not be prepared for or have the desire to assimilate an innovation due to relevant determinants, such as tension for change, innovation system fit, power balances, assessment of implications, dedicated time/resources, and monitoring and feedback (Greenhalgh et al. 2004). This component captures the situational aspects of the farming business that relate to preparedness to assess and adopt an innovation.

In addition, sometimes employees could be dissatisfied with an existing process. If an employee realises that the existing situation is insupportable, a new technology is more likely to be adopted (Gustafson et al. 2003). Similarly, if technology matches with the prevailing values, goals, and approaches of the organisation, the technology will be more likely to be adopted (Gustafson et al. 2003).

New technology adoption is not an easy job, and it takes time and effort. Several factors, such as lack of skilled workforce, financial circumstances, supporters and opponents of technology adoption, and compatibility of technology with the organisational systems, could be issued in technology adoption. For example, the use of a fruit picking machine needs skilled human resources to run the machine. Therefore, the farm manager or grower needs to manage skilled employees before adopting the technology.

Besides system readiness for innovation, the linkage component is another distinguishing component of MDDDII. It covers the nature and timing of the development of links between the potential adopter and other players involved in the innovation. Shared meanings and mission, effective knowledge transfer, user involvement in specification, capture of user-led innovation, communication and information, user orientation, product augmentation and project management support are examples of determinants within the linkage component (Greenhalgh et al. 2004). MDDDII highlights that if the technology developers capture and integrate adopters' view regarding technology development, the technology is more likely to be adopted.

Prospective users of technology, such as farmers might have gained knowledge from farming experience. Therefore, technology manufacturers or research scientists should communicate with prospective users while developing new technology. As farmers are the users of the technology, they know how easy and useful existing technology is. Based on their feedback, technology manufacturers can expand their products.

Assimilation is another critical aspect of MDDDII. New technology is assimilated in the organisation such as agricultural enterprise, by the team, or by the department. Assimilation of technology is a complex and nonlinear process.

The implementation process component of MDDDII looks similar to the implementation component of Rogers's DOI theory, but the implementation process component of MDDDII provides more information than the implementation component of Rogers's DOI theory. Implementation of new technology within an agricultural business is not a single-step process. It is a complex sequence of trialling, adapting and refining until the innovation can be considered to have been adopted as part of the system. Determinants such as decision-making devolved to frontline teams, a hands-on approach by leaders and managers, human resource issues (especially training), dedicated resources, internal communication, external collaboration, reinvention/development, and feedback on progress are all included under the implementation process component (Greenhalgh et al. 2004). If an organisation arranges high-quality training materials and appropriate on-the-job training, the implementation of the technology will be more likely to be effective (Gustafson et al. 2003).

Human resources is an essential aspect of technology adoption. By providing training, existing employees increase their skills, and then they feel comfortable using new technology. Similarly, communication with employees helps farm managers or growers to acquire more information in terms of ease and usefulness of new technology which have positive influences in technology adoption. Likewise, the external collaboration of agricultural enterprise provides an opportunity to share knowledge. As knowledge sharing is a dual process of questioning and contributing to knowledge, new information, ideas, techniques or technology through advising, listening and enquiring and recognizing cues (Bosua & Scheepers 2007), external collaboration could be considered an essential aspect of PA technologies adoption. Figure 2.8 below outlines the components/determinants of MDDDII and their interaction in technology adoption.

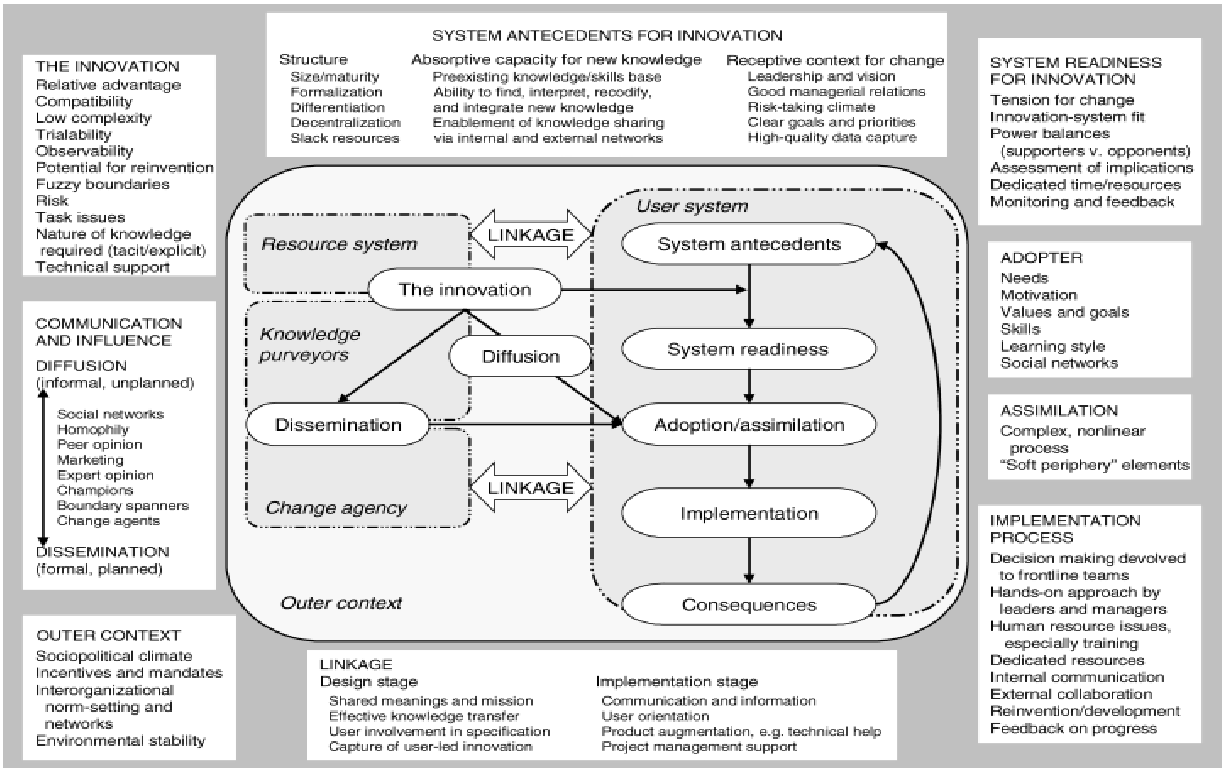

Figure 2.7: The model of determinants of diffusion, dissemination and implementation of innovations

Source: Greenhalgh et al. (2004)

MDDDI outlines and measures the technology adoption in organisations and examines the literature in an organised and reproducible way so as to identify the approach to spread and sustain innovation in an organisation. Undeniably, MDDDII reflects the distinct features of a multifaceted situation and their numerous connections that could contribute to PA technologies adoption.

2.9 Conclusions

While it is generally accepted that there are a large number of determinants that influence PA technologies adoption, there is no single set of determinants that uniquely predict adoption. Each context and approach of the technology adoption process is likely to be impacted by a diversity of factors. Therefore, the identification of technology adoption influencing factors is important to understanding the PA technologies adoption process.

MDDDII is considered a powerful tool to understand PA technologies adoption in Australia due to its unique features. For example, MDDDII helps to understand a complex technology adoption process and has expanded Rogers' DOI theory by adding more determinants in the innovation component and the communication and influence component. It also includes background features of the organisations and their willingness to adopt technology and provides a lens to study how technologies are adopted within an organisation, such as an agricultural enterprise.

The analysis of the PA technologies adoption literature is essential in this thesis because the findings of the PA technologies adoption literature allow comparison with the outcomes of the case studies and the reports, and the strategic plans of the RDCs. The outcome of the comparison could be helpful in addressing why is there such a gap between expectations of certain stakeholders (such as researchers, research funders, and policymakers) relating to the adoption of PA technologies and actual adoption rates in Australia.

PA technologies adoption literature are based on scientific methods which report original, empirical, and theoretical work. This literature is exceptionally credible and provides evidence of their claims. PA technologies adoption literature includes a large number of components/ determinants that influence practice change in agriculture. Similarly, this literature includes several models/theories of technology adoption, which report how several factors influence the behaviour of farmers in terms of technology adoption, such as PA technologies. The following chapter (Chapter 3) includes the methodologies to examine PA technologies adoption literature (academic literature) and the Australian grey literature so as to meet the objectives of this thesis.

3 CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

This thesis explored different models/theories of innovation/technology adoption in Chapter two, and across the various models/theories, the model of determinants of diffusion, dissemination and implementation of innovations (MDDDII) was found to be potentially the most comprehensive framework for understanding the technology adoption process.

As this thesis reviews both PA technologies adoption literature (academic literature) and the Australian grey literature (the case studies and the reports, and the strategic plans of RDCs), this chapter broadly outlines the methodology used to identify which components/determinants of MDDDII are present/absent in PA technologies adoption literature and also in the Australian grey literature. Identification of these components/determinants could be useful to understand PA technologies adoption process in Australia.

Quantitative and qualitative research methods were separately used for this research to understand PA technologies adoption and to acquire a deeper insight into the nature and determinants of adoption. This chapter is organised into two parts to reveal the rationale and process of the research design. Part one outlines the methodology related to the procedural steps for a systematic literature review regarding PA technologies adoption literature. Part two presents the main methods and scholarship behind the thematic analysis of the case studies and the reports, and the strategic plans of RDCs around PA technologies adoption.

3.2 Research methodology

Research methodology is decided by the characteristics of the research question as well as the subject being examined (Denim & Lincoln 2005). This thesis used data available from the academic literature and the Australian grey literature (Australian case studies and the reports, and the strategic plans of the RDCs), and then addressed the following research questions:

1. Which components/determinants of MDDDII are/are not recognised in PA technologies adoption literature?

2. Which components/determinants of MDDDII are/are not recognised in the case studies and the reports, and the strategic plans of the RDCs?

This thesis uses a systematic review method to address research question one. In this thesis, the systematic review method includes studies that have numerical data. By using systematic review method, this thesis collected the information regarding the background of selected publications, such as year of publication, the country in which the research was conducted, tools of PA technologies and agricultural industries. In addition, this thesis identified the frequency of components/determinants of PA technologies adoption within selected publications in the second task.

For research question two, quantitative and qualitative research methods were used separately. A quantitative research method was used to understand the background of the case studies and the reports, and the strategic plans of the RDCs, for example, year of publication, tools of PA technologies and agricultural industries. These data were extracted manually. Additionally, a qualitative research method was also used to understand the way in which PA technologies adoption occurs, what may be influencing this, and how the relevant Australian grey literature discusses PA technologies adoption. As quantitative and qualitative research methods applied in this thesis provide different information, these methods are not integrated.

3.3 Quantitative research method

Quantitative research methods are suitable for collecting numerical data and exposes, for example, what percentage of the farmers adopt PA technologies, their distribution by age, marital status, education level, income, location of publications, year of publications, and tools of PA technologies. This thesis sought to explore the background of PA technologies adoption literature and the components/determinants of MDDDII that are/are not recognised in PA technologies adoption literature. Therefore, a quantitative research method is useful to meet this objective. As quantitative data are more objective and scientific (Crowther & Lancaster 2008), the outcomes of the research are more reliable.

Using a different set of keywords in three databases (Scopus, Web of Science, and CAB Abstracts), much PA technologies adoption literature was identified in a systematic review. The date of publication was restricted to 2000 to 2018. This thesis filtered publications as per predefined criteria. Then, the background of the publications, such as the location of publications, year of publications, agricultural industries, and tools of PA technologies were extracted manually. Similarly, the components/determinants of MDDDII included in each of the selected publications were also extracted manually. Figure 3.1 below outlines the research process in the systematic review of the PA technologies adoption literature.

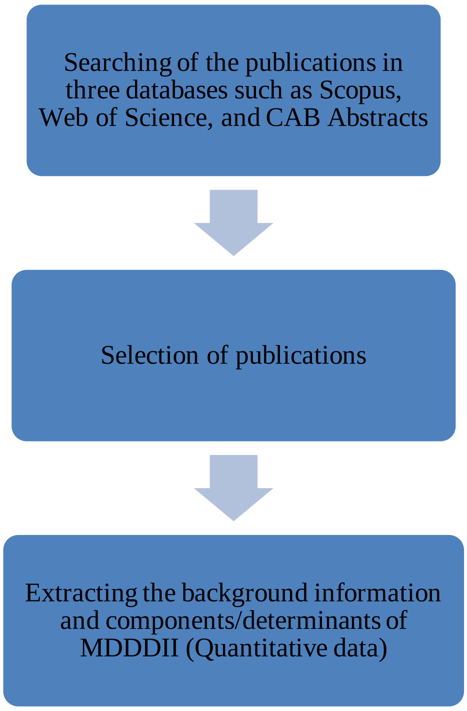

Figure 3.1: Research process in the systematic review of the PA technologies adoption literature

There were two sets of quantitative data in this thesis. The first set of quantitative data was extracted from the PA technologies adoption literature (as discussed above). It is mentioned above. Another set of quantitative data was extracted from the Australian grey literature.

Using a number of keywords in a Google search and homepages of industries/RDCs, the case studies and the reports, and the strategic plans of the RDCs (the Australian grey literature) were collected. These documents (case studies and the reports, and the strategic plans of the RDCs) were restricted to the years between 2000 and 2018 and were relevant to PA technologies adoption in Australia. The frequency of papers that covered a year of publication, agricultural industries and tools of PA technologies are quantitative data in this research. Figure 3.2 below outlines the quantitative data collection process in the Australian grey literature.

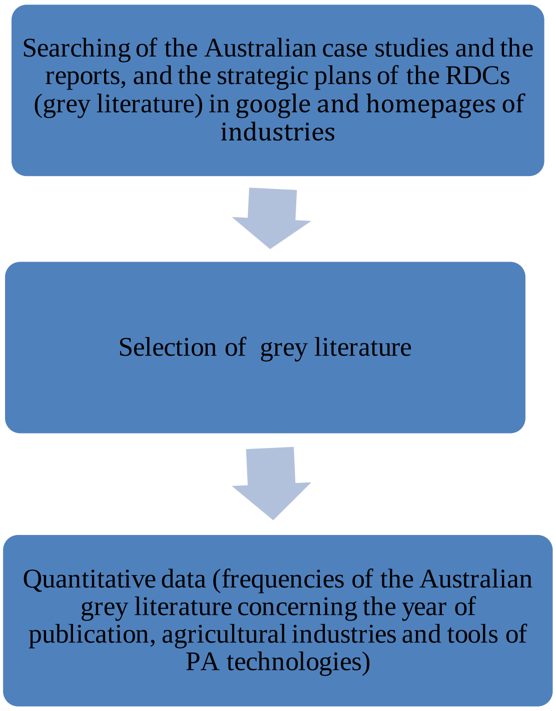

Figure 3.2: Quantitative data collection process in the Australian grey literature

3.4 Qualitative research method

A qualitative research method is used to study about dispersed information within texts and documents, for example, government reports, and articles available on the websites (Hammarberg, Kirkman & de Lacey 2016). As this research sought to acquire PA technologies adoption information from the case studies and the reports and the strategic plans of the RDCs, the qualitative research method was applied. Common themes in the Australian grey literature are qualitative data in this research, and these themes are identified using thematic analysis.

Purposive sampling was used for this research to focus on particular characteristics of the Australian grey literature, such as published between 2000-2018 in Australia, and covered PA technologies adoption process, which would best enable answering the research question. There was a range of potential biases that needed to be addressed-not least of which is the selection and data extraction biases, which are addressed in section 3.6.5 below. Importantly, to support the rigour of the work, several strengths and limitation were considered in identifying the answer to research question 2. The Australian grey literature were selected based on the key topics of adoption and those that can be learnt the most from in understanding the features and determinants of MDDDII. The data that was generated was analysed and presented in Chapter five was not as a measure of adoption, but rather as a method to advance the understanding of the adoption mode and its application to PA technologies.

Using different keywords in Google search and industry/RDCs websites, a number of reports to the House of Representatives Standing Committee (HRSC) on Agriculture and Industry (Australian Dairy Farmers 2015; Australian Pork Limited 2015a; Department of Agriculture and Water Resources 2015; Grains Research and Development Corporation 2015), and also industry reports (Grain Research and Development Corporation 2016; Grains Research and Development Corporation 2013; Llewellyn & Ouzman 2014), and case studies (Precision Agriculture 2014), and the strategic plans of the RDCs were searched. Figure 3.3 below outlines the qualitative research process in the Australian grey literature.

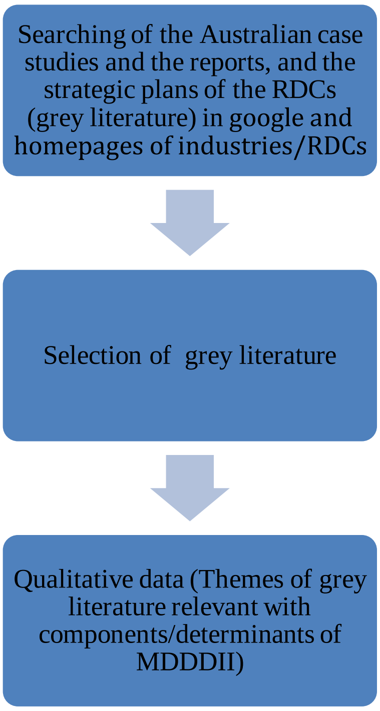

Figure 3.3: Qualitative research process in the Australian grey literature

3.5 PART ONE: SYSTEMATIC LITERATURE REVIEW METHOD

3.5.1 Introduction

Given the complexity and multidimensional nature of the adoption process, it is not surprising that PA technologies adoption studies examining only some of the many interacting factors have tended to produce variable and often conflicting findings. Therefore, another review of the literature was required to synthesise the body of published literature on the process of PA technologies adoption within a theoretical framework of MDDDII.

A systematic literature review offers a precise and transparent structure of the literature, which synthesises the results of multiple previous studies (Mallett et al. 2012). As a systematic review uses a logical and reliable methodology to identify and synthesise research results of large and complex bodies of research literature, it is an important scientific research approach.

Many authors (De Vries, Bekkers & Tummers 2016; Knoll et al. 2018; Schroeck et al. 2019; Uman 2011) used systematic reviews in their research study. Knoll et al. (2018) stated that a systematic review includes several steps, for example, formulation of research question, development of a research protocol, searching of literature, critical appraisal, extraction of data, and analysis of data and findings. However, there is also another approach known as PRISMA (preferred reporting items for systematic reviews and meta-analyses) which provides guidelines to conduct a systematic review (Moher et al. 2009). This approach was developed by a group of 29 clinicians, medical editors, review authors, methodologists and consumers after attending three days of meeting in 2005 (Moher et al. 2009). PRISMA contains seven topics (title, abstracts, introduction, methods, results, discussion, and funding) and 27 statements within these topics. Similarly, it also contains a four-phases flow diagram: 1) identification of publications in databases, 2) screening the title and abstracts of potentially relevant publications, 3) eligibility of the publications based on predefined criteria, and 4) final selection of publications for analysis (Liberati et al. 2009). As the PRISMA approach contains a large number of statements, and improves the reporting of the systematic review, it is commonly used in systematic review of academic literature. Therefore, this thesis also applies the PRISMA approach to conduct a systematic review of PA technologies adoption literature. However, three topics of PRISMA (title, abstracts and funding) are not suitable to describe here because it is beyond the scope of the current study.

3.5.2 Research question formulation

All of the PA technologies adoption literature includes a different set of factors that influence PA technologies. However, a systematic review synthesises the results of multiple previous studies and provides a definite answer on a research question. This thesis has framed a well-defined research question by using the PICO (population, intervention, comparison, and outcome) framework (Eldawlatly et al. 2018). The research question for systematic review is, Which components/determinants of MDDDII are/are not recognised in PA technologies adoption literature?

3.5.3 Methods

3.5.3.1 Research protocol development

The research protocol includes criteria as to whether to include the publications in the review, for example, peer viewed journal articles published between 2000 to 2018. Likewise, data were extracted manually following a review of each full publication and were collated into a spreadsheet designed for this systematic review. Finally, the frequency of publications published in specified years, the frequency of most discussed technologies, and agricultural industries were counted manually. Likewise, the occurrence of components/determinants of MDDDII were also counted manually and presented in a table.

3.5.3.2 Eligibility criteria

The title and abstracts of each of the publications were examined, and these were either included or excluded from further analysis based on the following criteria:

i. Was the study peer-reviewed?
ii. Was the study in English?
iii. Was the study published between 2000 and 2018?
iv. Was the research in the study relevant to PA technologies?
v. Did the study address the rate of adoption or adoption process in the context of PA technologies?

3.5.3.3 Literature search

A systematic literature search was conducted on 31 December 2018 and used three databases: Scopus, Web of Science, and CAB Abstracts. Two broad groups of keywords in the areas of 'Precision agriculture' (Group 1) and 'Practice change' (Group 2) were formed to capture relevant studies for the systematic review. The studies within the two groups were then combined to capture all the studies that dealt with the factors that influence the adoption of PA technologies. Table 3.1 below outlines the number of studies identified in Scopus, Web of Science and CAB Abstracts databases.

Table 3.1 Number of studies identified in the three databases per search term used.

Group	Keywords	Scopus	Web of Science	CAB Abstracts
'Precision agriculture'	Precision agriculture	4736	3230	2089
	Precision farming	1531	1800	1276
	Site specific agriculture	2911	1801	2088
	Site specific farming	1139	1979	1293
	Variable rate technology	7619	4824	1461
	GPS guidance	1110	670	46
	GPS autosteer	3	1	2
	Remote sensing	113956	59029	16855
	Agricultural robots	848	302	244
'Practice change'	Adoption	118506	80422	8818
	Diffusion of innovation	18545	7954	453
	Agricultural extension	7048	2998	10097
	Practice change	198821	137696	13235

Table 3.2 below outlines the number of studies identified after combining the keywords.

Table 3.2 Search results of keyword combinations

Group	Keywords combinations	Scopus	Web of Science	CAB Abstracts
'Precision agriculture'	Precision agriculture OR Precision farming OR Site specific agriculture OR Site specific farming OR Variable rate technology OR GPS guidance OR GPS autosteer OR Remote sensing OR Agricultural robots	130640	70851	21291
'Practice change'	Adoption OR Diffusion of innovation OR Agricultural extension OR Practice change	331760	220715	29834
Combined		2469	1944	633

Scopus, Web of Science, and CAB Abstracts searches produced a total of 130640, 70851 and 21291 journal articles, respectively, in the first search term group and 331760, 220715 and 29834, respectively, in the second group. After combining the keywords in the first group with the combination of keywords in the second group, 2469, 1944 and 633 journal articles were identified from Scopus, Web of Science, and CAB Abstracts databases, respectively.

Only journal articles meeting the above-mentioned eligibility criteria were selected for analysis. Of the journal articles from Scopus, 45 of 2469 studies were included, whereas 32 of 1944 studies from Web of Science, and 20 of 633 studies from CAB Abstracts met the inclusion criteria. After removing duplicates and triplicates of publications, 58 PA technologies adoption publications were left for analysis in this systematic review.

In this study, a keyword search was used to identify the relevant research articles for the systematic review. Other studies (De Vries, Bekkers & Tummers 2016; Green et al. 2019; Greenhalgh et al. 2004; Koekkoek, Panteleon & van Zanten 2019; Tey & Brindal 2012; Thomsen et al. 2019) also applied keyword search to identify relevant research journal articles. Effective keyword search has a higher chance of including many studies that are relevant to the specific research topic. For example, while using a keyword 'Precision agriculture' in the Scopus database on 31 December 2018, the keyword search provided 4736 publications (see table 3.1 above).

In addition, literature can be identified using a citation and reference tracking method. This method of literature search starts from key studies either in Scopus or Web of Science database. These databases helped to identify which studies have cited the key studies and also identified which studies were cited and referenced by those key studies. Similarly, these databases also helped to identify the published document from the authors of key studies.

Citation and reference tracking methods provided a large number of publications which may or may not be relevant to PA technologies adoption. However, when deciding whether to include or exclude the searched publications in the systematic review, it is necessary to read the abstracts or the full publications. As the present study has limited scale and time, the citation and reference tracking method was found unsuitable to be used to search PA technologies adoption literature in this case.

3.5.3.4 Data extraction

As a first task, the backgrounds of the 58 selected studies were reviewed. Six parameters of the studies were recorded: publication year, authors, bibliographic publication details, a country in which the research was conducted, PA technologies, and industries examined in the study (details of selected publications are given in appendix A).

As a second task, the components/determinants of MDDDII that were described in each of the publications were identified. Data were extracted manually following the review of each full publication and were collated into a spreadsheet designed for this systematic review. Accuracy of the extraction process was verified independently by two of the supervisors, and if discrepancies were identified, they were solved by discussion.

3.5.3.5 Risk of bias in individual studies

The findings of a systematic review rely on data from other studies (Drucker, Fleming & Chan 2016). Therefore, the outcomes of the systematic review are only useful when it is free from bias. Each study included in the systematic review was evaluated very carefully to minimise the bias. The selection criteria of the publications and the process were cross-checked by the supervisors to ensure the systematic review process was valid.

Publication bias could be a bias in the systematic review. Drucker, Fleming and Chan (2016) mentioned that there would not be a bias in a systematic review toward positive findings if the research includes published and statistically significant data. This research study used peer-reviewed published studies since published studies should be of higher methodological quality than grey literature. Likewise, Hartling et al. (2017) revealed that in most situations, the influence of including unpublished studies in the outcomes of a systematic review was small. Besides, the analysis of four studies (Burdett, Stewart & Tierney 2003; Egger et al. 2003; Fergusson et al. 2000; McAuley et al. 2000) conducted by Hopewell et al. (2007) disclosed that published literature was more valuable than grey literature as a source of data in a systematic review. This research used only published literature in the systematic review so that the outcomes of the systematic review would be more accurate for understanding PA technologies adoption.

3.5.4 Results

The results section included the characteristics of the studies, classification of technologies, study location, and classification of the agricultural industry. The frequency of publications published in specified years and location, the frequency of most discussed technologies and agricultural industries within selected publications were counted manually and are presented graphically. In addition, the occurrence of components/determinants of MDDDII were also counted manually and are presented in a table. The outcomes of the systematic review of PA technologies adoption literature are discussed in detail in chapter four.

3.6 PART TWO: CASE STUDIES AND THE REPORTS, AND THE STRATEGIC PLANS OF THE RDCS

3.6.1 Introduction

Although the Australian Government has invested heavily in RD&E, the PA technologies adoption in Australia has been slower than desired. However, the adoption rate is different for each PA technology. For example, a survey conducted by the GRDC found that the national average adoption of yield mapping was 13.5%, 21.8%, and 29% of the cropped area in 2008, 2011, and 2014 respectively (Umbers, Watson & Watson 2015). Further, an agriculture technology survey conducted by GrainGrowers Limited in 2015 showed that 16.56% of the respondents had adopted variable rate fertiliser application and 14.7% of the respondents had adopted satellite imagery (GrainGrowers Limited 2017). Therefore, it is essential to understand what factors can influence PA technologies adoption in Australia.

Many organisations provide precision agriculture technologies services in Australia. For example, Precision Agriculture, Precision Ag Solutions, and Precision Agronomics Australia assist farmers to take advantage of precision agriculture technologies. Precision Agriculture is a leading service provider of PA in Australia (Precision Agriculture 2016). It has employed PA specialists who assist farmers to collect and interpret field data. Likewise, Precision Agriculture also develops a plan to address a farmer’s concerns. Thus, it plays a significant role in agricultural extension.

The Australian Government is supporting the uptake of PA technologies in various ways. In 2015 the House of Representatives Standing Committee asked universities, government departments, research centres, and industry groups to submit reports on an inquiry into agricultural innovation aiming to improve the efficiency and productivity of the agricultural sector in Australia. Similarly, the Australian Government invests a big amount in protecting natural resources through different departments such as the Department of Agriculture and Water Resources, and the Department of Environment and Energy (Department of Agriculture and Water Resources 2017b). The Australian Government has also invested a considerable amount of money in promoting PA technologies adoption. The Australian Government allocated $134 million under the Smart Farms (Smart Farms runs over six years from 2017-18 to 2022) to promote the expansion and uptake of best practices, tools, and agricultural technologies (Department of Agriculture and Water Resources 2019). Thus, the support of the Australian Government influences PA technologies adoption.

There are 15 RDCs of which five are commonwealth statutory bodies, and 10 are industry-owned companies (Department of Agriculture and Water Resources 2017a). Wine Australia (WA), Cotton Research and Development Corporation (CRDC), Fisheries Research and Development Corporation (FRDC), Rural Industries Research and Development Corporation (RIRDC trading as AgriFutures Australia), and Grains Research and Development Corporation (GRDC) are commonwealth statutory bodies (Department of Agriculture and Water Resources 2017a). In contrast, Australian Egg Corporation Limited (AECL), Australian Livestock Export Corporation Limited (ALECL/LiveCorp), Australian Meat Processor Corporation (AMPC), Australian Pork Limited (APL), Australian Wool Innovation Limited (AWIL), Sugar Research Australia Limited (SRA), Dairy Australia Limited (DAL), Horticulture Innovation Australia Limited (HIAL), Meat and Livestock Australia (MLA), and Forest and Wood Products Australia (FWPA) are industry-owned companies (Department of Agriculture and Water Resources 2017a). These RDCs invest in RD&E to enhance the profitability of the Australian growers.

While the published information in Australia provides a reasonable assessment of the status and potential of PA technologies adoption, to date there has been inadequate research that explores explicitly the components/determinants of PA technologies use by farmers in Australia. With such a diverse and extensive land mass used for agriculture production, the case studies and the reports, and the strategic plans of the RDCs are important sources of information for exploring and understanding the components/determinants of MDDDII that are considered most influential to PA technologies adoption in Australia.

This thesis kept the examination of the Australian grey literature under its part two which has the following research question: Which components/determinants of MDDDII are/are not recognised in the case studies and the reports and the strategic plans of the RDCs? Understanding of components/determinants of MDDDII in the Australian grey literature facilitates the identification of opportunities to improve adoption rates of PA technologies in Australia.

3.6.2 Searching of literature

Using some keywords in Google search and homepages of industries, the case studies, reports and the strategic plans of the RDCs are collected. These documents (the case studies, reports and the strategic plans of the RDCs) were restricted to the years between 2000 and 2018 and were relevant to PA technologies adoption in Australia.

The keyword, 'Agricultural innovation' was used in a Google search which provided the webpage of the Parliament of Australia. The webpage contained 116 reports, and 16 supplementary reports submitted by universities, government departments, research centres, and industry groups to the House of Representatives Standing Committee (The Parliament of the Commonwealth of Australia 2015). However, only 20 out of 116 reports discussed PA technologies adoption influencing factors. Thus, this thesis selected this 20 reports for analysis.

Further, the keywords 'Adoption', 'Precision agriculture', and 'Agricultural innovation' were used on the webpage of the GRDC, and then these keywords generated five useful reports for analysis. Similarly, the term 'Precision agriculture' was used in a Google search which led to the webpage of PrecisionAgriculture.com.au. The webpage provided six case studies related to various tools of PA technologies used in rice production.

The RD&E plans of Australian RDCs were extracted from the websites of each RDC. Three of the RDCs: the Australia Meat Processor Corporation, Forest and Wood Product Australia Limited, and the Fisheries Research and Development Corporation, were excluded from the analysis as their industry focus, technology base, and investment strategy diverged significantly from the land-based agricultural crop and livestock production systems represented by the remaining 12 RDCs. This research study analysed the RD&E strategies of 12 RDCs in Australia between 2012 and 2017. Table 3.3 below outlines the number of the RDCs, keywords and outcomes.

Table 3.3 List of RDCs, keywords, and outcomes

RDCs	Keywords	Outcomes
RIRDC	'R& D Plan'	Strategic R&D Plan 2017-2022
GRDC	'R& D Plan'	Strategic Research & Development Plan 2012-17
CRDC	'R& D Plan'	Strategic R&D Plan 2013-2018
WA	Acquired the strategic plan directly from homepage without using any keyword	Strategic Plan 2015-2020
AECL	Acquired the strategic plan directly from the homepage without using any keyword	Strategic Plan 2017-21
ALECL	'Strategic Plan'	Strategic Plan 2016-2020
MLA	'Strategic Plan'	Strategic Plan 2016 - 2020
APL	'Strategic Plan'	Strategic Plan 2015-2020
AWIL	'Strategic Plan'	Strategic Plan 2016/17 to 2018/19
SRA	'Strategic Plan'	SRA Strategic Plan 2017/18-2021/22
DAL	Acquired the strategic plan directly from the homepage without using any keyword	Strategic Plan 2016/17 to 2018/19
HIAL	Acquired the strategic plan directly from the homepage without using any keyword	Strategic Plan 2016

Copies of each RDCs planning document relating to the strategy for investment and management of their RD&E portfolio were found via web searches. A search using a keyword 'R&D Plan' in the homepage of each of RIRDC, GRDC, and CRDC identified their strategic R&D plans. Likewise, the keyword 'Strategic Plan' on the home page of each of ALECL, MLA, APL, AWIL and SRA identified the URL for the strategic plans of the RDCs, while direct links to strategic plans were found on the home pages of WA, DAL, HIAL, and AECL.

RD&E strategies of RDCs used in the analysis were current, but with commencement dates over the years between 2012 and 2017. Finally, a total of 43 Australian grey literature was collected for analysis.

3.6.3 Data extraction

The backgrounds of the 43 selected Australian grey literature was reviewed at the preliminary stage. The frequencies of three parameters of the papers: year of publication, agricultural industries, and tools of PA technologies were counted.

As a second task, the main themes of the selected papers were identified by using thematic analysis, and these themes were compared with the components/determinants of MDDDII to identify which components/determinants of MDDDII are/are not recognised in selected papers.

3.6.4 Data analysis

By using thematic analysis, themes or patterns of meaning within the case studies and the reports, and the strategic plans of the RDCs were identified, analysed, and interpreted. Six phases of thematic analysis: 1) familiarizing with data, 2) generating initial codes, 3) searching for themes, 4) reviewing themes, 5) defining and naming themes, and 6) producing the report (Braun & Clarke 2006), was applied to identify the patterns of meaning within the Australian grey literature.

Phase 1: Familiarising with data

The preliminary step was to read and re-read the papers to acquire an overall understanding of what the papers are discussing about (Erlingsson & Brysiewicz 2017). Each of the Australian grey literature was read several times to acquire overall understanding of their content.

The RD&E strategies of each of the RDCs covered the full spectrum of governance, management, and strategy planning. Therefore, only the sections considered directly relevant to agricultural development and extension plans/strategies were taken as useful information. Next, the content of the case studies and the reports, and the strategic plans of the RDCs was condensed by retaining the core meaning.

Phase 2: Generating initial codes

Data were coded manually using a highlighter to take notes on the text. For example, innovation process, agricultural innovation, innovative product, new technology, emerging technology, robotic technology, digital technology, genetic technology, agricultural technology, role of technology, insect technology, and improved technology are different codes used in the Australian case studies and the reports, and the strategic plans of the RDCs. The occurrence of PA technologies relevant words within the case studies and the reports, and the strategic plans of the RDCs were counted. Any word relevant to PA technologies adoption which was frequently used in the text, was considered as an initial codes (keyword). The list of keywords (initial codes) are given in appendix B. When codes were mentioned in the executive summary, table of contents, and footer and header of the reports, these were not counted because they neither provide a new insight nor any specific meaning, and only increase the word count.

Phase 3: Searching for themes

By combining the initial codes within the same field, the initial themes were identified. For example, the initial theme, 'technologies' was searched by combining other initial codes such as new technology, emerging technology, robotic technology, digital technology, genetic technology, agricultural technology, role of technology, insect technology, and improved technology.

Phase 4: Reviewing themes

The text was re-read and checked whether the initial themes had common content. Then, the initial themes were refined. For example, the innovation, adoption, technologies, benefits, precision agriculture, controlled traffic farming, costs, production and profitability were various initial themes, but they were similar through their content. Therefore, these initial themes made one overarching theme, for example, 'agricultural innovation'.

Phase 5: Defining and naming themes

Each of the overarching themes was defined, and it was also explained how these overarching themes contributed to understanding the data. For example, 'agricultural innovation' is one of the overarching themes identified within the Australian grey literature. So, it was defined as the ideas, new knowledge, or technology used in the agricultural industry to increase production and minimise cost.

Phase 6: Producing the report

Finally, the report was produced and was reviewed. The report was written as a concise, clear, reasonable, and accurate account of the story and contained adequate proof with enough examples from the data.

3.6.5 Risk of bias in studies

This thesis used a number of strategies to minimise the bias in the outcomes. First, supervisors were used to discuss the validity of the resources for thematic analysis, and any differences or incongruent themes were discussed until consensus was reached. Second, sampling was purposeful over a specific time frame with specific keywords to define the type of research being examined. Finally, the research was presented in a way that included patterns of meaning within the Australian grey literature which provided the best possible interpretation in terms of PA technologies adoption. This research collected government reports, industry specific reports, case studies and the strategic plans of the RDCs. These documents contained reliable information.

3.7 Conclusions

In the systematic review of PA technologies adoption literature, data were extracted manually following review of each full publication and were collated into a spreadsheet designed for this systematic review in order to review it critically. Bias in an individual publication was minimised using several techniques, such as using scientific literature only and cross checking with the supervisors to confirm the systematic review process was valid.

The case studies and the reports and the strategic plans of the RDCs were identified using several keywords in a Google search and industries webpages. The data was collected in order to understand and explore the ways in which features of the MDDDII may present in industry and government related discussion of PA technologies adoption. The next chapters present the results of the systematic review of PA technologies adoption literature.

4 CHAPTER FOUR: DATA ANALYSIS AND RESULTS OF THE SYSTEMATIC REVIEW

4.1 Introduction

The methodology presented in chapter three described the overall structure and process of analysis and review for selected PA technologies adoption literature. This chapter presents the results of the systematic review in two ways. Firstly, this chapter reviews the characteristics of the studies, including year of publication, study location, classification of PA technologies, and classification of the agricultural industries. The frequency of publications published in specified years and location, the frequency of most discussed technologies, and agricultural industries within selected publications were counted manually and are presented in a bar diagram.

Secondly, using MDDDII as a framework, the number of components and determinants influential in the adoption of PA technologies are identified and explored from the selected 58 publications. Then, the frequency of the components/determinants of MDDDII in selected publications are tabulated.

4.2 Part 1: Data analysis and results of the systematic review

4.2.1 Characteristics of the studies

This thesis analysed a total of 58 articles published until the end of December 2018. The number of publications relevant to the systematic review topic fluctuated over the target period. No relevant publications were published in 2000, 2002 and 2006, and only one to four publications per year fitted the selection criteria used in the review between 2001 and 2008 (except 2002 and 2006). This number increased to a maximum value of nine publications in 2014, followed by seven publications in each of the years 2016 and 2010.

Based on the keyword search and pre-defined selection criteria of publications mentioned in Chapter three, it can be seen in Figure 4.1 that PA technologies adoption research was lowest in 2001 and 2017. There might be more publications published in 2001 and 2017, however, the keyword search process used in this thesis may not capture those publications. Much PA technologies adoption research could have been conducted in 2001, and 2017, but PA technologies adoption researchers perhaps did not publish these research within that period.

Specifically, the rate of technology development and innovation in agriculture can be seen to rapidly change and develop across various existing practice and products, as well as the form of innovation, whether biotech or mechanical or agronomic processes (Sunding & Zilberman 2001). As such, there could be many changes in the development of PA technologies and many PA technologies adoption research studies were conducted after 2009. The following bar diagram (Figure 4.1) shows the number of publications published from 2000 to 2018 and also presents the list of countries where the studies were conducted.

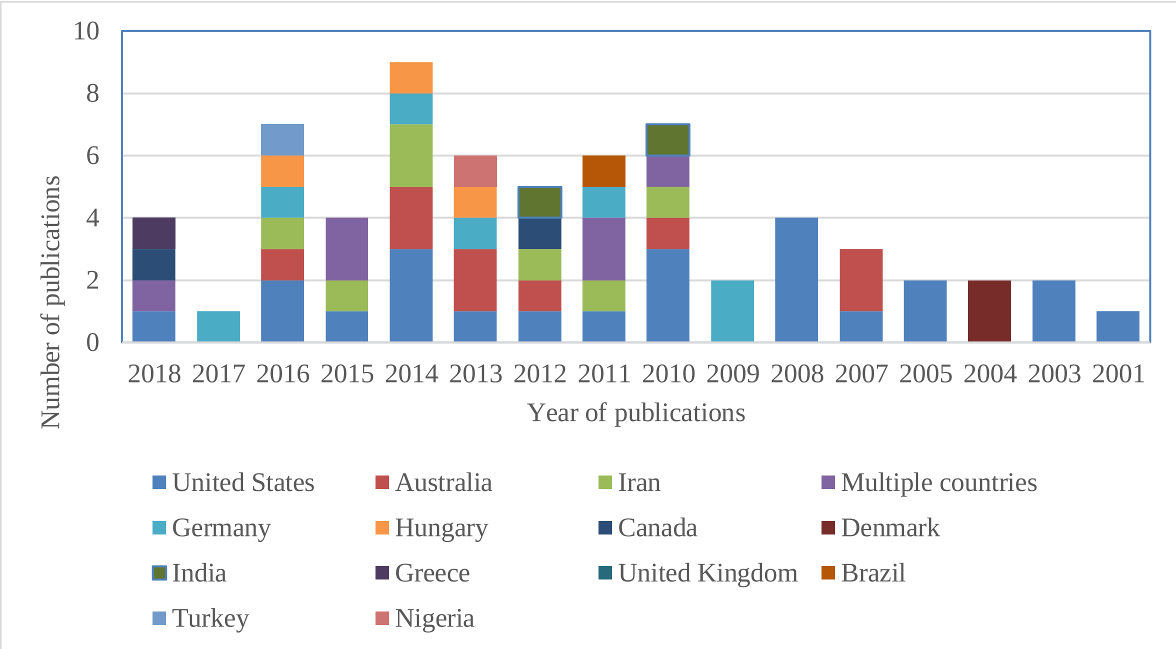

Figure 4.1 Number of publications published per year meeting selection criteria of the systematic review

The primary location where studies were conducted was the United States, with 37.9% of all selected publications describing technology adoption in the United States agricultural industries. The United States has the most papers on PA technologies adoption because it is a large country with large population of scientists and national entities seeking to promote the productivity and efficiency of the agricultural industry. On the contrary, only a small percentage (1.7%) of PA technologies adoption studies were relevant to the agricultural industry of Greece, United Kingdom, Brazil, Turkey and Nigeria. It should be noted that 5.6% of the studies were conducted in more than one country.

4.2.2 Classification of technologies

Many technologies are identified within the selected publications; therefore, in this thesis, these technologies have mainly been divided into two groups: 1) information technologies and 2) management technologies.

4.2.3 Information technologies

Information technologies support farmers by providing information about soil, crops, livestock, weeds, insects, and diseases. These technologies are further divided into six subgroups:

i. Soil monitoring technologies, such as grid soil sampling, georeferenced soil testing, and EM38.
ii. Remote sensing, such as aerial photos and satellite imagery.
iii. Geographical information systems.
iv. Animal/plant monitoring technologies, such as mastitis detector, electronic identification, and tissue sampling.
v. Yield mapping, such as yield monitoring.
vi. Bundle of technologies, such as the combination of grid soil sampling and yield monitoring.

The following bar diagram (Figure 4.2) shows the distribution of publications discussing information technologies by year and technology type.

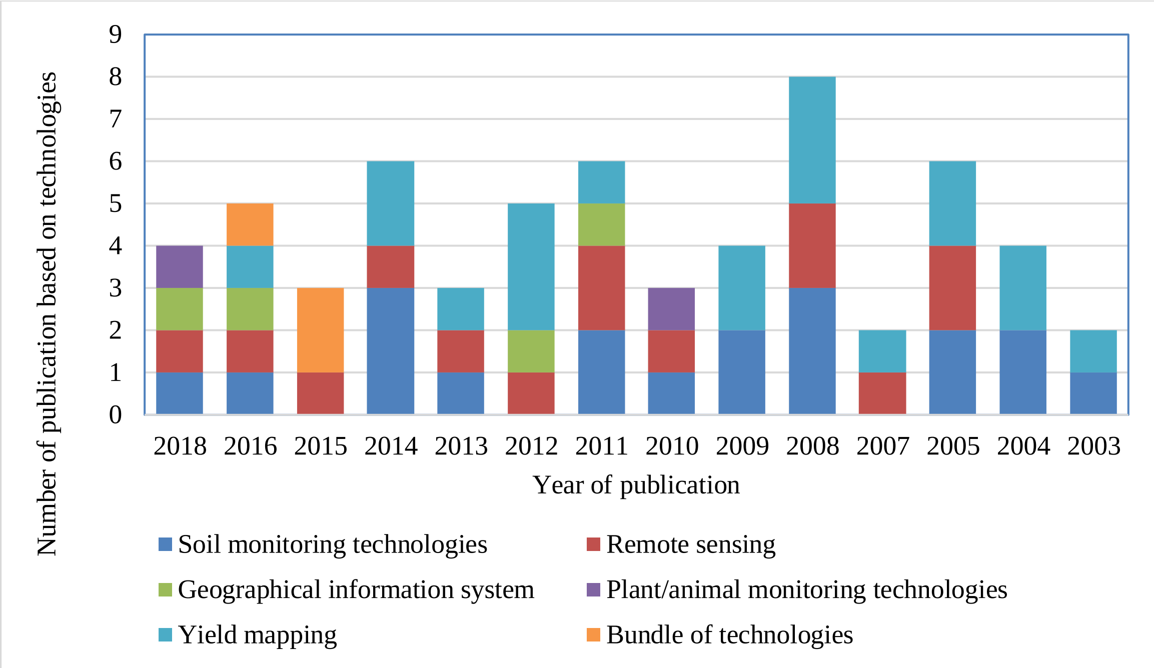

Figure 4.2 Distribution of publications discussing information technologies by year and technology type

Soil monitoring technologies, remote sensing, yield mapping, geographical information system, plant/animal monitoring technologies, and a bundle of technologies were discussed a total of 19, 14,19, 4, 2 and 3 times, respectively, and these publications were distributed throughout 2003 to 2018. Publications examining the adoption of animal monitoring technologies were not found until 2009, while the first studies focussing on bundles of information technologies were published in 2015.

Both soil monitoring technologies and yield mapping were mostly covered in the publications. As soil is the main component of the agricultural production system, information related to water status and level of nutrients in the soil are most important in crop production. PA technologies adoption researchers may like to examine the scope of soil monitoring technologies. Similarly, due to the benefits of yield mapping, such as identification of low performance area in the paddock, this technology may be researched extensively.

Plant/animal monitoring technologies, for example mastitis detector, tissue sampling, and electronic identification were not adopted until 2009. However, there could have been a number of studies conducted about plant/animal monitoring technologies before 2009, but these publications might not fit in the selection criteria of this thesis, or the research was conducted before 2009, and the papers might be published after 2009. Another possible reason could be that plant/animal monitoring technologies were not fully developed until 2009.

4.2.4 Management technologies

Management technologies involve systems for precision control of production inputs in farming systems. These systems often use outputs of information management technologies to guide precise input utilisation. The management technologies are further divided into three subgroups for this analysis:

i. Variable rate technologies (variable rate fertilizer/lime application, variable rate irrigation).
ii. Automation technologies (autosteer vehicles, robotic milking, automated insect traps, automated irrigation controllers).
iii. Controlled traffic farming system.

The following bar diagram (Figure 4.3) shows the distribution of publications discussing management technologies by year and technology type.

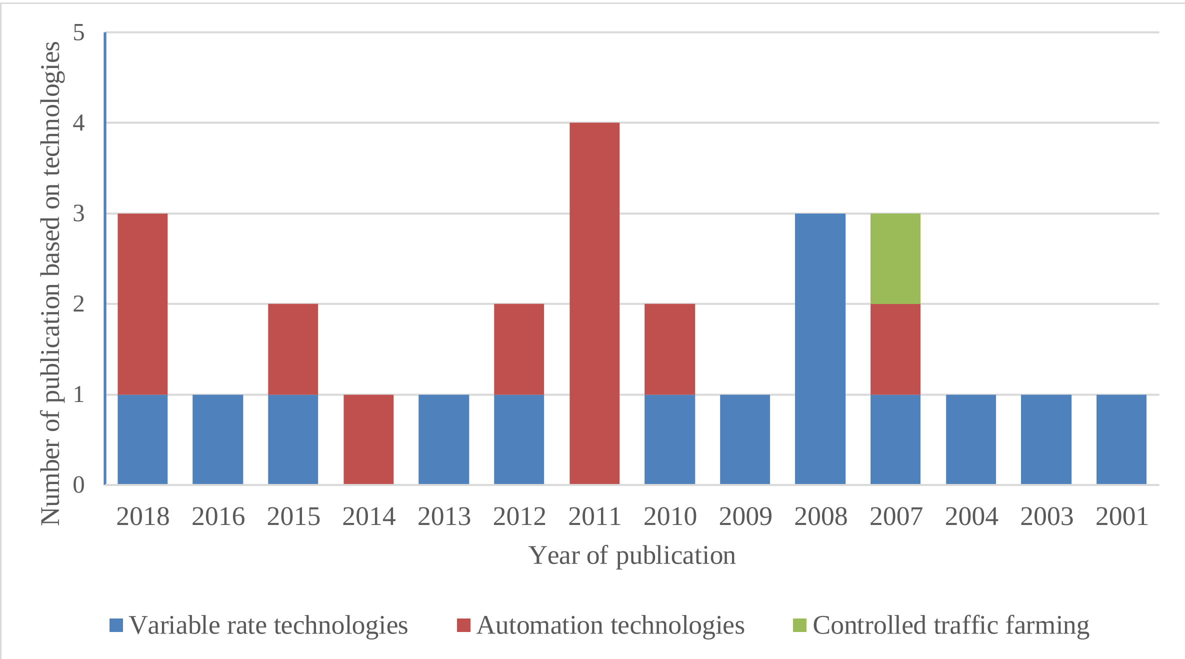

Figure 4.3 Distribution of publications discussing management technologies by year and technology type

A total of 14, 11, and one publication discussed variable rate technologies, automation technology and controlled traffic farming, respectively, and these publications were distributed over the period of 2001 to 2018. Thus, variable rate technologies dominated.

Also, the types of PA technologies examined in the selected publications changed over the study period.

Based on the above data, it can be seen that more research was conducted in terms of variable rate technologies worldwide. The possible reason could be PA technologies adoption researchers performed a quantitative assessment of the benefits of variable rate technology in different agricultural industries. However, the low frequency of controlled traffic farming (CTF) could be because of the lack of research conducted in the area of CTF worldwide. On the other hand, there might be more CTF researches conducted since 2001-2018, but the keyword search process used in this thesis did not capture those publications or the publications did not fit in the pre-defined selection criteria of this thesis.

4.2.5 Classification of the agricultural industry

There is a broad range of agricultural industries mentioned in the literature, and these were grouped as industrial crops, multiple crops, grains, livestock, tree fruit, and grape. Industrial crops is predominant followed by multiple crops in the publications. The following bar diagram (Figure 4.4) shows the year and the number of publications based on agricultural industries.

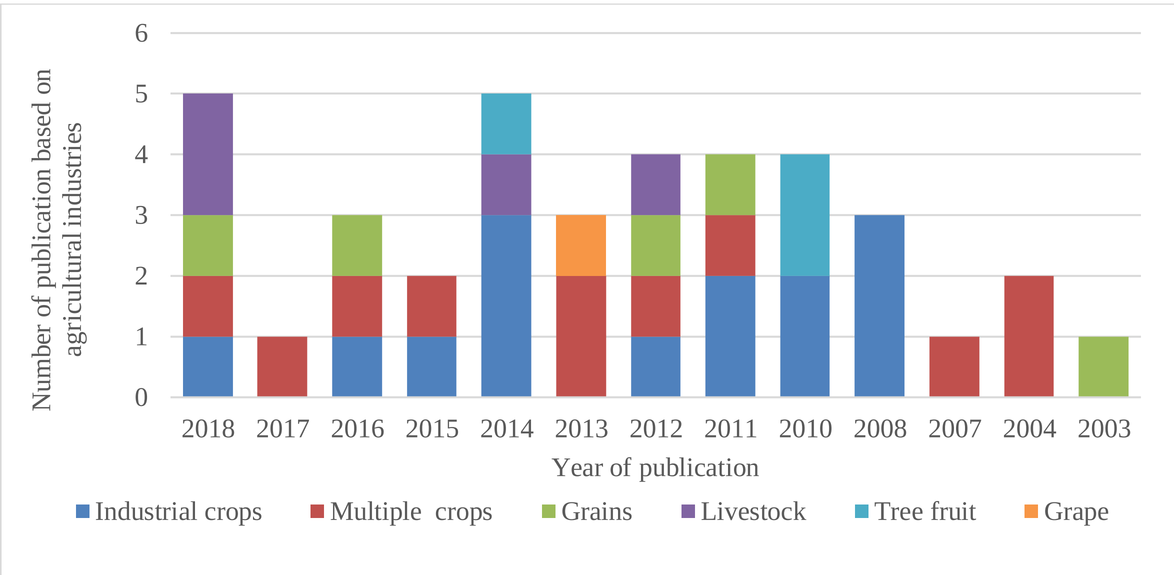

Figure 4.4 Year and number of publications based on agricultural industries

The most significant percentage of publications (5.2%) looking at industrial crops appeared in 2014. However, no publications mentioned other agricultural industries except one study of tree fruit and another study of livestock in the same year. A total of 3.4% of publications discussing multiple crops appeared in 2013 and 2004. Similarly, 3.4% of publications discussed livestock in 2018, and 1.7% of publications examined grain industries in each of the years 2018, 2016, 2012 and 2003. None of the 2009 and 2005 publications mentioned any specific types of agricultural industries. Once again, it is necessary to bear in mind that there might be more publications within the above mentioned years and agricultural industries, but the keyword search process used in this thesis did not capture those publications or the publications did not fit in the pre-defined selection criteria of this thesis.

4.3 Components/determinants of PA technologies adoption

The frequency of inclusion of components/determinants of MDDDII in the studies of PA technologies adoption was also quantified. Table 4.1 shows the number of studies that included the components/determinants of MDDDII.

Table 4.1 Number of studies that included the components/determinants of MDDDII

The Innovation	Communication and Influence	Outer Context	System Antecedents for Innovation	System Readiness for Innovation	Linkage	Adopter	Assimilation	Implementation Process
Relative advantage (51)	Social network (2)	Socio political climate (0)	Size/maturity (0)	Tension for change (0)	Shared meanings and mission (0)	Needs (0)	Complex, non-linear process (0)	Decision making devolved to frontline teams (0)
Compatibility (11)	Homophily (0)	Incentives and mandates (19)	Formalization, Decentralization (0)	Innovation system fit (0)	Effective knowledge transfer (2)	Motivation (42)	Soft periphery elements (0)	Hands on approach by leaders and managers (0)
Low complexity (9)	Peer opinion (5)	Inter organizational norm setting and networks (0)	Slack resources (0)	Power balances (Supporters vs. opponents) (0)	User involvement in specification (0)	Values and goals (0)		Human resource issues, especially training (0)
Trialability (4)	Marketing (24)	Environmental stability (0)	Clear goals and priorities (0)	Assessment of implications (0)	Capture of user led innovation (0)	Skill (30)		Dedicated resources (0)
Observability (3)	Expert opinion (29)		High quality data capture (0)	Dedicated time/ resources (0)	Communication and information (1)	Learning styles (0)		Internal communication (0)
Potential for reinvention (0)	Champions (0)		Pre-existing knowledge/skill base (0)	Monitoring and feedback (0)	User orientation (0)	Social networks (0)		External collaboration (0)
Fuzzy boundaries (0)	Boundary spanners (0)		Ability to find,		Product augmentation (0)			Reinvention/development (0)

		interpret, recodify and integrate new knowledge (0)		
Risk (0)	Change agents (19)	Enablement of knowledge sharing via internal and external networks (0)	Project management support (0)	Feedback on progress (0)
Task issue (0)		Leadership and vision (0)		
Nature of knowledge required (0)		Risk taking climate (0)		
Technical support (3)		Good managerial relations (0)		

Most of the selected publications included analysis or discussion of features related to the innovation component. The innovation component is predominant (87.9% of publications) in the studies. A systematic review of the literature also identified that the adopter component (82.8% of publications) and communication and influence component (75.9%) were included in the majority of publications. The outer context component was discussed in 32.8% of the publications, while the linkage component was included in 5.2% of the publications, respectively. However, none of the publications included four of the components of MDDDII (system antecedents for innovation, system readiness for innovation, assimilation, and implementation process).

The innovation component is most important in PA technologies adoption due to its benefits, including increased yield, higher profit, and time flexibility. Many aspects of the innovation were identified as being able to influence the adoption process. The relative advantage was analysed, inferred, or discussed in 51 publications and was the dominant determinant in the innovation component. The dominance of relative advantage could be the reason that farmers perceived that PA technologies provide more benefits than existing agricultural technology in either effectiveness or cost-effectiveness. For example, robotic milking is more efficient than milking cows by hand. Although relative advantage is a significant aspect of technology adoption, it alone does not increase the rate of PA technologies adoption. Besides, compatibility, complexity, trialability, observability and technical support were also frequently included in the selected studies.

Many studies considered the communication and influence component to have a significant role in PA technologies adoption. 58% of publications included an expert opinion determinant. Crop consultants, agricultural scientists, agricultural engineers, advisory service providers, universities, research centres, agronomists, and veterinarians are considered expert, and their opinion or suggestion is a useful source of agricultural information.

41.4% of studies considered that marketing is an essential channel of communication. Machinery dealers, manufacturers, and input suppliers might offer discounts or provide free training and technical support while marketing their technology. These activities of machinery dealers, manufacturers, and input suppliers may influence farmers' decisions to use technology, such as PA technologies.

Change agents are a person or an organisation external to the farm that supports farmers to bring about improvements and changes in a farms' effectiveness and development. The systematic review showed that 32.8% of the studies believed that change agents are essential in PA technologies adoption. Private extension personnel, agency, and contractors are considered change agents. Change agents can personally meet with individual farmers and support them by providing PA technologies information and services.

An individual, such as a farmer is a decision-maker regarding whether to accept or reject PA technologies. The decision is influenced by many factors including education level, experience, age, and income. Thus, the features of the adopter play a significant role in PA technologies adoption. Motivation and skills were the most commonly covered determinants in the adopter component. Age of a farmer, farm size, location, farm condition, the layout of the farm, and financial status are motivational factors which influence farmer use of PA technologies. Younger farmers are self-motivated and are more willing to take an alternative approach to others by using technology on the farm. Similarly, large farms purchase a large quantity of agrochemicals and acquire the benefit of economies of scale. Further, the production could be higher when the farm has fertile soil, which increases the income of the farmer, and more income means the farmer can purchase new technology.

Both managerial and technical skills are required to use PA technologies. Factors such as level of education, training, management capacity, and the work experience of a farmer could be used as indicators of skills. These factors increase farmer knowledge, and then the farmer feels more confident using PA technologies.

A few publications highlighted that the outer context component influence PA technologies adoption. Most of the publications (32.8%) included incentive and mandates determinants, such as land conservation programs and regulation, as influencing PA technologies adoption. The land conservation programs provide cost-share payments to develop and implement soil nutrient management plans. Therefore, this factor had a more considerable influence on the adoption of PA technologies.

Many of the possible determinants within the outer context and linkage were not detected in any of the PA technologies adoption literature examined, as highlighted in Table 4.1 above. The potential for these determinants, for example, several programs of instruction, education, and exploration provided by PA adoption promoter to farmers (user orientation) and user involvement in specification within the linkage component, and socio-political climate within the outer context, to influence the innovation diffusion process of PA technologies is a significant gap in the literature.

In addition to gaps in the literature on specific determinants, the lack of appreciation of the complex interactions between components that are implicit in MDDDII is evident within the published PA technologies adoption literature. Of the 58 selected publications, none covered all nine components of MDDDII. Two studies (Bagheri & Bordbar 2014; Busse et al. 2014) included analysis or discussion of five components of MDDDII. Nearly all publications covered two or more components, but three studies (Asare & Segarra 2018; Boyer et al. 2016; Khanna 2001) only covered a single component of MDDDII. However, many of the studies covering four or fewer components focussed predominantly on only one or two of the components but did not provide any examination of the importance of others. Table 4.2 shows the number of publications and the number of components of MDDDII included in those publications.

Table 4.2 Number of publications and the number of components of MDDDII included in the selected PA technologies literature

Number of components	Number of publications
The innovation, communication and influence, outer context, adopter and linkage (5 components)	2
The innovation, communication and influence, outer context and adopter (4 components)	13
Any three components	25
Any two components	15
One component	3

The systematic review of the literature found that some determinants of the innovation component, for instance, the potential for reinvention, fuzzy boundaries, risk, task issue, and nature of knowledge required were not mentioned in any of the selected literature. Likewise, some determinants within adopter components, such as values and goals, needs, learning styles, and social networks were also not covered in any of the literature included in this systematic review. Further, some determinants within communication and influence component, such as homophily, champion,_and boundary spanners,_were not analysed, inferred, or discussed in any of the publications, even though these determinants have an important role in PA technologies adoption.

Social networks and peer opinion determinants within communication and influence were covered in a small number of studies (by two and five studies, respectively). Likewise, effective knowledge transfer and communication and information determinants of the linkage component were covered by only two and one studies, respectively. Given these are contributing features of the communication and influence and linkage components of MDDDII, it could be that more explicit assessment, measurement, and consideration of these determinants should be conducted in future research.

The impact of the low number and, in many cases, the absence of analysis of some determinants in the literature, as well as the low frequency of the coverage of multiple components, suggests that the innovation diffusion process on how PA technologies adoption is theorised, how PA technologies adoption programs are implemented, and therefore current PA technologies adoption rates needs further investigation. The absence of four components of MDDDII and the low frequency of the coverage of some components/determinants could be a lack of awareness of the importance of these components/determinants to PA technologies adoption. It could be the result of a focus of most studies on only part of the awareness-assessment-uptake-sustained use-widespread diffusion continuum of technology adoption. This is identified as a major characteristic of the PA technologies adoption literature relating to what may be important components/ determinants influencing PA technologies adoption. This knowledge gap reflects that extension strategies to promote PA technologies adoption are based on incomplete understanding of the innovation diffusion process. This needs to be further studied.

4.4 Conclusions

Based on the outcome of the systematic review of the PA technologies adoption literature, it can be said that more PA technologies adoption research were conducted in the United States than in other countries, such as Iran, Greece and Hungary. Similarly, the systematic review revealed that soil monitoring and yield mapping technologies were more popular than other PA technologies, for example, remote sensing, controlled traffic farming and automation technologies.

The systematic review showed that PA technologies adoption literature included only five components (the innovation, communication and influence, outer context, adopter and linkage) and with only low frequency of the coverage of several of the determinants within these components of MDDDII. Therefore, it is concluded that the lack of four of the components of MDDDII and absence of analysis of several determinants of MDDDII within the PA technologies adoption literature needs further investigation to identify how the exclusion of these components and low coverage of the frequency of several determinants influence PA technologies adoption in Australia.

5 CHAPTER FIVE: DATA ANALYSIS AND RESULTS OF THE CASE STUDIES AND THE REPORTS, AND THE STRATEGIC PLANS OF THE RDCs

5.1 Introduction

The previous chapter analysed the PA technologies adoption literature and found that the MDDDII components are relevant and are applied in a number of publications utilising various methods and frameworks of adoption. The finding of the previous chapter is a substantial finding, given the diversity of literature, crops, and technology use in PA technology adoption. However, none of the publications included or referenced of all the components outlined and covered in MDDDII, and only five out of the nine components of MDDDII could be identified in a single study. So, this chapter explores the presence/absence of components/determinants of MDDDII in the case studies and the reports, and the strategic plans of the RDCs (the Australian grey literature) and then compare the outcomes of the Australian grey literature to the outcomes of the systematic review of the PA technologies adoption literature. The comparison may provide opportunities to improve adoption rates of PA technologies in Australia.

As the first step of data analysis, the frequencies of three parameters, year of publication, agricultural industries, and tools of PA technologies, were counted from 43 selected Australian grey literature. In the second step, thematic analysis was applied to examine the data collected from the Australian grey literature. After conducting thematic analysis, the available themes were compared with MDDDII to identify the presence/absence of components/determinants of MDDDII in the selected Australian grey literature.

5.2 Characteristics of the studies

A total of 43 Australian grey literature items available from 2010 to 2018 were analysed. Most of the relevant sources (46.5%) were from 2015, followed by 2014 (18.6%), and 2016 (16.3%). Only 9.3% of the Australian grey literature sources were from 2017. Likewise, only a single source relevant to this thesis was identified in each of the years 2010 and 2012. There might be more Australian grey literature in 2000-2009 and also in 2011 and 2018, but the keyword search process used in this thesis did not capture those papers or the papers did not fit in the pre-defined selection criteria of this thesis. Figure 5.1 below outlines the percentage of the Australian grey literature available per year based on selection criteria.

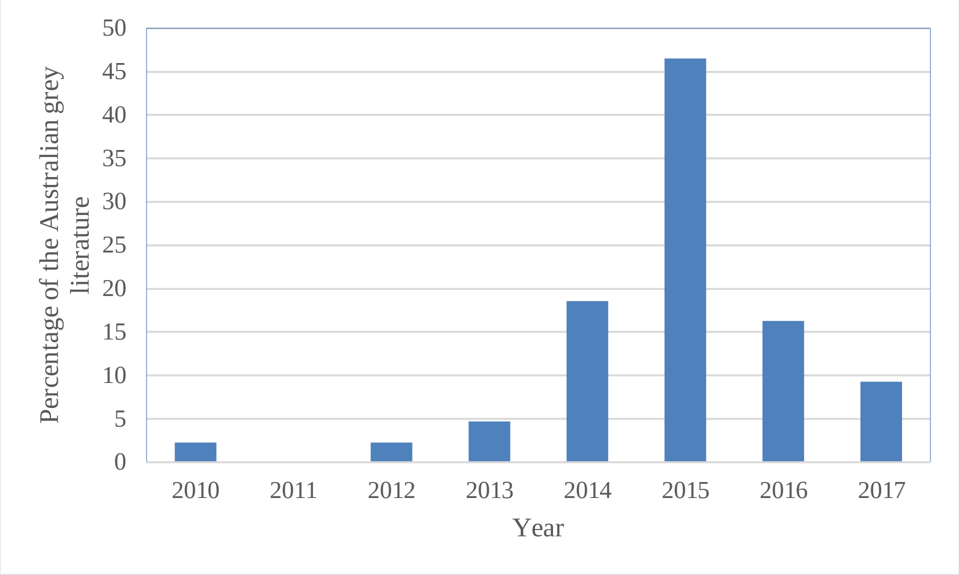

Figure 5.1 Percentage of the Australian grey literature available per year based on selection criteria

5.3 Tools of PA technologies

The highest proportion of the Australian grey literature (30.2%) examined robotic technologies, whereas 27.9% studied crop sensor. Similarly, 23.3% of the Australian grey literature included variable rate technology and 11.6% covered autosteer. Further, yield monitor and yield mapping were included in 9.3% and 7% of the Australian grey literature, respectively. Only one item of the Australian grey literature (2.3%) examined controlled traffic farming.

As mentioned above, the data shows that more studies were conducted about robotic technologies than other technologies, and PA technologies adoption researchers may be more interested in exploring the potential benefits of robotic technologies. Robotic technologies have been used in different agricultural sectors, such as livestock, grain, industrial crops and horticulture in Australia (AgriFutures Australia 2016). Conversely, the low frequency of controlled traffic farming (CTF) could account for the lack of research conducted in the area of CTF in Australia. However, once again, it is necessary to be aware that there might be more CTF research conducted in Australia, but the keyword search process used in this thesis may not have captured those papers or the papers did not fit in the pre-defined selection criteria of this thesis. Figure 5.2 below outlines the tools of the PA technologies mentioned in the Australian grey literature.

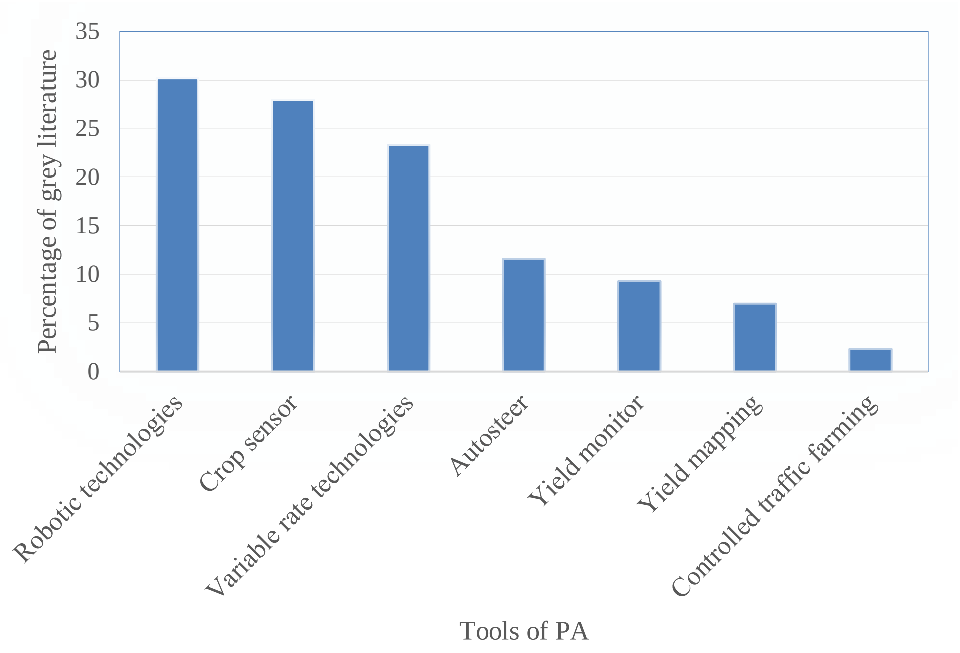

Figure 5.2 Tools of the PA technologies identified in the Australian grey literature

5.4 Classification of the agricultural industry

27.9% of the Australian grey literature covered the grain industry, with a focus on crops, including wheat, barley, and pulses, whereas 18.6% of the sources covered livestock. Likewise, 11.6% of the Australian grey literature covered industrial crops such as sugarcane and cotton. 4.7% of the Australian grey literature included the grape industry, but only one source covered the poultry industry. It was also identified that 34.95% of the Australian grey literature did not mention any types of agricultural industries.

The grain industry is regarded as a key agricultural contributor to the Australian economy (Gordon 2016). Therefore, PA technologies adoption researchers might be more interested in promoting PA technologies adoption in the grain industry. Second to the grain industry, PA technologies adoption researchers were interested in the development of the livestock industry. Figure 5.3 below outlines the different types of agricultural industries covered in the Australian grey literature.

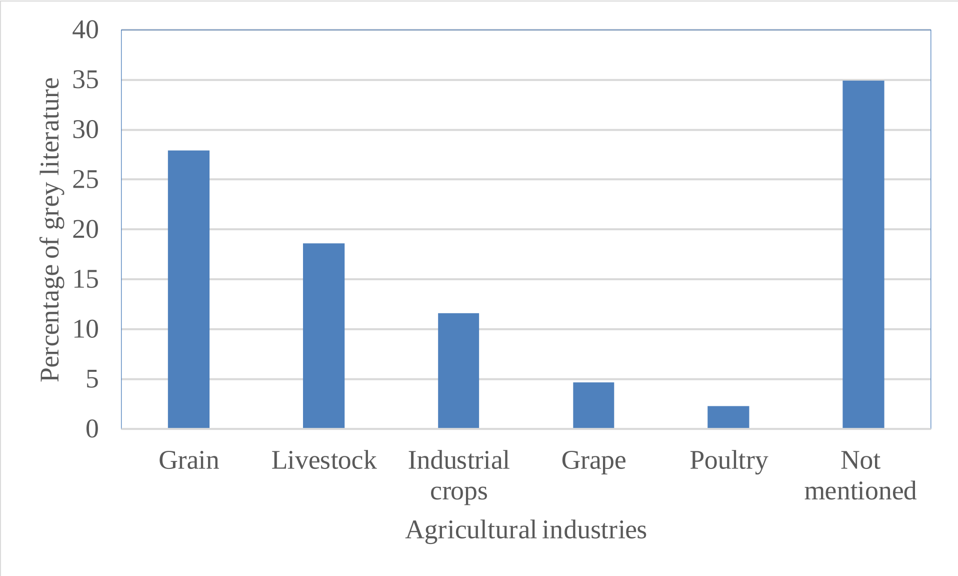

Figure 5.3 Agricultural industries mentioned in the Australian grey literature

5.5 Identifying the themes of the selected Australian grey literature

This thesis applied thematic analysis to identify themes (pattern of meanings) arising from the selected 43 items of Australian grey literature. For this purpose, the Australian grey literature was read and re-read several times to acquire an overall understanding of their content. 278 key issues and 74 recommendations that specifically addressed PA technologies adoption pathways were found. These key issues and recommendations are shown in appendix B.

Data were coded manually and systematically to generate initial codes. Some of the words, such as government decisions, successive governments, role of government, reports from Federal and State Governments, government agencies, Australian Government, and support of government were frequently used in the Australian grey literature. Based on their frequency within the Australian grey literature, these words were considered as keywords (initial codes). The list of initial codes is provided in appendix B.

Some of the initial codes had similar features in concept and meaning. Therefore, their combination created initial themes. For example, as mentioned above, government decisions, successive governments, role of government, reports from Federal and State Governments, government agencies, Australian Government, support of government are initial codes and their combination created the initial theme, ‘government’.

After reviewing the initial themes, it was found that some had common content, and therefore, these initial themes were combined to produce overarching theme. For example, skills, leadership, capacity, and training are initial themes with similar content (relevant to attributes of farmer), therefore, these initial themes were kept in a single theme which produced an overarching theme such as 'attributes of farmer'. Hence, the thematic analysis produced four overarching themes and 24 initial themes from 43 items of the Australian grey literature. The overarching themes and initial themes are listed below (Table 5.1).

Table 5.1 List of overarching and initial themes

Overarching themes	**Initial themes**
Agricultural innovation	The innovation
	Adoption
	Technologies
	Benefits
	Precision agriculture
	Controlled traffic farming
	Costs
	Production
	Profitability
Information	Internet
	Research and development
	Marketing
	Communication
External environment	Governments
	Regulatory
	Levies
	Investment
Attributes of farmer	Management
	Skills
	Leadership
	Capability
	Capacity
	Training
	Development

5.5.1 Agricultural innovation

The overarching 'agricultural innovation' theme is the ideas, new knowledge, or technology used in the agricultural industry to increase production and minimise the cost. It describes several technologies with various features, such as advantages and costs or other benefits provided to users. The initial themes, such as the innovation, adoption, technologies, benefits, precision agriculture, controlled traffic farming, costs, production, and profitability were derived from keywords (initial codes) included in the Australian grey literature. (The list of initial codes are given in appendix B). Then, the combination of these initial themes produced an overarching 'agricultural innovation' theme. Thematic analysis found that the adoption of innovation improves the production of the farm. Thus, the relative advantage, such as improvement of farm productivity, was frequently reported to influence the adoption of agricultural innovations (Australian Dairy Farmers 2015; Australian Sugar Milling Council 2015; Charles Sturt University 2015; Grains Research and Development Corporation 2015; Sorensen 2016; The University of Sydney 2015; Winemakers' Federation of Australia 2015). Similarly, the cost of PA technologies is another determinant that was noted to influence the adoption of agricultural innovation (Australian Sugar Milling Council 2015; Grains Research and Development Corporation 2014; The University of Melbourne 2015).

5.5.2 Information

The overarching 'information' theme is defined as the various channels of communication that provides information on the agricultural technology. Research and development programs provide information to potential users about the development of technologies and their features. Similarly, technology manufacturers, or retailers communicate with farmers while promoting their agricultural technologies (marketing) and provide information regarding the benefits of technologies. The internet is also a good source of agricultural information (Precision Cropping Technologies 2015).

5.5.3 External environment

The overarching 'external environment' theme is relevant to the influence of government contributions and government rules and regulations related to the development of the agricultural industry. Environmental law and government support, such as investment and subsidy, influence the adoption of agricultural innovation (Australian Sugar Milling Council 2015; Cotton Australia 2015; Deakin University 2015; Precision Agriculture Pty Ltd 2016; Precision Cropping Technologies 2015; Queensland Dairyfarmers' Organisation Ltd 2015; The University of Melbourne 2015). The Australian Government through the RDCs has invested a large sum of money in many RD&E projects focused on PA technologies. For example, the Australian Government provided $2,600,000 to Dairy Australia Limited for the project 'Enhancing profitability and productivity of livestock farming through virtual herding technology' to improve understanding of the learning, management, and ethical challenges related to the adoption of virtual fencing on farms (Department of Agriculture and Water Resources 2018a). Likewise, the Cotton Research and Development Corporation received $1,397,561 for the project 'Accelerating precision agriculture to decision agriculture' in order to design a solution for the use of big data in agriculture and to increase profitability and improve farming strategies (Department of Agriculture and Water Resources 2018a).

Levies refer to a charge to farmers for the development of the agricultural industry. RDCs receive funds from the growers' levy. The collected levy is spent on research and development. According to the levies Act 1999, sugarcane growers need to pay 70 cents per tonne of the sale value as R&D levy to Sugar Research Australia Limited while rice growers need to pay $2.94 per tonne of the sale value as R&D levy to the Grains Research and Development Corporation (Department of Agriculture and Water Resources 2018b).

5.5.4 Attributes of farmer

Farmers are the decision-makers for accepting or rejecting the technology, and they might have various features which could impact agricultural innovation adoption such as PA technologies. In this study, initial themes such as skills, management, leadership, capability, capacity, training, and developments are considered under the overarching 'attributes of farmer' theme. The technical knowledge of the adopter influences the adoption of PA technologies (Grains Research and Development Corporation 2013; Reef and Rainforest Research Centre 2015). Similarly, training programmes also influence the adoption of PA technologies (Australian Women in Agriculture 2015; Grains Research and Development Corporation 2014).

5.6 Themes compared to MDDDII

MDDDII covered nine components and several determinants and has been described in Chapter two. Further, the methods for conducting a thematic analysis have been described in Chapter three. The themes identified in the Australian grey literature have been analysed and compared with the components of the MDDDII to address research question two. Consequently, by viewing the four overarching themes and 24 initial themes through the lens of MDDDII, it is possible to understand better the similarities and differences of the Australian grey literature to MDDDII. Table 5.2 presented below shows the four overarching themes and subsequently initial themes which have been explored for their alignment with the MDDDII. This was done based on keyword and phrases that identified each theme and was compared with the clearly defined components of MDDDII.

Table 5.2 Comparing the main themes of the Australian case studies and the reports, and the strategic plans of the Australian RDCs with MDDDII

Overarching themes	Initial themes	Main themes of the Australian grey literature that align with MDDDII	Main themes of the Australian grey literature that do not align with MDDDII
Agricultural innovation	The innovation Adoption Technologies Benefits Precision agriculture Controlled traffic farming Costs Production Profitability	The innovation, communication and influence, outer context, and adopter	System antecedents for innovation, system readiness for innovation, linkage, implementation process, and assimilation
Information	Internet Research and development Marketing Communication		
External environment	Governments Regulatory Investment Levy		
Attributes of farmer	Management Skills Leadership Capability Capacity Training Development		

The overarching 'agricultural innovation' theme is relevant to the innovation component of MDDDII because it covers various features of technology, such as cost and benefits of technology. Similarly, the overarching 'information' theme is relevant to communication and influence component of MDDDII because it captures various sources of agricultural information, such as R&D, and the internet.

Another important overarching ‘external environmental’ theme is relevant to the outer context component of MDDDII because it explains how the government contribution and regulations influence the development of the agricultural industry. Similarly, another overarching ‘attributes of farmer’ theme is relevant to the adopter component of MDDDII because it explains how the characteristics of farmers such as skill, leadership and training influence technology adoption.

As shown in Table 5.2, four components of MDDDII were covered in the case studies and the reports, and the strategic plans of the RDCs. These components are the innovation, communication and influence, outer context, and adopter. It was also found that the other components of MDDDII were not readily identified in the thematic analysis of the case studies and the reports, and the strategic plans of the RDCs. These components include system antecedents for innovation, system readiness for innovation, linkage, assimilation and implementation process.

Based on the keyword search in the Australian grey literature, it was identified that the innovation component of MDDDII was dominant in the Australian grey literature and the relative advantage determinant within the innovation component was mostly focused by the Australian grey literature. The reason behind the dominance of the innovation component could be the perceived features of the PA technologies, such as improvement in the crop production, which results in profitability and other perceived benefits, such as ease of using PA technologies in farming operations.

The absence of system antecedents for innovation, system readiness for innovation, linkage, assimilation, and implementation process components of MDDDII in the Australian grey literature could be a lack of awareness, or there could have been limited opportunity to explore other models/theories of innovation/technology adoption. This is identified as a feature of the Australian grey literature. However, scientific literature revealed that system antecedents for innovation (Dopson et al. 2002), system readiness for innovation (Gustafson et al. 2003), linkage (Greenhalgh et al. 2004), assimilation (Sugarhood et al. 2013), and implementation process (Gustafson et al. 2003) are important aspects of technology adoption.

The background features of any organisations (system antecedents for innovation), no matter whether it is the service industry or agricultural enterprise, influence technology adoption. An organization such as an agricultural enterprise needs enough financial and human resources (slack resources determinant within system antecedents for innovation component) to purchase and use new technology. For example, a farmer requires approximately $42,200-$45,600 to use CTF (Davies et al. 2017), which indicates that a sound financial circumstance is required to use PA technologies.

Likewise, the size and maturity determinant within the system antecedents for innovation component is also important in technology adoption because the bigger agricultural enterprise uses a large farm that requires many employees in farming operations. Employees may have different knowledge and skills and may share their knowledge within the agricultural enterprise. Likewise, the maturity of the agricultural enterprise may be able to identify new knowledge and integrate that new knowledge in farming operations.

Further, leadership and vision determinants within system antecedents for innovation, encourage employees to be innovative and therefore is considered an important element of behavioural change (Emmons et al. 2012). Managers or farmers need effective leadership skills to influence, motivate and enable employees so that employees contribute towards the effectiveness and success of the agricultural enterprise. Leadership is a ladder to achieve the goals of agricultural enterprise because leadership creates a clear vision and communicates that vision to employees. Once the vision is clear, employees can examine the fitness of a new technology with the prevailing values and purposes of the agricultural enterprises.

Managers/farmers should have a positive relationship (good managerial relations determinant within system antecedents for innovation) with supervisors and other employees within an agricultural enterprise so as to promote change. Good relations among employees create a favourable working environment, and therefore employees support the adoption of the new technology (system readiness for innovation). For example, if employees perceive that the current technology is not supporting farming operations (tension for change determinant), then agricultural enterprise may be more interested to use new technology such as PA technologies. Similarly, new technology needs to be suitable with existing values and goals and be supported by the majority of the employees (power balance determinant). Further, managers/farmers need to identify the available resources and time for the change (dedicated time and resources determinant) because the adoption of PA technologies may not meet the expectations of the farmer without proper planning of budget and resources, such as human resources and machinery.

Further, communication with potential users while developing technologies, management of technical help, and user orientation (Linkage component) link potential users such as farmers with the external environment. In this way, farmers acquire more information about the technology, which could inspire them to use the technology. Furthermore, the initial usage activities that often follow the decision of PA technologies adoption (implementation process) are most relevant to the system readiness for innovation component. Management of dedicated resources, such as funding and workforce, effective communication across agricultural enterprise, and timely and accurate evaluation of the effectiveness of PA technologies adoption, provide more information on how PA technologies are working. This information helps farmers to decide whether PA technologies should be adopted continuously.

Significantly, the Australian grey literature systematically excludes several components/ determinants of MDDDII that are found to be critically influential in innovation within other industries and contexts. The impacts of this exclusion in PA technologies adoption rates in Australia needs further investigation to determine the relationship between the systematic exclusion of some components of MDDDII and PA technologies adoption rates in Australian agricultural industry.

5.7 Comparing the outcomes of the systematic review of PA technologies adoption literature and the Australian grey literature

To bring together awareness of how the MDDDII components are represented in both of the Australian grey literature and the systematic review findings, a brief comparative analysis was conducted so as to enable similarities and differences to be highlighted. The table below (Table 5.3) shows the components of MDDDII identified in the systematic review of PA technologies adoption literature and the Australian grey literature.

Table 5.3 List of components of MDDDII identified in the systematic review of PA technologies adoption literature and the Australian grey literature

Components of MDDDII found in systematic review of PA technologies adoption literature	Components of MDDDII found in the Australian grey literature
1) The innovation	1) The innovation

2) Communication and influence	2) Communication and influence
3) Outer context	3) Outer context
4) Adopter	4) Adopter
5) Linkage	

As shown in Table 5.3, the systematic review (methodology in chapter three and findings in chapter four) identified that PA technologies adoption literature covered five components of MDDDII: 1) the innovation, 2) communication and influence, 3) outer context, 4) adopter, and 5) linkage. However, the Australian grey literature covered only four components of MDDDII: 1) the innovation, 2) communication and influence, 3) outer context, and 4) adopter. Four components of MDDDII were captured in both PA technologies adoption and the Australian grey literature: 1) the innovation, 2) communication and influence, 3) outer context, and 4) adopter.

PA technologies adoption literature includes the linkage component, but it was not covered in the Australian grey literature. This means that the Australian grey literature did not place value on several determinants of the linkage component, for example, the effective knowledge transfer, user involvement in specification, user orientation, and product augmentation, which link potential adopters and other players involved in the innovation development. These determinants are important in technology adoption (Greenhalgh et al. 2004). Neither the PA technologies adoption literature nor the Australian grey literature included system antecedents for innovation, system readiness for innovation, assimilation and implementation process components. After comparing the findings of the Australian grey literature and the systematic review of the PA technologies adoption literature, it is evident that the innovation component and relative advantage determinant within the innovation component of MDDDII is consistently recognised in both studies.

The missing the components of MDDDII could influence the adoption of PA technologies in the Australian agricultural industry. For example, the adopter component and system antecedents for innovation component interact in that the farmer will have varying degrees of risk aversion (adopter). However, the financial structure of the business (system antecedents for innovation) may impose an additional source of risk (financial risk) that may significantly impact the willingness to adopt for farmers (system readiness for innovation) with increasing levels of financial leverage. Likewise, components such as the innovation, adopter, linkage, and assimilation interact in that complex technologies (for example, variable rate application of fertilizer) may require expertise beyond that of the farm team and many farmers may delegate the VRT decisions and perhaps applications to off-farm service providers or consultants.

The use of a broad-based conceptual model (MDDDII) in the Australian grey literature review allows analysis of the significant areas of research focus within the complex processes of PA technologies adoption. Most of the Australian grey literature assesses only a subset of the components of MDDDII without considering the interactions and contextual features captured by MDDDII. The Australian grey literature did not consider most of the components of MDDDII. This research study may, therefore, have identified gaps in the Australian grey literature that prevent a more comprehensive understanding of the adoption processes being reached.

5.8 Conclusions

It was identified that most of the relevant Australian grey literature was available in 2015, and noted that most of the Australian grey literature included robotic technologies and the grain industry. Similarly, the Australian grey literature contained a wide range of strategies and recommendations regarding the adoption of PA technologies. Thematic analysis of the Australian grey literature provided four themes, and these themes covered four components of MDDDII: 1) the innovation, 2) communication and influence, 3) outer context, and 4) adopter. Thus, the other five components of the MDDDII were not present in any of the selected Australian grey literature: 1) system antecedents for innovation, 2) system readiness for innovation, 3) linkage, 4) assimilation, and 5) implementation process.

The comparative analysis of PA technologies adoption literature and the Australian grey literature showed that one more component of MDDDII (linkage) was included in the PA technologies adoption literature. The PA technologies adoption literature is scientific literature and prepared for a specific purpose and could be useful worldwide. Their focus is different from the focus of the Australian grey literature. Therefore, the PA technologies adoption literature might cover more components/determinants of MDDDII. The outcome of the PA technologies adoption literature suggested Australian PA technologies promoters focus on the linkage component of MDDDII in the PA technologies adoption process. However, this is not the only case; there are other components of MDDDII which influence PA technologies adoption process.

The analysis of the Australian grey literature helped to identify the gap between the expectation of the Australian PA technologies adoption stakeholders and the actual adoption rate in Australia. Importantly, the missing five components of MDDDII (system antecedents for innovation, system readiness for innovation, assimilation, linkage and implementation process) could be due to the lack of awareness of these components in PA technologies adoption, or these components might not be relevant in the practice of innovation/technology in agriculture. Thus, further investigation is needed to identify how the absence of those five components of MDDDII might be affecting the rate of PA technologies adoption in Australian agricultural industry.

6 CHAPTER SIX: DISCUSSION OF RESULTS, CONCLUSION, AND RECOMMENDATIONS

6.1 Introduction

This thesis reviewed a number of innovation/technology adoption models/theories (see Chapter Two) to understand the technology adoption process in agricultural industry, and it was identified that these models/theories included different influencing factors in technology adoption. Within those models/theories, this thesis considered one comprehensive theoretical model, the model of determinants of diffusion, dissemination and implementation of innovations (MDDDII) as a tool to capture the multiple influencing components/determinants involved in the adoption of innovation/technology that has been presented in the literature, variously and partially covered by other models/theories of innovation/technologies adoption. The novel feature of MDDDII is that it is a unique framework to understand diverse aspects of a multifaceted situation and their interactions in technology adoption.

In particular, by examining PA technologies adoption literature, and the Australian grey literature through the lens of MDDDII, this thesis identified which aspects of the innovation adoption process are being considered as influential in the adoption process, and equally not considered, by Australian PA technologies adoption researchers and practitioners. Thus, this knowledge may provide opportunities to improve PA technologies adoption strategies in Australia.

PA technologies adoption literature is academic literature, and the examination of this literature provides a snapshot into the technology adoption process and factors most explored in agricultural extension literature worldwide. Thus, the examination of PA technologies adoption literature is relevant for understanding both how technology adoption is discussed in published literature and also how the applied agricultural industry settings discuss and understand PA technology adoption.

This thesis first conducted a systematic review of PA technologies adoption literature by applying a rigorous methodology, the PRISMA approach (preferred reporting items for systematic reviews and meta-analyses), which provides guidelines to conduct a systematic review (Moher et al. 2009). Literature were searched by using PA technologies adoption keywords within three databases: Scopus, Web of Science, and CAB Abstracts, dated from 2000-2018. The frequency of components/determinants of MDDDII within the selected PA technologies adoption literature were extracted manually. Similarly, the background features of PA technologies adoption literature, for example, tools of PA technologies, agricultural industries, year of publication, and location were also extracted manually.

Second, this thesis identified the Australian grey literature using a number of keywords in a Google search, and through industries' webpages. The search was restricted to 2000-2018 and relevant to PA technologies adoption. The background features of the Australian grey literature were examined and then the themes of this literature were identified by using thematic analysis. Finally, the themes were compared with the components of MDDDII. The following section interprets the outcomes provided by the methodology outlined above.

6.2 Outcomes of the systematic review of the PA technologies adoption literature (research objective 1)

The systematic review of the PA technologies adoption literature from the past 19 years found that five components of MDDDII: 1) the innovation, 2) communication and influence, 3) outer context, 4) adopter, and 5) linkage were covered in the PA technologies adoption literature. Due to a lack of specific examples in the agricultural industry, research conducted in other industries, such as healthcare, is a useful comparison to identify whether the findings of the PA technologies adoption literature reflect the outcomes of other research. For example, this thesis readily identified a number of MDDDII components in the PA technologies adoption literature. Similarly, a qualitative survey conducted by Makowsky et al. (2013) in Canada identified that MDDDII was useful in understanding the multidimensional nature of pharmacists' prescribing practices technology adoption. Consequently, the importance and relevance of four components of MDDDII (innovation, communication and influence, outer context, and adopter) was common to this study and the pharmacists' survey. In contrast, both of the studies included one different component of MDDDII. PA technologies adoption literature included the linkage component, but the pharmacists' survey included system antecedents for innovation component of MDDDII. The inclusion of different components in these studies could be due to the different types of industries studied (the agricultural industry versus the healthcare industry), and it may be that these studies looked at technology adoption influencing components for a different purpose.

This thesis identified that the PA technologies adoption literature covered five components of MDDDII, but they did not cover many determinants of those five components that influence PA technologies adoption. For example, the innovation component has 11 determinants, but PA technologies adoption literature included only six determinants. The low frequency of determinants within the innovation component, such as the omission of the risk determinant, within PA technologies literature may influence the adoption. Also, if the prospective users think that the technology will bring a high degree of ambiguity of outcome, then they will have less interest in adopting the technology (Meyer, Johnson & Ethington 1997).

Recent research is starting to address measures and assessment of risk determinant in PA technologies adoption (Gardezi & Bronson 2020; Li et al. 2020). For example, a survey of 449 farmers in China examined how the risk determinant influences PA technologies adoption and found that it influenced PA technology adoption negatively (Li et al. 2020). Therefore, the influences of components and low frequency of determinants within the PA technologies adoption literature needs to be further studied.

In addition, significantly, four components of MDDDII were absent from the PA technologies adoption literature: 1) system antecedents for innovation, 2) system readiness for innovation, 3) assimilation, and 4) implementation process. The absence of the four components and the low frequency of determinants within the PA technologies adoption literature could be because MDDDII has been developed to understand the technology adoption process in a service organisation where a team or department is involved in the technology adoption process. However, the available PA technologies adoption literature examines the technology adoption process in the agricultural industry where an individual farmer or possibly a group of farmers is engaged in the technology adoption process. The features of the service organisation are different from the features of the agricultural industry in the sense that the intention and work-related roles for consumers is different. For example, in a service organisation, the team or department is administered by laws, rules, and structural organizational checks and balances and the team or department requires strong communication and service-oriented skills in technology adoption with end-users. In contrast, there is more freedom in the agricultural industry, and whilst there are also various rules, laws, structural production, and industry standards, a farmer requires analytical thinking, business understanding, and creative marketing techniques. Consequently, because of the different features between service organisations and the agricultural industry, the interpretation of similar components/determinants in the technology adoption process between service organisations and the agricultural industry may have varying applications. Nonetheless, by highlighting the presence and absence of components of MDDDII, the current findings provide a potential context to consider other contributing interactions and contexts that, if addressed, might support adoption.

MDDDII emphasises that a set of components interacts with each other and builds a complex relationship in the technology adoption process. For example, farmers perceived that variable rate technology (VRT) provides economic and environmental benefits (the innovation component) and are willing to use it in farming operations (system readiness for innovation component), but they need robust financial circumstances (system antecedents of innovation) to use VRT because this technology is expensive. It is also a complex technology. Therefore, product augmentation, such as technical help, and user orientation (linkage component) could be required that might be provided by off-farm service providers. Similarly, farmers may use consultancy services (communication and influence) to increase their knowledge (adopter component). So, the innovation, system readiness for innovation, system antecedent for innovation, linkage, communication, and influence and adopter components interact with each other in the adoption of VRT. This thesis found that multiple components are not included or readily identified in any PA technologies adoption literature. Therefore, an incomplete picture of the complex technology adoption processes emerges. Further, a lack of appreciation of the complex interactions between components that is implicit in MDDDII is also evident within the published PA technologies adoption literature. While the intricacy of the adoption of PA technologies process is highlighted in many publications, none presented an extensive examination of component interactions. This is identified as a major gap in the literature relating to what may be important factors influencing the adoption of PA technologies. Identification of this knowledge gap may provide an opportunity to increase understanding and application of PA technologies adoption in Australia.

In several agricultural industries, such as grain, dairy, cotton, sugarcane, and fruit and vegetable, the PA technologies adoption literature has not explicitly measured, highlighted, or included many of the components linked with adoption (for example, the background features of agricultural enterprise, their willingness, and the implementation process). Therefore, this outcome of the systematic review included in this thesis could also provide an opportunity to increase the understanding and application of PA technologies adoption.

6.3 Outcomes of the Australian grey literature (research objective 2)

This thesis identified 278 key issues and 74 recommendations from 43 items of the Australian grey literature (the case studies and the reports, and the strategic plans of RDCs) regarding the adoption of PA technologies across the agricultural industry in Australia. The thematic analysis provided core themes from those 43 Australian grey literature documents, and these themes reflected four components of the MDDDII: 1) innovation, 2) communication and influence, 3) outer context, and 4) adopter.

This thesis did not find any agricultural extension literature that used a similar thematic design to the current research. Therefore, research conducted in the healthcare industry is a useful comparison to identify whether the findings of the Australian grey literature reflect the outcomes of healthcare research. For example, this thesis identified four components of MDDDII as mentioned above in the Australian grey literature. Similarly, a qualitative survey conducted by Sugarhood et al. (2013) identified and explored influencing factors of telecare innovations/technologies adoption in the healthcare industry in the UK. They used a similar thematic design to the current research and showed that all nine components were considered as influential factors of telecare innovations/technologies adoption in the UK. So, the significance and relevance of four components of MDDDII (the innovation, communication and influence, outer context, and adopter) was common in this study and in the study of telecare innovations/technologies adoption. In contrast, the thematic context across the Australian grey literature did not reflect aspects of the other five components of the MDDDII: 1) system antecedents for innovation, 2) system readiness for innovation, 3) linkage, 4) assimilation, and 5) implementation process. Missing these five components of the MDDDII in the Australian grey literature suggests that elements of the adoption process may not be adequately covered in the Australian grey literature. This gap in the extension strategies may influence PA technologies adoption in the Australian agricultural industry that should be investigated further.

Thematic analysis showed that the Australian grey literature did not incorporate all components of MDDDII. Thus, extension strategies within funded R&D projects such as ‘Enhancing profitability and productivity of livestock farming through virtual herding technology' (Department of Agriculture and Water Resources 2018a) and 'Accelerating precision agriculture to decision agriculture' (Department of Agriculture and Water Resources 2018a), may not be explicitly constructing or communicating innovation/ technology adoption messages that address the full suite of components that influence PA technologies adoption.

If explicit awareness and description of the components/determinants of MDDDII identified are absent in the strategic plans, then it could be assumed that without these functional components, adoption of PA technologies in the Australian agricultural industry might be impeded. While taking one specific example, in the *Strategic Plan 2017/2018-2021/22*, it is found that the sugar industry seeks to develop understanding and uptake of PA technologies and increase profitability across the industry value chain through innovation (Sugar Research Australia Limited 2017). Technology adoption starts with the background features of the industry (system antecedent for innovation component). Therefore, the sugar industry needs a sound background (system antecedents for innovation), such as enough slack resources, knowledge sharing capacity, effective leadership and vision, risk taking climate, and clear goals and priorities, to improve understanding and uptake of PA technologies. The sugar industry also needs willingness/preparedness for technology adoption (system readiness for innovation component) to increase profitability across the industry value chain through innovation. Based on the thematic analysis, it is noted that Sugar Research Australia Limited (2017) did not reflect the following five components of MDDDII in the *Strategic Plan 2017/2018-2021/22*: 1) system antecedents for innovation, 2) system readiness for innovation, 3) linkage, 4) assimilation, and 5) implementation process. Therefore, it can be seen that the strategic plan of the sugar industry only addressed a few of the components of MDDDII.

MDDDII considers a lot of components/determinants and highlights that each of the components/determinants interact with each other in the technology adoption process. For example, controlled traffic farming (CTF) is an expensive technology; therefore, farmers need to be in a strong financial position and also need to have the willingness to use CTF. Similarly, they may use consultants to increase their skills and knowledge and then they feel confident to use CTF in farming operations. Further, they may receive technical support to resolve technical issues.

The Australian grey literature focussed on a narrow set of components of MDDDII. They did not recognise that PA technologies adoption needs a set of inter-related factors, such as the perceived features of the technology, attributes of the adopter, several channels of agricultural information, background features of the adopter, and their willingness. Therefore, the Australian PA adoption researchers and practitioners should address the relative importance of components and their linkage in extension strategies to rapidly promote PA technologies adoption.

Technology adoption is well developed in service organisations, such as public hospitals, but less so in private sector organisations, for example, the agricultural industry. Technology adoption in public sector organisations focuses on the underlying social welfare and public services (Windrum & Koch 2008) and is observed by several interest groups while the adoption of technology in the agricultural industry concentrates on market development to acquire economic benefit. Likewise, public sector organisations cover the whole community in the society. Therefore, this sector becomes the interest of the whole community whereas private sector organisations, such as the agricultural industry, are usually related to an individual farmer. Further, public sector organisations are owned and run by the federal, provincial or state government, but the agricultural industry, whilst tied to government influence, is not owned by the government and is run by an individual or a group of farmers. Thus, it is plausible that adoption of technology is better developed in the public sector organisations rather than private sector organisations due to different influences of public interest and private ownership. MDDDII has been developed to understand innovation/ technology adoption processes in the service industry. As the service industry has different features (described above) than the agricultural industry, this may be one reason that the Australian grey literature may not cover all components of MDDDII in the PA technologies adoption process.

Also of consideration, MDDDII was developed using 495 published sources across 13 distinct research fields, for example, marketing, psychology, sociology, information and communications technology, clinical epidemiology, economics, political science, ecology, organisation and management, and anthropology (Greenhalgh et al. 2004). As such, there is perhaps a broader context that has informed MDDDII's internal rationale and grounding in scientific evidence (Cook et al. 2012). Therefore, MDDDII can be seen as an advanced model for understanding the extent of the innovation/technology adoption and behaviour change process in technology adoption. In contrast, perhaps agricultural technology adoption models have been developed and applied with a well-researched framework but with a narrower focus point to examine adoption. Consequently, the Australian grey literature provides fewer perspectives and themes about the adoption and, based on current findings, does not capture some components of MDDDII, such as system antecedents for innovation, system readiness for innovation, linkage, assimilation, and implementation process. While the interpretation and evidence for how the potential absence of these components influence adoption rates is unclear, this desktop review of the Australian grey literature highlights the potential for where future research could focus. Specifically, there is a lack of evidence to show how the absence of the components of MDDDII influence the PA technologies adoption process in Australia. This needs to be further studied, and some suggestions on how this could be done are offered in section 6.6 below.

There is still a gap in both the PA technologies adoption literature and the Australian grey literature. This gap may be due to a lack of awareness of how these types of components can be related to technology adoption in agriculture, as opposed to technology adoption in the service industry, such as health care. Also, this gap may exist in the literature because MDDDII has explored different aspects of technology for different purposes as part of the development of the service industry. Therefore, some components of MDDDII have not been captured in the PA technologies adoption literature. Further insights can be gained through appraisal of the studies, particularly those that include analysis or discussion of four or more components, and by using MDDDII as the lens through which the study data and discussion are viewed.

After analysing both the PA technologies adoption literature and the Australian grey literature, it can be said that no single factor can explain the technology adoption process. There are a number of different factors that play a significant role in PA technologies adoption process. This finding is similar to the results of Pannell et al. (2006), who found that a number of factors, such as personal, cultural, social, economic, and features of the innovation, influence the adoption of agricultural technology. Likewise, most recent PA technologies adoption literature also highlighted that a variety of different factors, such as reduced work time, knowledge, perceived risks, availability of consultant services and usefulness of technology, influences PA technologies adoption (Gotor et al. 2020; Li et al. 2020; Salimi, Pourdarbani & Nouri 2020; Vecchio et al. 2020). Further, this thesis identified that the relative advantage within the innovation component was predominant in both PA technologies adoption and the Australian grey literature. This means that the relative advantage of technology highly influences the adoption of PA technologies.

This thesis shows that the exclusion of the components/determinants of MDDDII in the Australian grey literature, whilst may be related to low adoption rate, is not the cause of the low rates of PA technologies adoption in Australia. Therefore, this thesis highlighted that the systematic inclusion of components/determinants of MDDDII in the Australian grey literature may provide insights into why there are low adoption rates. Thus, this needs further tests to see whether the exclusion of components/determinants of MDDDII in the Australian grey literature are influential, and if they are influential, then how does the lack of consideration of these influential components/determinants contribute to low PA technologies adoption rate?

6.4 Strengths and limitations of thesis

The main strength of this thesis is that it examined both PA technologies adoption literature (academic) and the reports and case studies and the strategic plans of the RDCs (the Australian grey literature) to understand the complex technology adoption process. This thesis synthesised the individual results of the 58 selected academic research within a single study using the PRISMA approach (preferred reporting items for systematic reviews and meta-analyses). This approach is commonly used in systematic reviews of published literature (Moher et al. 2009). Further, the strength of this thesis is that it explored a complex issue in a novel way and utilised an explicit and widely used innovation model (MDDDII) that has not been previously explored as relevant for PA technologies adoption.

Another important strength of this thesis is that it offered a comparison between the outcomes of the PA technologies adoption literature and the Australian grey literature to understand better how the adoption of PA technologies is considered and discussed. This thesis also interpreted the results of both sources of literature in a convincing way. Another strength of this thesis is that it helps the understanding of what concepts and factors are important to support and improve PA technologies adoption in Australia. Finally, this thesis has contributed to the emerging discussion about the adoption of PA technologies through its discussion of how consideration of other components/determinants might be useful in PA technologies adoption.

There are also a few potential limitations of this thesis. This thesis limited its systematic review of the PA technologies adoption literature to peer-reviewed journals that focus on outcomes relevant to PA technologies adoption. Thus, the review process might have a publication bias if other sources, for example, conference papers and books, include a reliable and valid measure of PA technologies adoption influencing components. Similarly, this thesis restricted the publication date of the PA technologies literature to 2000-2018, but there could be relevant PA technologies adoption literature before 2000 and after 2018 that could provide a different context to the findings. Similarly, this thesis uses 13 keywords in three databases, Scopus, Web of Science, and CAB Abstract, to identify PA technologies adoption literature. However, there are other keywords, for example, digital agriculture, satellite, farming technology that potentially might have expressed or reflected the various processes of adoption that might have been relevant to more components of the MDDDII. Therefore, while this thesis provided a comprehensive review, different review processes and keywords may have captured different PA technologies adoption literature. Similarly, there are other databases, such as Science Direct, Agricola, and CSIRO, that may provide PA technologies adoption literature. Thus, further reviews may benefit from searching different databases for finding other relevant PA technologies adoption literature. However, the databases and search terms used for this thesis were considered useful for the current research question because they reflected the most robust searches and were considered the most relevant for the research question of the current thesis.

As MDDDII has been developed to understand the technology adoption process in the service industry, where the employer-employee relationship and institutional borders are more fluid and less delineated, the model captured many components/determinants. However, in the agricultural industry, relationships tend to be more voluntary/participatory and the boundaries of the context in which technology adoption has no physical boundaries in the agricultural industry. Further, the adoption of technology in public and private sectors is administered by slightly different values, with unique groups managing their system and practices. Therefore, there is a question of whether all components of MDDDII influence PA technologies adoption.

In terms of further limitations of this thesis, it is acknowledged that the author is unable to collect the primary data due to time constraints. Therefore, this thesis is based on a desktop literature review using both the PA technologies adoption literature and the Australian grey literature. Thus, this limits the scope for interpretation of outcomes but provides a foundation upon which further research can be conducted.

6.5 Recommendations for future research

Based on the systematic review of the PA technologies adoption literature, and the Australian grey literature, the following recommendations are made for future research to enhance the understanding of the PA technologies adoption process in Australia.

First, research surveying Australian farmers should be undertaken to assess if the nine components of MDDDII and interactions between them were involved in their decision to adopt or abandon PA technologies in Australia. This would be important because it would expand the measures or specific components and features of adoption in a systematic way. The potential research could then start to unravel the meaning and context of how the nine components of MDDDI might be understood and aligned in the agricultural industry. The understanding of the importance of the nine components may be useful to identify the reason for the gap between the expectations of PA technologies adoption researchers, policymakers, and funders and actual adoption rate in Australia. Thus, future research could investigate, for example, the following research questions:

RQ.1. Are the nine components of MDDDII relevant to PA adoption in Australia?

RQ. 2. How might failure to consider the excluded components of MDDDII be affecting the rate of PA technologies adoption in Australian agriculture?

In addition, thematic analysis of the Australian grey literature covers only four components of MDDDII: 1) the innovation, 2) communication and influence, 3) outer context, and 4) adopter. However, literature shows that the other five components of MDDDII: 1) system antecedents for innovation (Gosling, Westbrook & Braithwaite 2003), 2) system readiness for innovation (Cook et al. 2015), 3) linkage (Greenhalgh et al. 2004), 4) assimilation (Greenhalgh et al. 2004), and 5) implementation process (Durlak & DuPre 2008) are equally important in technology adoption in other industries. Therefore, future research should apply MDDDII in the agricultural industry to test whether each of the components of MDDDII influences PA technologies adoption in Australia.

Further research that explores and assesses the components of MDDDII across industries could usefully consider a combination of primary quantitative and qualitative data. Thus, a mixed-methods research approach would be useful for a proposed survey. Though conducting a survey was beyond the scope of the current study, a full outline of a potential survey and approach is included in the appendix C.

Second, technology manufacturers and retailers should consider the various components/ determinants of MDDDII in their marketing strategies. Literature highlights that the availability of technical support from technology manufacturers, wholesalers and, retailers motivates farmers to use PA technologies in farming operations (Castro et al. 2015). Similarly, user involvement in specification and knowledge sharing facilities could change potential users' behaviour towards technology use (Ferlie et al. 2001). Technical support and knowledge sharing are a few examples of determinants within the innovation and system antecedents for innovation components, which influence the buying behaviour of farmers.

Third, the Australian Government and private organisations are involved in promotion of PA technologies adoption. However, the adoption rate of PA technologies is still low. So, there could be several factors that hinder PA technologies adoption in Australia. The literature showed that MDDDII is a comprehensive model to understand the technology adoption process. Thus, it would be appropriate to consider the components/determinants of MDDDII to improve extension strategies.

6.6 Conclusions

After analysing several models/theories of innovation/technology adoption, this thesis considered MDDDII as a useful tool to understand the complex structure of the PA technologies adoption process. Therefore, this thesis examined both the academic and the Australian grey literature to identify the inclusion/exclusion of the component/determinants of MDDDII within that literature to improve how PA technologies adoption strategies are designed and developed in Australia.

This thesis produced six important outputs: 1) neither PA technologies adoption literature nor the Australian grey literature covered all components of MDDDII; 2) PA technologies adoption literature included only five out of nine components of MDDDII, but missed many determinants of those five components; 3) there is a lack of appreciation of the complex interactions between components that is implicit in MDDDII; 4) the Australian grey literature included only four out of nine components of MDDDII; 5) four components of MDDDII (the innovation, communication and influence, outer context, and adopter) were covered by both literature; and 6) this thesis found a clear knowledge gap (the gap between the expectations of PA technologies adoption stakeholders and the actual rate of adoption) in which further research can be carried out.

In addition, PA technologies adoption researcher can note the suggestions of this thesis to conduct further research which could increase new knowledge, and this thesis encourages other researchers to test how the inclusion/exclusion of all components of MDDDII influence the rate of PA technologies adoption in Australian agricultural industry. Finally, this is a useful thesis for the Australian agricultural industry because it highlights an area of further exploration and deeper consideration that supports PA technologies adoption.

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Appendices

Appendix A: Details of selected publications

Year	Journal	Volume: Page numbers	Authors	Title	PA technologies	Industry	Location
2018	Precision Agriculture	19: 992-1010	Asare, E Segarra, E	Adoption and extent of adoption of georeferenced grid soil sampling technology by cotton producers in the southern US	Georeferenced grid soil sampling	Industrial crop	United States
2018	Precision Agriculture	19: 537-554	Kountios, G Ragkos, A Bournaris, T Papadarid, G Michailidis, A	Educational needs and perceptions of the sustainability of precision agriculture: survey evidence from Greece	Variable rate technology Remote sensing Geographical information systems	Multiple (Cotton, cereal, vegetables, arboriculture)	Greece
2018	Plos One	13: 1-17	Lima, E. Hopkins, T. Gurney, E. Shortall, O. Lovatt, F. Davies, P. Williamson, G. Kaler, J.	Drivers for precision livestock technology adoption: A study of factors associated with adoption of electronic identification technology by commercial sheep farmers in England and Wales	Electronic identification technology	Livestock	UK
2018	Acta Agriculturae Scandinavica Section B: Soil and Plant Science	68: 349-357	Tamirat, T. W. Pedersen, S. M. Lind, K. M.	Farm and operator characteristics affecting adoption of precision agriculture in Denmark and Germany	Auto guidance technology	Not mentioned	Denmark and Germany
2018	Canadian Journal of Animal Science	98: 250-259	Medrano-Galarza, C LeBlanc, S J Jones-Bitton, A DeVries, T Rushen, J de Passille, AM Haley, D B	Producer perceptions of manual and automated milk feeding systems for dairy calves in Canada	Automated milk feeding	Livestock	Canada
2017	Precision agriculture	18: 701-716	Paustian, M Theuvsen, L	Adoption of precision agriculture technologies by German crop farmers	Not described	Multiple (Wheat, barley, rye,	Germany

						oilseed, corn, feeding crops)	
2016	Agronomy Research	14: 1307-1320	Keskin, M. Sekerli, Y. E.	Awareness and adoption of precision agriculture in the Cukurova region of Turkey	Geographic information systems Remote sensing	Grain, vegetable, industrial crop, fruit	Turkey
2016	Journal of Agricultural and Resource Economics	41: 81-96	Boyer, C. N. Lambert, D. M. Velandia, M. English, B. C. Roberts, R. K. Larson, J. A. Larkin, S. L. Paudel, K. P. Reeves, J. M.	Cotton producer awareness and participation in cost-sharing programs for precision nutrient-management technology	Variable rate technology Georeferenced precision soil sampling	Industrial crop	United States
2016	Journal of Agricultural and Resource Economics	41: 97-115	Schimmelpfennig, D. Ebel, R.	Sequential adoption and cost savings from precision agriculture	Yield monitor Combination of yield monitor and yield mapping	Grain	United States
2015	International Journal of Agricultural Technology	11: 609-620	Monfared, N.	The adoption of variable-rate application of fertilizers technologies: the case of Iran	Variable rate technology	No industry mentioned	Iran
2015	Computers and Electronics in Agriculture	115:40-50	Fountas, S. Carli, G. Sørensen, C. G. Tsiropoulos, Z. Cavalaris, C. Vatsanidou, A. Liakos, B. Canavari, M. Wiebensohn, J. Tisserye, B.	Farm management information systems: Current situation and future perspectives	Not described	No industry mentioned	Multiple locations
2015	Computers and Electronics in Agriculture	110 : 131-138	Fountas, S Sornsen,C G Tsiropoulos, Z Cavalaris, C Liakos,V Gemtos,T	Farm machinery management information system	On the go sensors Automated technology	Grain, industrial crop	Multiple locations (Denmark and Greece)

					Bundled of Yield monitors and grid soil sampling Bundled of COTMAN and digital maps Bundle of aerial, satellite imagery, handheld devices with GPS and soil survey maps		
2015	Journal of Agricultural and Resource Economics	40 : 325-345	Lambert, D M Paudel, K P Larson, J A	Bundled Adoption of Precision Agriculture Technologies by Cotton Producers		Industrial crop	United States
2014	International Sugar Journal	116:278-285	Markley, J. Hughes, J.	Understanding the barriers to the implementation of precision agriculture in the central region	Variable rate technology Electrical conductivity Satellite imagery	Industrial crop	Australia
2014	Journal of Agricultural and Resource Economics	39: 106–123	Lambert, D M English, B C Harper, D C Larkin, S L Larson, J A Mooney, D F Roberts, R K Velandia, M Reeves, J M	Adoption and frequency of precision soil testing in cotton production	Georeferenced soil testing	Industrial crop	United States
2014	Agricultural Engineering International: CIGR Journal	16:119-123	Bagheri, N. Bordbar, M.	Solutions for fast development of precision agriculture in Iran	Not described	No industry mentioned	Iran
2014	International Journal of Agricultural Science, Research and Technology in Extension and Education Systems	4:185-189	Yazdanifar, A.	Identify the barriers to the application of precision agriculture in Khouzestan province, Iran	Not described	No industry mentioned	Iran

2014	Sustainability	6 : 8452-8465	Lencses, E Takacs, I Takacs-Gyorgy, K	Farmers’ Perception of Precision Farming Technology among Hungarian Farmers	Auto guidance technology	No industry mentioned	Hungary
2014	Precision Agriculture	15:403-426	Busse, M. Doernberg, A. Siebert, R. Kuntosch, A. Schwerdtner, W. König, B. Bokelmann, W.	Innovation mechanisms in German precision farming	Yield mapping Soil sampling	No industry mentioned	Germany
2014	Precision Agriculture	15:427-446	Watcharaanantapong, P. Roberts, R. K. Lambert, D. M. Larson, J. A. Velandia, M. English, B. C. Rejesus, R. M. Wang, C.	Timing of precision agriculture technology adoption in US cotton production	Grid soil sampling Remote sensing	Industrial crop	United States
2014	HortTechnology	24:81-87	Caplan, S. Tilt, B. Hoheisel, G. Baugher, T. A.	Specialty crop growers' perspectives on adopting new technologies	Harvesting technology Automated traps	Fruit	United States
2014	International Sugar Journal	116:278-285	Markley, J. Hughes, J.	Understanding the barriers to the implementation of precision agriculture in the central region	Variable rate technology Electrical conductivity Satellite imagery	Industrial crop	Australia
2013	Studies in Agricultural Economics (Budapest)	115: 40-46	Takacs-Gyorgy, K. Lencses, E. Takacs, I.	Economic benefits of precision weed control and why its uptake is so slow	Soil sampling Variable rate technology Yield mapping	No industry mentioned	Hungary
2013	Wine and Viticulture Journal	28: 69-73	Bramley, R	Wine sector attitudes to the adoption of Precision Viticulture	Remote sensing Yield mapping	Grape	Australia
2013	Engenharia Agricola	33: 575-588	Bramley, R. Trengove, S.	Precision agriculture in australia: Present status and recent developments	Autosteer Variable rate technology	Grain, industrial crop	Australia

					Yield monitor		
2013	Middle East Journal of Scientific Research	13: 1230-1237	Adekunle, I. O.	Precision agriculture: Applicability and opportunities for Nigerian agriculture	Yield mapping Remote sensing	Grain, vegetable, industrial crop, fruit, grape, oleaginous	Nigeria
2012	International Journal of AgriScience	2: 860-874	Salehi, S. Hayati, D. Karbalaee, F. Chin, W. W.	Factors affecting intention to use variable rate technology-tillage by structural equation modeling	Variable rate technology-tillage	No industry mentioned	Iran
2012	Precision Agriculture	13: 181-199	Robertson, M J Llewellyn, R S Mandel, R Lawes, R Bramley, R G V Swift, L Metz, N O'Callaghan, C	Adoption of variable rate fertiliser application in the Australian grains industry: status, issues and prospects	Variable rate technology Yield mapping	Grain	Australia
2012	Computers and Electronics in Agriculture	87: 121-128	D'Antoni, J M Mishra, A K Joo, H	Farmers' perception of precision technology: The case of autosteer adoption by cotton farmers	Autosteer	Industrial crop	United States
2012	Precision Agriculture	13: 713-730	Tey, Y S Brindal, M	Factors influencing the adoption of precision agricultural technologies: a review for policy implication	Variable rate technology Yield mapping	Not mentioned	Not described
2012	Indian Journal of Animal Research	46: 389-392	Kumar,B. R. Dharmar, B. Pandian, A. S. S.	Factors influencing the adoption of new feeding technology by the Farmer Interest Groups (FIGs) of vellore district in Tamil Nadu		Livestock	India

2012	Decision Support Systems	54: 510-520	Aubert, B A Schroeder, A Grimaudo, J	IT as enabler of sustainable farming: an empirical analysis of farmers' adoption decision of precision agriculture technology	Yield monitor Geographic information systems	Cereal and oleaginous	Canada
2011	African Journal of Agricultural Research	6:1219-1225	Najafabadi, M. O. Hosseini, S. J. F. Bahramnejad, S.	A Bayesian confirmatory factor analysis of precision agricultural challenges	Geographic information systems	No industry mentioned	Iran
2011	Precision Agric	12:67-81	Silva, C B De Moraes, M A F D Molin, J P	Adoption and use of precision agriculture technologies in the sugarcane industry of Sao Paulo state, Brazil	Satellite images Aerial photography Automatic pilot	Industrial crop	Brazil
2011	Precision Agric	12: 2-17	Kutter, T Tiemann, S Siebert, R Fountas, S	The role of communication and co-operation in the adoption of precision farming	Auto guidance technology Yield mapping Soil sampling	Grain	Multiple locations (Czech Republic, Denmark and Greece)
2011	Agricultural and Resource Economics Review 40/1 (April 2011) 133–144	40: 133-144	Paxton, K W Mishra, A K Chintawar, S Roberts, R K Larson, J A English, B C Lambert, D M Marra, M C Larkin, S L Reeves, J M Martin, S W	Intensity of Precision Agriculture Technology Adoption by Cotton Producers		Industrial crop	United States
2011	Computers and Electronics in Agriculture	77: 7-20	Lawson, L G Pedersen, S M Sorensen, C G Pesonen, L Fountas, S Werner, A Oudshoorn, F W Herold, L Chatzinikos, T Kirketerp, I M Blackmore, S	A four nation survey of farm information management and advanced farming systems: A descriptive analysis of survey responses	Auto guidance technology Robotic milking Grid soil sampling	Vegetable, industrial crop, cereal, livestock	Multiple locations (Denmark, Finland, Germany and Greece)

2010	African Journal of Agricultural Research	5: 1191-1199	Rezaei-Moghaddam, K Salehi, S	Agricultural specialists' intention toward precision agriculture technologies: Integrating innovation characteristics to technology acceptance model		No industry mentioned	Iran
2010	HortTechnology	20: 1043-1048	Ellis, K Baugher, T A Lewis, K	Results from Survey Instruments Used to Assess Technology Adoption for Tree Fruit Production	Automated traps Remote sensing	Fruit	United States
2010	California Agriculture	64:149-154	Lopus, S. E. Santibáñez, M. P. Beede, R. H. Duncan, R. A. Edstrom, J. Niederholzer, F. J. A. Trexler, C. J. Brown, P. H.	Survey examines the adoption of perceived best management practices for almond nutrition	Tissue sampling	Fruit	United States
2010	Agricultural Science Digest	30: 270-272	Lahoti, S. R. Chole, R. R. Rathi, N. R.	Constraints in adoption of sugarcane production technology.	Not described	Industrial crop	India
2010	Precision Agric	11: 135-147	Walton, J C Roberts, R K Lambert, D M Larson, J A English, B C Larkin, S L Martin, S W Marra, M C Paxton, K W Reeves, J M	Grid soil sampling adoption and abandonment in cotton production	Grid soil sampling Variable rate technology	Industrial crop	United States
2009	Precision Agric	10: 73–94	Reichardt, M Jurgens, C	Adoption and future perspective of precision farming in Germany: results of several surveys among different agricultural target groups	GPS based soil sampling Yield mapping Variable rate technology	No industry mentioned	Germany

2009	Precision Agriculture	10: 525-545	Reichardt, M. Jürgens, C. Klöble, U. Hüter, J. Moser, K.	Dissemination of precision farming in Germany: Acceptance, adoption, obstacles, knowledge transfer and training activities	Yield mapping GPS based soil sampling	No industry mentioned	Germany
2008	Computers and Electronics in Agriculture	64: 140-148	Torbett, J C Roberts, R K Larson, J A English, B C	Perceived improvements in nitrogen fertilizer efficiency from cotton precision farming	Yield monitor Remote sensing Grid soil sampling	Industrial crop	United States
2008	Precision Agric	9: 195-208	Larson, J. A. Roberts, R. K. English, B. C. Larkin, S. L., Marra, M. C. Martin, S. W. Paxton, K W Reeves, J M	Factors affecting farmer adoption of remotely sensed imagery for precision management in cotton production	Remote sensing Variable rate technology	Industrial crop	United States
2008	Computers and Electronics in Agriculture	62: 231-242	Isgin, T Bilgic, A Forster, D L Batte, M T	Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption	Grid soil sampling Variable rate technology Yield monitor	No industry discussed	United States
2008	Journal of Agricultural and Resource Economics	33: 428-448	Walton, J C. Lambert, D M. Roberts, R K. Larson, J A. English, B C. Larkin, S L. Martin, S W. Marra, M C. Paxton, K W. Reeves, J M.	Adoption and Abandonment of Precision Soil Sampling in Cotton Production	Soil sampling Variable rate technology	Industrial crop	United States
2007	Soil and Tillage Research	97:272 - 281	Tullberg, J N Yule, D F McGarry, D	Controlled traffic farming - From research to adoption in Australia	Controlled traffic farming	No industry mentioned	Australia
2007	Field Crops Research	104: 68-76	Jochinke, D C Noonon, B J Wachsmann, N G Norton, R M	The adoption of precision agriculture in an Australian broadacre cropping system-Challenges and opportunities	Autosteer Yield monitor Aerial photography	No industry discussed	Australia

2007	Agricultural finance review	67: 295-310	Nganje, W E Friedrichsen, M S Gustafson, C R McKee, G	Marginal impact of sales consultant visits and financing opportunities on adoption of variable-rate fertilizer application	Variable rate technology	Grain, vegetable, oleaginous	United States
2005	Computers and Electronics in Agriculture	48: 256-271	Adrin, A M Norwood, S H Mask, P L	Producers' perceptions and attitudes toward precision agriculture technologies	Grid soil sampling Yield monitor Remote sensing	No industry discussed	United States
2005	Computers and Electronics in Agriculture	48: 256-271	Adrin, A M Norwood, S H Mask, P L	Producers' perceptions and attitudes toward precision agriculture technologies	Grid soil sampling Remote sensing Yield monitor	No industry discussed	United States
2004	Acta Agriculturae Scandinavica Section B: Soil and Plant Science	54: 2-8	Pedersen, S M Fountas, S Blackmore, B S Gylling, M Pedersen, J L	Adoption and perspectives of precision farming in Denmark	Yield mapping Variable rate technology Soil sampling	Grain and oleaginous	Denmark
2004	Adoption and perspectives of precision farming in Denmark	54: 2-8	Pedersen, S M Fountas, S Blackmore, B S Gylling, M Pedersen, J L	Adoption and perspectives of precision farming in Denmark	Yield mapping Variable rate technology Soil sampling	Grain and oleaginous	Denmark
2003		51: 39-53	Hudson, D Hite, D	Producer Willingness to Pay for Precision Application Technology: Implications for Government and the Technology Industry	Variable rate technology Yield monitor GPS guidance	Not mentioned	United States
2003	Computers and Electronics in Agriculture	38: 125-139	Batte, M T Arnholt, M W	Precision farming adoption and use in Ohio: case studies of six leading-edge adopters	Yield monitor Variable rate technology Grid soil sampling	Grain	United States
2001	American Journal of Agricultural Economics	83: 35-51	Khanna, M	Sequential adoption of site-specific technologies and its implications for nitrogen productivity: a double selectivity model.	Variable rate technology	Grain	United States

Appendix B: Condensing the text (the Australian case studies and the repors, and the strategic plans of the Australian RDCs) and identifying the keywords/codes regarding PA adoption

Author of submissions, reports, case studies /Industry	Title and page number of the collected information	Key issues/adoption influencing factors (Condensing the text)	Key findings/recommendations (Condensing the text)	Identifying the keywords or codes
1. The University of Melbourne (2015)/ No particular industry is mentioned.	Submission from the Rural Innovation Research Group to the Inquiry into Technological Advancement in Agriculture, Submission no. 4, pp. 2-5	- Characteristics of the technology or practice, e.g., level of implementing difficulty, cost - Characteristics of the target population such as financial capacity, education level - Relative advantage of using the technology/ practice, e.g., benefits or profitability, incentives for change - Capacity to learn/adapt to generate a relative advantage such as support networks to aid decision-making and learning - The learning challenge such as development of new skills - The management challenge such as data management, information in decision making and application of new skills and training employees - The ethical and moral challenge	- Provide incentives to support the use of multi-disciplinary and trans-disciplinary R&D teams - Investment in capacity building of farmers and advisors related to data interpretation - Investment in research to better understand the implications of the privatization of advisory services on farmers' utilization of emerging agricultural technologies - Explore and encourage greater opportunities for collaboration and networking - Consider establishment of a cross-sectoral research program related to the institutional arrangements and policy context	<u>**Innovation (12)**</u> - Agricultural innovation systems - Agricultural innovation - Continued innovation - Innovation - Innovation systems - Innovation network - Innovation process <u>**Adoption (16)**</u> - Adapt - Adapting - Adaptation - Adoption decisions - Variation in adoption - Potential adopters - Adopters - Farmers' adoption <u>**Technology/technologies (45)**</u> - Emerging technology - Agricultural technology - New technology/ies - Technology developers - Technology hardware - Deployment of technologies - Technology applications

				- Technology practice - Technology utilization - Adoption of technology - Precision technology - Technological advancement
2. Precision Agriculture Pty Ltd (2016)/ No particular industry is mentioned.	Submission for Agricultural Innovation Enquiry, Submission 106, pp. 1-2	- Methods to rapidly adopt new technology that actually work - A massive gap between university research and on-farm commercial adoption - Technologies are purchased from overseas - Exchange rate of dollar influences purchasing of technology from overseas	- Cost: Technology needs to reduce the costs of growers - Convenience: needs to make the lives of farmers easier - Compliance: technology needs to assist farmers if they are required to perform something. - Capacity: technology needs to enable famers to do more with less effort - Complexity: a piece of technology can deliver benefits - Champions: local farmer champions - The source of new technology should be Australia. - Government support is essential.	**Technology (16)** - New technology - Latest technology - PA technology - Variable rate technology - Adopting technology - Adoption of new technology - Adopt new technology - Technology adoption - Piece of technology - On-farm technology - Technology adoption **Innovation (5)** - Innovative products - Innovative technology - Agricultural innovation - Innovation in agriculture
3. Australian Women in Agriculture (2015)/ No particular industry is mentioned.	Agricultural Innovation, Submission 63, pp. 2-6	- Base of information - Technologies to improve sustainability - Training (Impacted by age) - Financial and environmental benefits	- Building telecommunication infrastructure - Encourage Ongoing R&D - Support farmer with training	**Technologie/technologies (8)** - New technologies - Modern agricultural technologie - Precision farming technologies - Précision technologie - Communications technologies

			- Face to face, online, print media training	- Mobile technologies **Training (16)** On-line training Training funding Access training Enrolling in the training
4. University of South Australia (2015)/ No particular industry is mentioned.	Agricultural Innovation Submission 7, pp. 1-2	- Optimising the land and resources - Increase production - Area of extension and commercialisation regarding applicability of technology, product, and service	- Agencies should increase investment - Technology needs to be further developed into commercial equipment -Demonstration of the technology products	**Technology/technologies (9)** - Advanced technologies - New technologies - Emerging technology - Sensor technologies - Sensor technology - Remote sensing technologies - New emerging technologies
5. Queensland Dairyfarmers' Organisation Ltd (2015)/ Dairy farming	Inquiry into role of technology in increasing agricultural productivity in Australia, Submission 15, pp. 1-3	- Confidence of farmers to invest in the business - Farm profitability	- Government legislation/support - Dairy industry experienced low profit	**Technology/technologies (7)** - Role of technology - Emerging technology/ies - New technology **Government/s (7)** - Government decisions - Successive governments - Effect test by Federal - Extension of unfair contract by Federal Government - Role of government - Report from Federal and State Governments
6. Sorensen (2016)/ No particular industry is mentioned.	Inquiry into and Report on Agricultural Innovation, Submission 114, pp. 4-8	- Impact on productivity -Cost, complexity - Networking capacity of producers - Quality and cost of essential infrastructure such as internet and energy supplies - Effectiveness of government-led organization - Acceptance of risk - Knowledge, idea, and decision-making capacity - Imagination, creativity, originality, and willing-ness to break with tradition	- Development of venture and other risk capital funds - Establish online forum documentation of all new technologies for the develop-ment of knowledge, ideas, and decision-making capacity. - Online multiple support - Recognition of the risk of failure. - Support from government	**Technology/ies (40)** - Role of technology - New technology\ies - Emerging technology\ies - Form of technology - Branch of technology - Particular technology - Application of technology - Technologies transfer - Use of technology - Transformative technologies - Individual technologies - Technological advances - Educational technologies - Other technologies - New financial technologies - Transforming technologies - Distinct technologies

			agencies, other business, community groups, private mentors.	- Transformative technology **<u>Government/s (12)</u>** - Government agencies - Effectiveness of government-led organization - Cameron government - Obama government - Australian Government
7. Department of Agriculture and Water Resources (2015)/ No particular industry is mentioned.	House of Representatives Standing Committee on Agriculture and Industry, Inquiry into Agricultural Innovation, Submission 88, pp. 5-16	- Save labour costs, helps to collect data, and pest and disease control - Access to broadband capacity - Different learning styles, such as face-to- face - Financial capacity to adopt research and development outcomes - System complexity, compatibility	- Involvement of private sector - Conducting effective extension programs - Inadequate protection of sensitive data	**<u>Innovation (29)</u>** - Investment in innovation - New innovations - Agricultural innovation - Adoption of innovation - Innovation of products - Innovation of Australia's primary industries - Publication on innovation - Role of innovation - Innovation process **<u>Research and development</u> <u>(R&D-42)</u>** - Agricultural research - RD&E - Adoption of R&D **<u>Government (21)</u>** - Government investment - Australian Government - Government programs - Government fund\s **<u>Adoption (23)</u>** - Adoption of technological and research outcomes - Barriers to adoption - Likelihood of adoption - Adoption of new technology - Adoption in Australian agriculture - Grower adoption
8.Deakin University (2015)/ No particular industry is mentioned.	Agricultural Innovation Inquiry, Submission 28, pp. 3-6	- Low cost and real-time monitoring of resources used in production - Cost/time: time required for validating technologies - Lack of awareness regarding benefit of technologies in other sectors	- Knowledge sharing - Interaction between agricultural sector and university - Creating policy and planning environment	**<u>Technology/technologies</u>** **<u>(25)</u>** - New technology/ies - Emerging technology/ies - Cost of technology - Irrigation technology - Suitable technology

		- Lack of data interpretation ability - Legislation such as CASA may prohibit to use of some drones		- Existing technology - Use of technology - Mobile phone technology - Technology deployed - Application of technology - Technology interface - Farm technology **Knowledge (6)** - Knowledge of the specific industry - Knowledge of all available technology - Required knowledge - Specific technical knowledge - New knowledge - Useful knowledge
9. Grains Research and Development Corporation (2015)/ No particular industry is mentioned.	The role of technology in increasing agricul-tural productivity in Australia, Submission 87, pp. 10-20	- Increase efficiency of production - Cost and complexity issues, such as consuming time and attention - Lack of commercialization to market	- Involvement of advisors and leading growers in R&D - Establishing network of growers, consultants, and researchers	**Technology/technologies (46)** - Development of technology - Technology improvements - New technology/ies - Technology available - Emerging technology/ies - Agricultural technology - Agricultural automation technology - Technology development - Technology transfer - Discovery of new technology - Curent technologies - PA technologies **Adoption (24)** - Adoption risk - Adoption of new technology/ies - Adoption of current technologies

				- Barriers to technology adoption - Adoption by growers - Adoption of research findings - Adoption rate - Complexity of adoption - Cultural determinants of adoption - Decision on adoption - Improving adoption - Effective adoption - Adoption of new knowledge **Grains Research and Development Corporation (GRDC 54)** - GRDC funding - Importance of GRDC - Recent structure of GRDC
10. The University of Sydney (2015)/ No particular industry is mentioned.	Inquiry into Agricul-tural Innovation, Submission 40, pp. 4-7	- Saving of labour - Increased productivity and product quality - Improved retention of staff - Lack of time - Lack of skills and money	- Education for innovation - Collaboration between industry, university, and government - Improvement in extension	**Technology/ies (25)** - Information technologies - New technology\ies - Technology/ies - Labour-saving technologies - Technology intervention - Technological solutions - Advancement in technology - Emerging technology\ies - Application of technology - Technology-driven agriculture - Costs of technology - Technology adoption - Agricultural technology - Technological innovation - Technological solutions

				Innovation (6) - Horticultural Innovation Australia Limited - Agricultural innovation - Education for innovation - Roll out innovation **Productivity (13)** - Agricultural production - Farm production - Food production - Animal production - Production management - Production of bulk commodities - Livestock production
11. Winemakers' Federation of Australia (2015)/ Grape	Submission to the House of Represent-atives Agriculture and Industry, Committee Inquiry into agricul-tural innovation, Submission 12, pp. 4-9	- Reduced input cost and improved production - Not enough investment in public R&D	- Government support for agricultural research - Extension and dissemination of the outcomes - Cooperative research approach among industry, researchers, and government	**Research and development (R&D- 22)** - R&D - R&D process - R&D outcomes - R&D capability - R&D investment - Results of R&D - Investment in R&D - Scope of R&D - Grape and Wine R&D **Technology/technologies (18)** - Emerging technology/ies - New technology/ies - Gene technology - Developing technologies - Application of the technology - Biotechnology

				- Innovative technology
12. Charles Sturt University (2015)/ No particular industry is mentioned.	Agricultural Innovation, Submission 17, pp. 2-5	- Reduce input costs and improve crop yield - Trust of adopter on desired outcome provided by technology	- Involvement of farmer in testing of new technology - Integration of RD&E approach	**Technology/ies (26)** - Adoption of emerging technology/ies -Adoption of new technology/ies - Sensor technology - Evaluation of technology - Genome-editing technologies - Integrating multiple technologies - Modern reproductive technologies **Adoption (11)** - Adoption on the whole farm system - Rate/s of adoption - Barriers to the adoption - Standard adoption - Accelerate adoption - Enhance adoption - Implication of adoption - Level of adoption
13. Department of Primary Industries and Regions South Australia (2015)/ No particular industry is mentioned.	Submission to the House of Representatives Inquiry into Agricultural Innovation, Submission 19, pp. 8-12	- Small size of farm - Potential regulatory constraint - Provides weather information	- Elimination of unnecessary regulation - Government support to build the capability of farmers - Increase awareness among farmers	**Technology/ies (45)** - Clean technology - South Australian Technology - New technology/ies - Supporting technology - Insect technology - Emerging technology - Coordinating technology - Novel technology - Transport technology - Adoption of technology - Adoption of new technologies -Technology advancing - Technology company - Key technology developments - Production technologie - Use of technologies - Surveillance technologies - Shed technologies

				- Exploit technologies **Research and development (42)** - Other research organisation - Industrial research organisation - Australian Research and Development Institute - Research outcomes - Agronomic research - Regional research - Targeted research - Australian research - Biosecurity Cooperation Research Centre - Grape and Wine Research and Development Institute - New research projects - GRDC - Applied research - Domestic research - International research - Research agencies - ABARES research report **Innovation (14)** - Agricultural innovation SA Food Innovation Centre - New technological innovation - Product innovation - Improved innovation
14. Precision Cropping Technologies (2015)/ No particular industry is mentioned.	Submission to House of Representatives Agricultural Committee Inquiry, Submission 24, pp. 2-5	- Improve the ability of growers to manage within field variability - Lack of higher education programmes in PA - Effective use of input	- Educational programmes should include PA concepts	**Internet (8)** - Internet access - Internet service - Internet coverage

			- Government support - Internet access and data upload and download	- Reliable internet **<u>Précision Agriculture </u>(PA-13)** - Concepts in PA - Evolution of PA - Precision Ag support - PA conference - Associate professor in PA - PA laboratory
15. Australian Dairy Farmers (2015)/ Dairy farming	Response to Agricultural Innovation Inquiry, Submission 65, pp. 2-8	- Offers to increase productivity and competitiveness - Lack of upfront capital, cost for farmers - Limited after sales service - Reduction in state government investment - Increased productivity and competitiveness - Extension, community attitude, and values	- Government supports, such as incentives - Combination of professional independent advice, training and education, technology support, and financial incentives	**<u>Innovation (38)</u>** - Development of innovation - R&D for innovation - Risks in innovation - Role of innovation - Support for innovation - Innovation for dairy farm - Impact of innovation - Targeted innovation - Application of innovation - Under-investment in innovation - Innovation on farm -Invest in innovation **<u>Technology/ies (46)</u>** - New technology/ies - Emerging technologies - MIR technology - Energy technology - Commercial technology - Technology decisions - Technology management - Technology assessment - Technology support

				- Appeal of technology - Recent technologies - Newer technologies - System technologies - Digital technologies - Existing technologies - Management technologies - Appropriate technologies - Advance technologies - Multiple technologies
16. Australian Sugar Milling Council (2015)/ Sugarcane	Submission to the Parliamentary Inquiry into Agricultural Innovation, Submission 68, pp. 1-7	- Improve productivity and environmental outcomes - Cost of new technology, cost of components, such as base station, installation and implementation cost - Lack of upfront capital cost - Poor network and data communication - Small size of the Australian sugar industry	- Australian Government funding encourages adoption of technology - Extension services demonstrating benefits - Cost effective mobile data technology	**Technology/ies (26)** - Adoption of technology - Range of technology - New technology/ies - Emerging technologies - GPS technology - Driverless technology - Data transfer technology - Satellite technology - Aerial technology - Roles of technology - Facial recognition technology - Robotic technology **Cost/s (14)** - Cost of components - Cost of implementing - Cost of installing - Cost effective - Low cost - Capital cost - Cost of electricity

				- Cost of products - Upfront costs **GPS (9)** - GPS guided - GPS operated - GPS tracker **Adoption (9)** - Barrier to adoption - Extension for adoption
17. Growcom (2015)/ Vegetable and fruit			- Levy funds could be spent - Investment in extension - Support early adopters	**Technology/ies (36)** - New technology/ies - Improved technology - Insect technology - Cool chain technology - GM technologies - Technology for native pests - Water use efficiency technology - Uptake of new technology - Current technology - Picking technology - Technology transfer - Irrigation technology - Higher risk technology - Modern communications technology
18. Australian Pork Limited (2015a)/ Meat	Inquiry into Agricultural Innovation, Submission 70, pp. 3-4	- Prediction of lean meat yield - Internet access	- Government matching funding	**Technology/ies (8)** - The role of technology - New biotechnologies - Recombinant technologies - Waste technologies - Cleaner composting technologies - Traceability technology

				- Barriers to technology adoption - Adopt new technologies
19. Australian Farm Institute (2015)/ Industrial crop (Cotton)	Inquiry into Agricultural Innovation, Submission 85, pp. 3-5	- Productivity improvement - Availability of suitably skilled technicians - Essential scientific knowledge - Computer storage and data integration software systems - Good telecommunications access - Regulatory cost and control associated with registration of new chemicals and novel plants and animals - Progressive reduction in public investment in R&D - Lack of sufficient efforts to engage in discussion - Low quality telecommunication service	- Government or joint industry collaboration	**Technology/ies (28)** - Adoption of new technology/ies - Agricultural technology - Robotic technology/ies - Emerging technology/ies - Digital technology/ies - Role of technology - Genetic technologies - Application of new technologies - Digital monitoring technologies **Productivity (24)** - Future productivity - Productivity growth - Agricultural productivity - Annual productivity - Livestock production - Agricultural production - Intensive production
20.Cotton Australia (2015)/ Industrial crops (Cotton)	The role of technology in increasing agricultural productivity in Australia, Submission 72, pp. 2-11	- Maximizing yield - Robust connections between R&D providers, researchers, policy staff, extension staff, and local grower/industry groups - Important leadership from local grower and industry groups driving research, stewardship activities, and policy direction - Access to large data sets through digital platforms	- Government support such as funding, reduction of regulatory burden, uptake of insurance - Industry consultation for review of agricultural chemicals - An established extension network to drive adoption of innovation	**Technology/ies (18)** - Role of technology - Emerging technology/ies - New technology - Implementation of technologies - Adoption of technologies - Transgenic technologies - Smarter ginning technologies - Biotechnology - Patent free technology

		- Regulatory burden		Innovative technologies **Management (27)** - Best management - Soil management - Pest management - Risk management - Farm management - Resistance management - Demand management **Innovation (22)** - Adoption of innovation - Innovation strategies - Significant innovation - Transgenic innovations **Government (25)** - Government support - Government investment **Regulatory (19)** - Regulatory burden for growers - Regulatory system/s - Regulatory process/es - Premature regulation
21. Grains Research and Development Corporation (2014)/ Grain	SPA00010 - Training and Demonstration of PA in Practice, pp. 3-6	- Economic and environmental benefits - Compatibility issues of equipments - Lack of computer skills - Limited support service - Low confidence - Lack of reliable local results	- PA training courses for growers and advisers - On-farm demonstration - Involvement of grower group	**Precision agriculture (PA-45)** - PA adoption - PA on agenda - PA goal - Adoption of PA - PA tools - PA training - PA grower groups - Adoption of PA

				- Extension of PA - Knowledge of PA - PA - PA in practice - PA on-farm - PA technology - PA support - PA equipment - PA uptake - Benefit of PA - PA in practice - Emphasis on PA - PA needs - PA sysmposium - PA projects - PA news - PA course - PA service providers - PA related activities - Advisers to PA - Application of PA **SPAA Precision agriculture Australia (37)** **Grains Research Development Corporation (GRDC- 21)**
22. Grain Research and Development Corporation (2016)	CSA00028 - Empirical Studies of Farming Systems Technology Adoption, pp. 3-6	- Increase crop profit-ability - Improve land manage-ment - Growers perceive that technology increases complexity	- Farm adviser plays an important role - Needs sufficient willingness to be familiar with technology	**Adoption (64)** - Adoption of key farming systems - Variable rate adoption - Low adoption - Adoption of profitable practices - Adoption in the Australian grains industry

				- Rapid adoption - Adoption of spatial management practices - Adoption of PA related practices - Adoption of PA - Adoption rate/s - Alignment with adoption - Adoption of beneficial practices - Time to adopt - Accelerated adoption - Adoption of cropping practices - Adoption of farming systems - Adoption by growers - PA technology adoption - Stages of adoption - Adoption process - Adoption constrainsts - Potential adoption - Adoption of PA related cropping pracitces - Adoption of PA - Adoption of many complex innovations - Innovation adoption process - Higher adoption - Adoption of new innovations - Adopton of farm organisational innovations - Adopton of complex innovations - VRT adoption - Potential adopter - Adopters of advisers **Technology/ies (14)**

				- New technologies - Technology/ies - PA technology - Spatial information technologies - Complex technologies **Inovation (15)** - Farm business structure innovation - Business structure innovation - Farm business innovations - Complexity of innovations - Stages of the innovation - Particular innovation - Agronomic innovation - Organisational innovations
23. Grains Research and Development Corporation (2013)/ Grain	SIP09 Precision Agriculture Initiative. Unlocking the benefits of PA for farm profits and the environment, pp. 2-5	- Economic and environmental benefits - Managerial ability is required - Many farmers use yield monitoring	- Engagement with farmer and farmer groups	**Technology/ies (10)** - PA technology - Variable rate technology (VRT) - Implementing VRT - Use of the technology - PA technology/ies **Adoption (5)** - Wider adoption - Adoption of PA
24. Grains Research and Development Corporation (2010)/ Grain and oil	US00017 - Incorporating PA into Australian farm management, pp. 1-6	- Economic, social, and environmental benefits - Coordinated farmer groups - Educational materials -Industry training	- Crop yield mapping was the best method to quantify crop yield - Electrical conductivity appeared to be the best predic-tor of spatial variabilty in crop yield	**Precision agriculture (PA-29)** - Uptake of PA - Integrating of PA - PA into farm management - PA in Australian farm management - Research into PA - PA techniques - Australian centre for PA

			- Gamma radiometric is an alternative - Outcome of the project should be communicated - Further research in PA is essential	- PA management - Rewards of PA - PA tools - Information on PA - Understands of PA
25. Llewellyn and Ouzman (2014)/ Grain	Adoption of PA-related practices: status, opportunities and the role of farm advisers, pp. 25-44	- Reduce input costs and increased profitability - Data management skill - Availability of technical support	- Availability of agronomic advice	**<u>Adoption (115)</u>** - Adoption by farmers - Rapid adoption - Trends in adoption - Adoption decisions - Adoption status - Adoption of PA practices - Rate of adoption - Adoption of a range of farming practices - Early time of adoption - Adoption curves - Adoption variables - Adoption of cropping practices - Adoption of autosteer - PA adoption - Adoption over time - Adoption of yield mapping - High adoption pattern - Adoption figures - Adoption intensions - Constraint to adoption - Probablity of adoption - Adoption of spatial management - Current adopters - Auto steer adopters

				- Yield map adopters - Expected adopters **<u>Technology (53)</u>** - PA technology - PA technology - Variable rate technology (VRT) - Computer technology - Low-technology - Uptake of a new technology
26. Precision Agriculture (2014)/ Grain/ Case study, Pate Farming, Murray Valley NSW	PA in rice production: grower experience and insights, pp. 1-4	- Improvement in the efficiency of field operation, cost saving on inputs and yield increase - Variability reduction - Information acquired from manufacturer, community base station, consultant - Equipment compatibility issue - Data analysis skill and time	- Using one system to miminise problem - Using PA consultant	**<u>Technology/ies (6)</u>** - PA technology/ies - Variable rate application technology - Technology hardware - Cutting edge **<u>Controlled traffic farming(CTF- 13)</u>** - Adoption of CTF - CTF system
27. Precision Agriculture (2014)/ Grain/ Case study, Sleigh Farming, Jerilderie, NSW	PA in rice production: grower experience and insights, pp. 5-6	- Fatigue reduction - Information gathering from friends, agricultural publications, community base station, contractor		**<u>Technology (4)</u>** - PA technology - GPS technology - Investment in technology - Technology hardware
28. Precision Agriculture (2014)/ Grain / Case study, Hicks Farming, North West of Deniliquin	PA in rice production: grower experience and insights, pp. 7-8	- Fatigue reduction, increased efficiency of inputs and time saving - Information gathering from agronomist		**<u>Controlled traffic farming (CTF- 4)</u>** - Goal of CTF - CTF system

29. Precision Agriculture (2014)/ Grain / Case studies, Demo Farm, Coleambally	PA in rice production: grower experience and insights, pp. 9-10	- Provides information regarding variability - Information gathering from agronomist and community base station		**Technology (4)** - PA technology - Auto steer technology - Mapping technology - Technology hardware
30. Precision Agriculture (2014)/ Grain / Case studies, Arnold Farming, Jerilderie	PA in rice production: grower experience and insights, pp. 11-12	- Reduction in overlap-ping of inputs - Information gathering from community base station		**Technology (3)** - Adopting PA technology - Technology hardware
31. Precision Agriculture (2014)/ Grain/ Case studies, Brill Farming, Griffith	PA in rice production: grower experience and insights, pp. 13-15	- Ease of operation and over-spray reduction - Information gathering from consultant, local dealer, neighbour		**Technology (6)** - PA technology\ies - Technology hardware
32. Rural Industries Research and Development Corporation (2017)/ Not mentioned	Strategic R&D Plan 2017-2022, pp. 10-52	- Focused on four areas, such as people and leadership, national challenges and opportunities, growing profitability, and emerging industries - People and leadership - To help people driving the future success of Australian rural industries and regional communities - To attract talented people into agricultural careers and to build competence of future leaders - Natural challenges and opportunities - To recognize and encourage research and innovation opportunities - Adapting new technology and working collaboratively on problems across rural sectors		**Government (s) - 17** - Australian Government - Government research **Skill - (17)** - Business skills - Skilled workforce - Skilled people - Skills - Skills transfer **Profitability - (11)** - Long-term profitability - Growing profitability - Profitability **Collaboration – (11)** - Internal collaboration -International collaboration **Management – (22)** - Management practices - Risk management **Investment – (35)** - Investment efforts - Co-investment - Levy investment - Public investment **Leadership – (19)** **Innovation – (25)**

		- Growing profitability - To enhance the profitability and sustainability of levied rural industries - To engage industry participants, spending on innovation, and delivering outcomes of research to increase industry uptake and adoption - Emerging industry - To support new and emerging rural industries - Communication with stakeholders through workshops, field days, emails, newsletters, social media, websites, and meetings – Government contribution, industry levy, rural RDCs, private companies provide fund		
33. Grains Research and Development Corporation (2012)/ Grain	Strategic Research & Development Plan 2012-17, pp. 1-3	- Understanding market opportunities for Australian grain - Genetic yield probable and steadiness improvement of cereal, pulse and canola varieties - Effective and sustainable management of weed, pest and diseases - Improving soil health, and water management - Management of leadership and communication program and capacity building of grain growers - Creating value by investing on RD&E		**Benefits – (30)** - Social benefits - Cost benefit - Overall benefits Greatest benefits **Management (51)** - Management of natural resources - Risk management - Management of woods - Management tools - Management techniques - Management practices - Fungicide management - Disease management

		- Coordinating the programs nationally and the output of the research are delivered to stakeholders regionally - GRDC relates to international RD&E sector to identify potential opportunities - Two-way communication with stakeholder about its investment and activities - Government contribution, growers' levy are the sources of fund		- Management cereal rusts **Government – (14)** - Government agencies - State government support -Territory government
34.Australian Pork Limited (2015b) /Pork	Strategic Plan 2015-2020, pp. 6-36	- Growing consumer appeal - Improving product quality - Advertising the product with celebrity chefs and television food programs - Product differentiation - Building markets - Deep understanding of markets - Development of both domestic and international markets - Driving value chain integrity - On-farm quality assurance system - Good agricultural practices - Meeting the needs of consumers in a timely manner - Leading sustainability - Addressing societal needs		**Development – (14)** - Regulatory development - Development of policy - Development plan **Management- (25)** - Value chain management - Risk management - Project management -Manure management - Effective management - Research management - Property management -Environment management **Fund – (14)** - Commonwealth funding - Statutory funding - Government funding - RD&E funding - Matching funds

		- Managing healthy herds and farms - Continuing growth of productivity - Improving capability - Disseminating the research outcomes - Building industry image and reputation		
35. Wine Australia (2015)/ Grape	Strategic Plan 2015-2020, pp. 8-42	- A successful Australian grape and wine community with a unity of purpose - Promoting Australian wine in domestic and international markets - Protecting the reputation of Australian wine - Building Australian grape and wine excellence - Improving resource management and sustainability - Improving vineyard and winery performance - Enhancing market success - Investing in developing the leadership and personal skills of future leaders - Continue partnership with wine sector organisations - Delivering new knowledge and encouraging the personal and professional development of grape growers and wine makers - Delivering extension and practical trials		**Benefits - (7)** - RD&E benefits - Benefits of recognition - Benefits of Australian wine **Fund - (16)** - Funding - Matching funding -Market development funding - Regulatory funding - RD&E funding **Investment – (25)** - RD&E investments - Australian Government investment - Projected investment **Levies – (10)** **Adoption - 25**

36. Cotton Research and Development Corporation (2013)/ Cotton	Strategic R&D Plan 2013-2018, pp. 5-31	- A worldwide competitive and reliable cotton industry - Profitable and farmers' crop of preference continuously - Successful crop protection from pest, weed, and disease - Optimisation of inputs for cotton production - Use of innovation in cotton production - Respected stewardship - Protection of production technologies and biosecurity - Managing natural resources - Capturing the full value of the product - Meeting the global benchmark with regards to quality - Australian cotton is different than international cotton - Skilled people driving the industry - Expert, educated, and progressive workforce - Connection with dynamic networks - Measurement of the performance and continuous improvement of the cotton industry		**Profit- (23)** - Profitability - Profitable **Production - (34)** - Cotton production - Global production - Production region - Production technologies - Production system **Adoption – (15)** - Adoption rate - Adoption of best practices **Investment – (50)** - Strategic investment - RD&E investment - Research investment - Investment portfolio - Industry's investment - CRDC investment - Investment strategies **Leader – (10)** - Global leader - Key leadership - Leadership skills **Government – (14)** - State and territory government - Federal government **Capacity – (25)** - Industry capacity - Internal capacity - Valuable capacity

				<u>Development – (36)</u> **<u>Communication - 11</u>**
37. Australian Eggs Limited (2017)/ Eggs	Strategic Plan 2017-21, pp. 2-17	**Vision:** Proactively support egg farmers to increase egg consumption and ensure industry sustainability - Value for money - Effective and well-resourced team responsible for marketing, and R&D - Demonstrating a clear link between key focus areas and the work conducted - Receive feedback from egg farmers - Increased consumption - Monitoring market cycles and responding to them speedily - Supply information regarding benefits of eggs and inspire awareness of egg farming - Sustainable production - Maximising the health and productivity of hens - Development of an autogenous vaccine to manage spotty liver - Development of a natural biocontrol agent to decrease salmonella contamination - Effective management		**<u>Marketing – (18)</u>** - Telemarketing - Egg's marketing - Sound marketing - Spot marketing - Marketing program **<u>Benefits – (13)</u>** - Nutritional benefit - Benefits for egg farmers **<u>Management – (8)</u>** - Disease management - Egg's management - Management practices - Best management - Better management **<u>Government - (8)</u>** - Australian Government - Government contribution

		- Consulting with egg farmers - Increasing future capacity of egg industry - Engage with retailers and regulators		
38. Sugar Research Australia Limited (2017)/ Sugar	SRA Strategic Plan 2017/18 – 2021/22, pp. 6-35	- Increase profitability across the industry value chain through innovation - Safeguard the industry from biotic threats, climate variability, environmental constraints - Build the skills, knowledge, and capacity of industry participants - Maintain investor satisfaction and positive returns investment - Improve breeding systems for genetics gain and delivery of new varieties - Improve understanding of plant physiology - Improve understanding of soil fertility - Improve soil resource management, nutrients, and chemical inputs - Enhance capacity to minimise biosecurity risks and deal with pests - Improve weed management technologies - Improve understanding and uptake of PA technologies - Improve irrigation and water management - Improve extension, communication, information and technology transfer, and adoption		**Capability- (51)** - Human capability - Capability development - Reproductive capacity - Milling capability - Extension capability - Industry capability - Leadership capability - Research capability - Workforce capability **Training - (10)** - Management training - Universal training - Research training **Government - (21)**

		- Enable regionally based partnership to private awareness and uptake of new research knowledge and technology - Attract, retain, and develop workforce		
39. LiveCorp (2016)/ Livestock	Strategic Plan 2016-2020, pp. 2-43	- Acquiring constant development in animal health and welfare across the supply chain - Development of the skills, knowledge, and capability of people, and acceptance of proof based standards - Improving the infrastructure in livestock export supply chains - Developing supply chain efficiencies and regulatory performance - Increasing the proficiency of the Australian livestock export industry regulatory structure - Delivering support for the adoption and enhancement of livestock control - Encouraging the productivity of Australian livestock export supply chain with required knowledge and tools - Offering technical advice to improve skills and infrastructure - Improve market access and conditions for both existing and new markets		**Development – (26)** - Herd development - Economic development - Trade development - Market development **Regulatory – (26)** - Regulatory performance - Effective regulatory - Government regulatory - Co-regulatory - Industry regulatory - Regulatory requirements **Collaboration – (10)** - Collaboration with international livestock export - Collaboration with key Australian and international stakeholders - Collaboration with a range of organisations **Government – (22)** - Australian Government - Overseas government **Productivity – (14)** **Skills – (9)**

		- Enhancing the understanding and knowledge of new and existing market access issues - Collaborating with the Australian Government to supply advice and support for trade and market access - Monitoring the policies of international governments which bring potential changes in demand - Develop and provide targeted exporter, government, and other stakeholders communication to encourage activities of the livestock export sector - Improving communication and informing the Australian Government and industry stakeholders of the livestock export sector - Enhancing the awareness and understanding of the livestock export industry - Increase collaboration with key Australian and international stakeholders involved in the livestock export industry - Development of the collaborative programs and long-term relationships with key livestock export industry stakeholders - Developing multi-level collaboration with international agencies,		

		foreign governments, and industries - Developing national-level collaboration with other RDCs		
40. Dairy Australia (2017)/ Dairy	Strategic Plan 2016/17 to 2018/19 (revised June 2017), pp. 8-56, and 5-40	- To drive improved levy payer profitability and to promote and protect the Australian dairy industry - Focus on animal performance, feed base and animal nutrition, people, farm business management, precision dairy and land, water and carbon - Profitable dairy farms with strategic programs such as genetic and herd improvement, animal nutrition and feeding system, cost reduction in supply chain - Capable people with regional extension service and capability development - Trusted dairy industry through pre-competitive promotion and communication activity, industry risk and reputation management - National and international collaboration		**Management- (115)** - HR management - Risk management - Profit management - Business management - Advanced management - Reputation management - Resource management - Information management - Property management **Investment – (128** - Planned investment - DA investment - Capital investment -Farm investment -Research investment - External investment - Co-investment - Key investment **Capability – (66)** - People capability - Industry capability - Management capability - Extension capability - R&D capability - Human capability - Adviser capability - Systems capability - Capability of farmers **Funding - (51)** - Research funding - Government funding - Matching funding - Strategic funding - DA's funding - Co-funding - Standard funding **Benefits- (35)** - Nutritional benefits - Health benefits - Strategic benefits

				- Industry benefits - Real benefits - Potential benefits - Maximise benefits - Dairy benefits **Communication – (61)** - Digital communications - Effective communication - Corporate communication - Formal communications - Other communication - Internal communication - Stakeholder communication - New communications **Collaboration – (20)**
41. Meat and Livestock Australia (2016)/ Livestock	Strategic Plan 2016-2020, pp. 12-35	- To promote the long-term success of the Australian red meat and livestock industry - Continuous enhancement of the welfare of animals by adopting new research in husbandry practices - Taking care of natural resources, such as soil and water - Delivering the nutritional benefits of red meat - Reducing economic and technical barriers to trade in global markets - Marketing and promoting Australian red meat and livestock - Conducting the program in genetics and genomics, animal nutrition, and reproduction to improve the efficiency of the producers' operation - Use of automation technologies and objective measurement to increase		**Productivity - (24)** - Live export productivity - Processing productivity - Feedlot productivity - Pasture productivity - SRA response **Capability - (17)** - Leadership capability - Management capability - Industry's capability **Investment - (18)** - Levy investment - Co-investment - Voluntary investment **Funding - (9)** - Government funding **Adoption - (16)** - Adoption of tools **Technologies - (15)** - Automation technologies - Weed management technologies

		efficiency and minimize production cost - Building genuine partnership - Supplying essential information to producers on time through the channels they prefer - Building leadership capability of workforce to make the industry more productive		- Electronic technologies - Processing efficiency technologies **Adoption - (16)** - Adoption of tools **Technologies - (15)** - Automation technologies - Weed management technologies - Electronic technologies - Processing efficiency technologies
42. Horticulture Australia Limited (2016)/ Horticulture	Strategic Plan, pp. 1-42	- Growing the future of Australia's horticultural industries - Communicate and listen to stakeholders using a full range of communication channels - Deliver on investment that meets the needs of growers and also increases adoption - Develop culture and leadership, investment actions and relationship - Invest in RD&E and marketing that deliver crop production, manage pests and disease - Discover, develop and use innovative technologies to increase both domestic and international competitive advantages for growers - Driving growers and supply chain capabilities		**Innovation - (28)** - Horticulture innovation - Innovation process **Investment – (176)** - Investment priorities - Cross-sectoral investment - Co-investment **Funding - (12)** - New funding - Ongoing funding **Government - (36)** - Australian Government **Communication - (13)** - Face-to-face communication - Communication strategy **Technologies - (16)** - Novel technologies - Innovative technologies New technologies **Levy - (25)** - Industry levy

				- Current levy - Levy payers - Levy funds **Leadership - (29)**
43. Australian Wool Innovation Limited (2016)/Wool	Strategic Plan 2016/17 to 2018/19, pp. 52-106	- To enhance profitability, and support the sustainability of the Australian wool industry - Improving the health of wool sheep, welfare and productivity - Farm automation and software development - Uptake of technology and training - Extensive consultation with stakeholders - Adoption of innovation technology adding significant value - Training and education of supply chain participants - Increase the participation of both domestic and international students in the wool supply chain - High quality support service - Develop and maintain effective relationships with partners across the supply chain - Provide effective communication with customers		**Profitability - (15)** - Wool grower profitability - Farm profitability - Profitability of Australian wool industry **Technologies - (17)** - Emerging technologies - New technologies - Innovative technologies - Wool technologies - Existing technologies - Management technologies **Investment - (29)** - Future investment - AWI investment - Specific investment **Government - (14)** - State Government **Education - (10)** - Student education **Training - (22)** **Innovation - (10)**

Appendix C: Survey design for future reserch

Research Methodology for a proposed survey

Further research that explores and assesses the components of the MDDDII across industries could usefully consider a combination of primary quantitative and qualitative data. Thus, a mixed method research approach would be useful for a proposed survey.

Proposed research question

The proposed research intends to assess if the nine components of the MDDDII and interactions between them would be involved in the decision to adopt or discard PA technologies by Australian growers. Thus, the proposed research will have the following research question.

RQ.1. Are the nine components relevant to PA adoption in Australia?

RQ. 2. How might failure to consider the excluded components be affecting the rate of PA adoption in Australian agriculture?

Data collection

Both quantitative and qualitative data will be collected from Australian farmers. Quantitative data will be the attributes of farmers and their farm such as age, education, farming experience, income, farm size and so on and will be collected through close ended questionnaire. Respondents, for example farmers will have an option to choose Yes, No or Don't know for their responses. Thus, no freedom will be available for respondents while collecting quantitative data. There will be 10 closed ended questions in this research.

Open ended questions will be posted to farmers while collecting qualitative data for the proposed research. Qualitative data provides in depth information regarding growers' perception to the ease of use of new technologies, the compatibility of technology with their existing farming practices, the benefits of technologies, support from government, consultants, extension staff, their financial situation and many more. These information are important aspects of MDDDII that influence the adoption of technologies. It is proposed that 19 open ended questions will provide enough information about the perception of farmers towards PA technologies adoption.

The author will prepare a draft copy of clear questions using a systematic process to find the answer for research questions. Then, the draft copy of questions will be piloted with the help of dissertation supervisors, and final questions will be formed undertaking required improvement. The prepared questions will be submitted to Human Research Ethics Committee of Central Queensland University for approval. After getting approval from Human Research Ethics Committee of Central Queensland University, these questions will be posted to the prospective respondents. It will be anticipated that respondents will provide their response in writing.

Sample size

The author will find the contact details of farmers from farmers groups, agencies, and friends. It will be proposed to select 10 farmers from each of the states: New South Wales, Victoria, Queensland, South Australia, Western Australia, and Tasmania. Thus, there will be 60 respondents in this research.

Data analysis

Farmers survey will provide qualitative and quantitative data. The qualitative data will be analysed using thematic analysis whereas the quantitative data will be analysed using correlation and regression base analysis such as SPSS.

Validity

The questions will be clear and concise to produce the valid outcomes of the research. The author will acquire support from thesis supervisors while piloting the questions and will receive the approval from Human Research Ethic Committee of Central Queensland University. The questions will be sent on the same day of the week to all respondents.

The proposed research would examine if the nine components of the MDDDII and interactions between them would be involved in the decision to adopt or discard PA technologies by Australian farmers. This knowledge would be a useful source of information to promote PA technologies adoption in Australia

Close ended questionnaire to collect quantitative data

Please tick (√) the relevant box.

1. My gender is

i. Male [ ] ii. Female [ ]

2. I am in the following age group.

i. 18-25 yrs [ ] ii. 26-35yrs [ ] iii.36-45yrs [ ] iv. More than 45yrs [ ]

3. I have farming experience of

i. 1-3 yrs [ ] ii. 4-7yrs [ ] iii. 8-10yrs [ ] iv. More than 10 yrs [ ]

4. My education level is

i. Primary school [ ] ii. Secondary school [ ] iii. Senior secondary school [ ] iv. Diploma [ ] v. Bachelor's degree [ ] vi. Master/higher degree [ ]

5. I have computer knowledge

i. Yes [ ] ii. No [ ]

6. I received income from farm

i. $50,000/yr [ ] ii. $50,001-100,000/yr [ ] iii. $100,001-$500,000/yr [ ] iv. More than $500,000/yr [ ]

7. The size of my farming land is

i. 1-50 ha [] ii. 51 ha-100 ha [ ] iii. 101 ha -200 ha iv. 201 ha – 500 ha v. more than 500 ha [ ]

8. I found field variability in my farm

i. Yes [ ] ii. No [ ] iii. Don't know [ ]

9. PA technologies provide benefits

Yes [ ] ii. No [ ] iii. Don't know [ ]

10. Use of PA technologies is difficult

Yes [ ] ii. No [ ] iii. Don't know [ ]

Open ended questionnaire to collect qualitative data

1. How aware are you about Precision agriculture (PA) technologies?

2. What technologies have you applied in your farm and why?

3. How do you acquire support from government, private or public agencies and communities to use technology in your farm?

4. How do you take decision to adopt or abandon technologies in the farm?

5. How do you receive information about technologies such as PA technologies?

6. How do you share your knowledge inside and outside of your business?

7. How strong are you financially and does the financial structure of your business impact the technologies adoption in your farm?

8. What is the vision of your business and how do you lead your business to achieve the vision?

9. How do you absorb new knowledge?

10. How do you cope the situation if your employees became unsatisfied with current process?

11. How do you manage dedicated resources in your business?

12. How do you monitor your business and provide feedback to your employees?

13. What are your own aspects that motivate you to adopt technologies?

14. What are the programs managed by technologies developers to transfer effective knowledge to you?

15. Were you invited by technologies developers to take part in development stage of technologies? If yes, what are the programs offered by technologies developers to you while promoting technologies?

16. How do you tackle the resource issues such as lack of skilled employees in your business?

17. How do you communicate internally about technologies adoption in your business?

18. Have you collaborated your business externally? If yes, why did you collaborate your business and with whom?

19. How do you provide feedback on progress to your employees when adopting technologies?