# Adoption of Automatic Milking Technologies

*Case studies of New Zealand automatic milking systems*

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A dissertation

submitted in partial fulfilment

of the requirements for the Degree of

Bachelor of Agricultural Science with Honours

at

Lincoln University

by

Marc Hayden Brakenrig

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Lincoln University

2014

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Automatic Milking Systems (AMS) represent a revolutionary innovation in dairy farming, which not only replaces the physical labour required to harvest milk, but also influences the entire farm system. This dissertation investigates the key drivers, planning and outcomes of AMS adoption for six established New Zealand AMS farms. All of the case study farmers were identified to be in the innovator class of adopters and operate three different farm systems (confined, hybrid or pasture-based) with differing use of structures, level of supplementary feeding and calving. Effective farm area and herd size of all of the case study farms were well below their respective district averages for traditional dairy systems. Production per cow and per hectare were however much higher than the district averages with some of the case studies producing twice as much as the traditional systems.

Key drivers of AMS adoption were linked to the individual circumstances of the participants and the physical resources of their farms. These also influenced the robotic system adopted. Potential production increases were key interests of confined and hybrid system farmers, while the challenge of making the systems work was a key driver across all of the farm systems. A number of different sources of information were used during the planning stage with the most valuable of these sources being physical visits to existing AMS operations. Key factors for successful AMS development included farm layout, cow to robot ratio, cow selection and system simplicity.

Key outcomes of AMS adoption included beneficial improvements in animal health/condition, high animal production and a change in lifestyle. Limitations of the system included large establishment costs, increased operating expenses and the stress of transitioning to the robotic system. Limitations of specific systems included added stress to the seasonal workload of pasture-based systems and a lack of professional advice, particularly for confined systems. Participants were positive in regard to the future for AMS in NZ dairy farming, especially for smaller farms, with opportunities to further improve current systems and integrate other farming disciplines.

**Keywords:** Innovation adoption, Automatic milking systems, AMS, robotics, New Zealand dairy farming, technology.

# Acknowledgements

This dissertation brings four years as an undergraduate at Lincoln University to an end. My time here has been an incredible journey full of endless opportunities and amazing people. None of this would have been possible without the support and encouragement of those around me.

Firstly I would like to thank my supervisors Marvin Pangborn and Keith Woodford for their continued guidance and motivation throughout the course of this dissertation. This dissertation would never have been completed to the standard that it is without your knowledge and support. Your hours of critiquing have been invaluable and I look forward to keeping in touch as I progress in life.

I would also like to thank Sharon Lucock and Guy Trafford for your insights into farm management. Sharon, the skills you have taught me in financial planning will be incredibly helpful for my career going forward and Guy your guidance throughout my degree has been much appreciated albeit your flexibility around assignments has probably been too much appreciated.

To the farmers that I have worked with, I am particularly grateful for your time and willingness to help with my studies. I have learnt so much from all of you and your experience has been extremely valuable. Your passion for your systems and enthusiasm for the industry is infectious and I am excited to see it grow. I am positive this work will be of benefit to others.

To Hamish Clarke, for sharing an interest in AMS and for your support with this dissertation. I hope one day you will finish university. I look forward to keeping in touch.

To Lincoln University Students Association (LUSA), it is an incredible honour to have helped build Lincoln Snow Department to where it is today and to leave on such a high note for the club. Jo Meyer, your dedication to student life is inspiring, my experience at Lincoln University would not have been the same without you.

I would like to thank DairyNZ, OneFarm, The Salvation Army, The South Island Agricultural Field Days Society, Putararu Veterinary Trust, Credit Union North, New Zealand Grassland Association and Lincoln University for their financial support throughout my time at Lincoln University. I am especially appreciative of the support shown by Bill Barwood and Susan Stokes at DairyNZ, and the many connections within the Dairy industry I have made through them.

To my parents Carolyn and Owen, without you I wouldn’t be where I am today, I thank you for your continued encouragement throughout my studies. To Owen for inspiring my interest in agriculture and encouraging me to make the most of every opportunity and to Carolyn for all your support, proof reading and gossip from the family.

Lastly I would like to thank all the incredible friends I have made along the way. Special mention must go to Matthew Benton for pretty much doing everything together, Tom Abernethy for the company on those many late nights doing last minute reports and to Matthew Bentley for keeping my feet firmly on the ground. Thank you to Natalie, Bev, Josiah, Tara, Kate, Nikki, Pup, Nick, Crawford, Sam, Dutchy, Maddy, Ryan, Annalise and the rest of the LSD Crew, anyone I have ever lived with and anyone else I have missed. You have all been an important part of my time at Lincoln University and I look forward to staying in touch.

# Table of Contents

# List of Tables

# List of Figures

# CHAPTER 1
# INTRODUCTION

## 1.1 Overview

The development and adoption of innovative technologies to maximise yield and profit has been a staple characteristic of the New Zealand dairy industry. Pressure to maximise efficiency and lower inputs has resulted in novel approaches to managing and milking dairy herds. Automatic milking systems (AMS) are no exception. AMS represent a revolutionary innovation in dairy farming, which replaces the physical labour required to harvest milk and has the potential to drastically alter the entire farm system.

"The initial concept of robotic milking was developed in Europe in the 1970's" (Woolford et al., 2004, p. 282), however robotic milking technology wasn't introduced into New Zealand until 2001 (J. Jago, 2009). Traditionally AMS have been designed to best suit free stall barn systems. Dairy farming in New Zealand has however focused on creating a competitive advantage by feeding high quality pasture in low cost systems.

While there has been extensive research into the adoption, benefits and limitations of AMS in confined systems overseas, there has been much less focus on AMS in New Zealand systems. Adopting farmers are relying on science and support that is aimed at overseas farms with different systems and resources.

This dissertation analyses a small number of established confined and pasture based AMS farms in order to identify the key drivers, planning and outcomes of AMS adoption in New Zealand. The literature review in chapter 2 puts the research in perspective, and methods selected are justified in chapter 3.

## 1.2 Research problem and relevance of research

Dairy farming systems in New Zealand have evolved substantially over the last 70 years. Continued innovations in farm management and milk harvesting technology have resulted in drastic improvements in efficiencies and production. AMS has the potential to influence the entire farm system by replacing the physical labour required to harvest milk and putting the cows in charge of the milking routine.

Since the introduction of AMS technology into New Zealand in 2001, its adoption and diffusion has been slow. As a result there are only a small number of established farms. With increasing land prices, environmental regulations and a shortage of skilled labour in the dairy industry there is increasing opportunity for AMS. In order to facilitate the successful adoption of AMS in New Zealand dairy systems, there is a need for more focussed research in this field.

## 1.3 Research aim

The aim of this research is to identify key drivers, planning and outcomes of AMS adoption in New Zealand. This research does not seek to prove that AMS farms are better or worse than other farming systems, but rather to understand the principles behind AMS adoption. Some comparisons are however made between AMS and traditional milking systems in order to provide a better understanding of the outcomes of AMS adoption.

## 1.4 Key objectives

The key objectives that provide direction to this research are to:

- Identify the type of farm systems that are run on these study farms
- Identify the key drivers of AMS adoption for the case study farmers
- Investigate the important aspects of the planning and development stage of AMS adoption
- Investigate the suitability of current adoption theory for AMS adoption
- Identify the positive and negative outcomes of AMS adoption
- Compare and contrast the differences in motivation and outcomes of adoption of different AMS farm systems
- Investigate the opportunities for AMS in the future of New Zealand dairy farming

## 1.5 Research approach

Individual case studies were conducted on six established AMS farms located in both the Waikato and Canterbury. A case study approach was selected, to allow sufficient depth in the research and for qualitative data to be included; increasing the understanding of the key drivers. Case studies were purposively selected for their knowledge of the industry and ability to provide the greatest amount of information. Data was collected through semi-structured interviews and farm records. Data was analysed by finding trends with the aim of identifying the key drivers and outcomes of AMS adoption.

## 1.6 Dissertation outline

The dissertation is arranged into six chapters as outlined below. This layout allows the research to be laid out in a format that provides context and background with the method clearly stated. The results between case studies are compared before final conclusions are made.

**Chapter 1** **Introduction**

Introduces the topic and provides an overview of the research

**Chapter 2** **Literature Review**

Reviews the literature relating to innovation adoption theory and the implications of AMS adoption. This helps identify the place of this research in existing research and industry.

**Chapter 3** **Methods**

Outlines the research methods used for sampling, data collection and analysis and the reasons these were used.

**Chapter 4** **Case Study Profiles**

Provides an outline of each farm with a summary of the interviews and outcomes

**Chapter 5** **Cross Case Analysis and Discussion**

Compares and contrasts the case studies and investigates the range of diversity between farms and robotic systems. The relevance and implications of the results are discussed.

**Chapter 6** **Conclusions**

Briefly summarises key findings and discusses limitations of the study. Future research is identified.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 Introduction

This literature review covers the literature that is relevant to the adoption of AMS in New Zealand. As comprehensive studies of the determinants and socio-economic implications of AMS adoption are still absent from the scientific literature, this review is limited to evidence from experimental farms, simulation studies and case studies. A number of Dutch sources have also been included due to a lack of scientific research from New Zealand in this field. AMS technology was originally developed in the Netherlands and adoption and experience is well documented in this area.

In general, an innovation can be characterised by its rate of adoption and diffusion. Adoption refers to if, when, and to what extent, an innovation is included into a new system. Diffusion refers to the extent of market penetration of an innovation (Sunding & Zilberman, 2001). Until now the adoption and diffusion of AMS technology in New Zealand has been slow. In order to formulate research questions in areas with the highest impact, gaps within the existing knowledge must be identified. Therefore, the objective of this review was to bring together, analyse and summarise relevant scientific literature from studies on the factors influencing the adoption and diffusion of automatic milking systems. This includes a short overview of current innovation adoption theory as well as reviewing existing literature on the implications of introducing AMS technology on to dairy farms.

## 2.2 Innovation adoption theory

Technological innovations have led to increases in agricultural product quality and output. However, many of the technological advances made in agricultural history have met some resistance during their introduction (Rauniyar & Parker, 1998). This section of the report provides a brief overview of innovation adoption theory, and identifies the theoretical framework for this research.

### 2.2.1 Individual innovativeness theory

Adopters can be categorised by their willingness to experiment with innovative technologies (Rogers, 1983, p. 22). This is defined as their rate of adoption relative to the rate of adoption of other members of the system. Based on innovativeness, a population of adopters can be partitioned into five adopter categories, which include innovators, early adopters, early majority, late majority, and laggards (Figure 2.2.1:1).

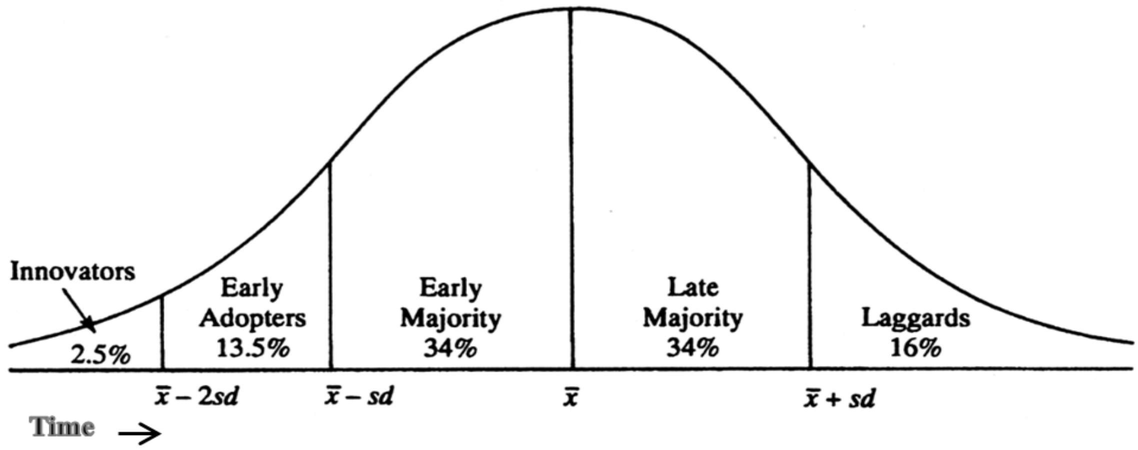


**Figure 2.1 Categories of adopters (Adapted from Rogers, 2003, p. 281).**

Rogers (1983, pp. 248-250) suggests that the dominant attributes of each category are: Innovators-venturesome (very eager to try new ideas); early adopters-respect (have a great degree of opinion leadership in most social systems); early majority-deliberate (a deliberate willingness in adopting ideas, but seldom lead); late majority-sceptical (innovations are approached with a sceptical and cautious air and usually do not adopt until most others in their social system have done so); and laggards-traditional (decisions are often made with reference to past generations and typically interact with those who also have traditional values).

It is noted by Rogers (1983, p. 251) that past research has identified that relatively earlier adopters in a social system are no different from later adopters in age, but they tend to have more years of formal education, are more likely to be literate, and have higher social status, a greater degree of upward social mobility, and larger-sized units, such as farms, companies, schools, and so on. These characteristics of adopter categories indicate that earlier adopters have generally higher socioeconomic status than do later adopters.

Also noted by Rogers (1983, pp. 257-258) was that earlier adopters in a system also differ from later adopters in personality variables. Earlier adopters have greater empathy, less dogmatism, a greater ability to deal with abstractions, greater rationality, greater intelligence, a more favourable attitude toward change, a greater ability to cope with uncertainty and risk, a more favourable attitude toward science, less fatalism (fatalism is the degree to which an individual perceives a lack of ability to control his/her future), greater self-efficacy, and higher aspirations for formal education, higher-status occupations, and so on than late adopters.

Finally, the adopter categories have different communication behaviour. Earlier adopters have more social participation, are more highly interconnected in the interpersonal networks of their system, are more cosmopolitan, have more contact with change agents, greater exposure to mass media channels and interpersonal communication channels, engage in more active information seeking, have greater knowledge of innovations, and a higher degree of opinion leadership (Rogers, 1983, pp. 258-259).

### 2.2.2 Limitations of adoption theory

Innovation adoption has been widely studied, however, in a review of innovation adoption literature, Wolfe (1994) noted the only consistency in past research was that of inconsistency. He suggests that this arises due to the difficulties in understanding the complex, context sensitive nature of innovation adoption; "*innovation* (adoption) *cannot be understood without careful attention to the personal, organizational, technological and environmental contexts within which it takes place"* (Tornatzky & Fleischer, 1990 as cited in Wolfe, 1994, p. 406). As a result, Wolfe (1994) suggests that this literature can offer little guidance to researchers.

Inconsistency in research results has also been noted by Pannell et al. (2006, p. 1407) who suggested the source of this inconsistency is the literature's "*disciplinary fragmentation*" with research conducted under the banner of economics, sociology, psychology, marketing, agricultural extension and anthropology. Pannell et al. (2006) and Nelson, Peterhansl, and Sampat (2004) both suggest that this fragmentation creates inconsistency in results thus constraining their comparability and ability to generalize. Similar to Wolfe (1994), Pannell et al. (2006, p. 1407) noted that adoption of rural innovations depends on the innovation itself as well as a range of personal, social, cultural and economic factors.

Furthermore Nelson et al. (2004) suggest that disciplinary fragmentation contributes to inconsistency, as different disciplines tend to have different theories about innovation adoption due to their diverse focus. Theory has been described by (De Vaus, 1995) as a tentative attempt to find some plausible explanation for a set of facts which can help identify how to interpret observations, what observations are relevant, and how these observations relate to one another, while also providing a context in which to place particular observations which help identify their significance and meaning.

Also noted by Nelson et al. (2004) was that different disciplinary theories are orientated towards different types of innovations and many innovations do not fit the idealised class presumed by a particular theory. As a result, they suggest that no one theory can be regarded as being generally right or wrong, and that there is merit in "*looking at what is going on through the lenses afforded by* *two or more theories*" (p. 679). Wolfe (1994, p. 406) also suggested that there can be no one theory of innovation, "*as the more we learn, the more we realise that 'the whole' remains beyond our grasp*".

Despite different disciplines and different theories, Pannell et al. (2006), Botha and Atkins (2005) and Nutley, Davies, and Walter (2002) note that when looking through a cross-disciplinary lens, the perspectives and emphasis of many research traditions appear to complement one another. Murphy (2014) used this cross-disciplinary approach to triangulate adoption theory, in order to develop a theoretical adoption framework relevant to farm management practice innovation. Due to the inclusive background of the framework developed by Murphy (2014), it has been identified as the most appropriate theoretical framework for the basis of this research. Details of this framework are further discussed in the following section.

### 2.2.3 Theoretical framework for this research

Murphy's (2014) review of the theoretical frameworks suggested that a range of factors influences the innovation adoption decision-making process. Of interest in this study is the influence of AMS farmers' personal characteristics, socio-demographics and farm characteristics. Murphy (2014) found that of the ten attributes of innovations identified by Rogers (1983, p. 211) and Tornatzky and Klein (1982), compatibility and profitability appeared to be the most important, with 'trialability', cost, 'observability', and complexity also shown to be important.

The basis of Murphy's (2014) theoretical framework is from Botha and Atkins' (2005) framework, which works to integrate complementary aspects of a number of different theories. These theories view innovation adoption as decision-making by individuals that requires cognition i.e. it requires the use of an individual's abilities to perceive, understand, and interact with their environment in an intelligent manner, and in this sense, the person and their environment play a role in the process. They also suggest that an individual's personal characteristics and contextual factors such as social and cultural contexts, climate and geography, resources and economic conditions influence the adoption decision-making process. Murphys' (2014) expansion of this framework included specifically recognising the influence of farmers' information seeking characteristics, their socio-demographics and the characteristics of the innovation. Murphys' (2014) findings suggest that these four sets of factors are not discrete but are likely to be inter-linked. At the centre of the adoption framework are the distinguishable stages that the adoption decision process passes through as adapted from Rogers' (1983, p. 164) model. These stages are classified as: 1) awareness, 2) knowledge, 3) evaluation, 4) trial and or adaptation and 5) adoption or non-adoption, which is possible after any stage of this process (Figure 2.2).

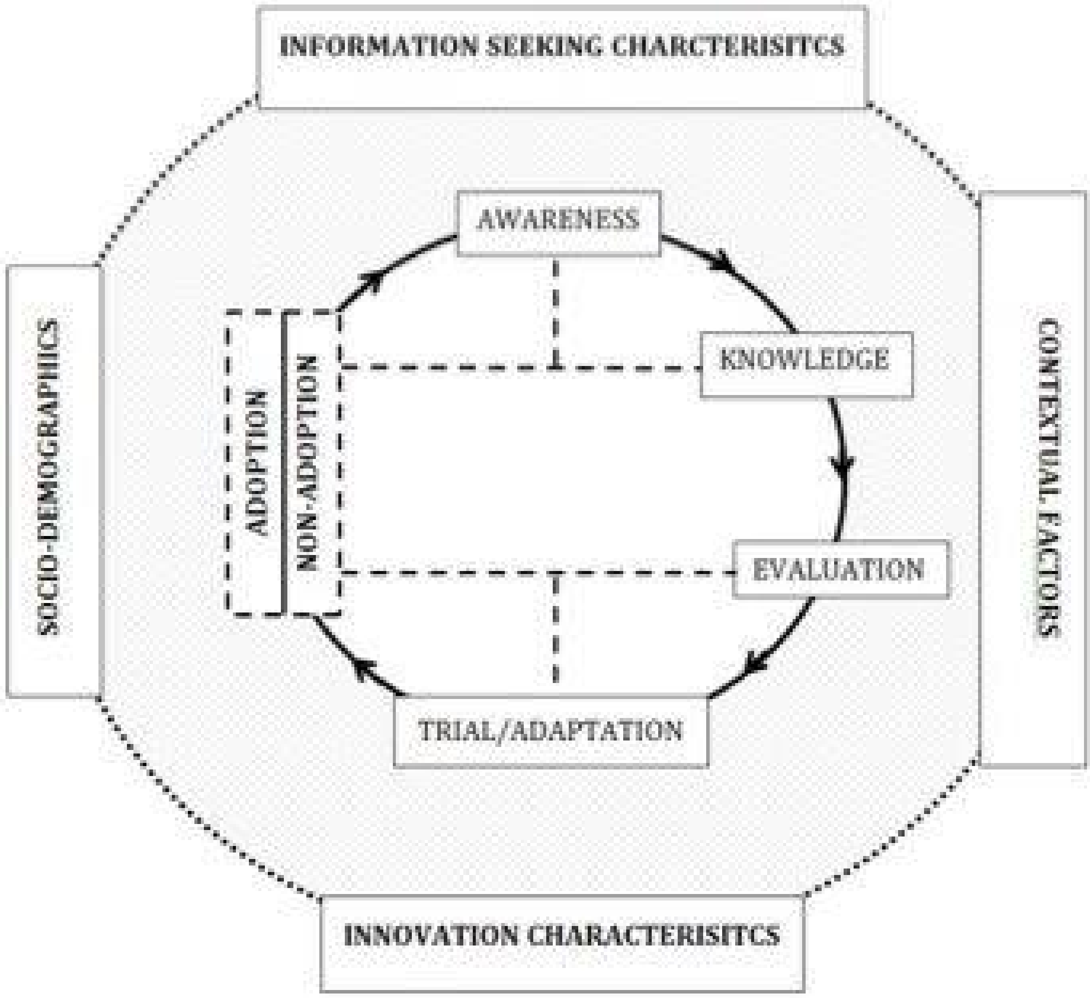


**Figure 2.2 Theoretical framework for investigating farm management practice innovation adoption (Murphy, 2014)**

## 2.3 Implications of AMS adoption

### 2.3.1 Changes in farm management following the Automatic Milking adoption

Automatic milking systems (AMS) have been developed in order to reduce the labour required to harvest milk. This is however only one of the many potential changes AMS can have on farm management (Kuipers & Van Scheppingen, 1992). For optimal benefit, a whole farm system should be designed around the AMS technology. Not only is labour reduced by the new technology superseding traditional milk harvesting technologies, but automatic milking systems can also be a very valuable management tool. Automatic milking systems therefore differ from most agricultural technologies as they have the potential to be the basis of a completely new dairy farm management approach. This includes changes to the farmer's schedule, herd management and capital distribution.

Automated milking systems integrate three management functions: milking frequency, supplementary feeding and cow traffic. As well as this, the system also has the ability to monitor milk quality, cow and udder health and cow fertility. This data and functionality when integrated with a Management Information System (MIS), which analyses and collates performance data for each cow, allows the farmer to make more informed farm management decisions. This ensures that each cow is reaching its full production potential and that all resources are being utilised efficiently (Devir, Maltz, & Metz, 1997).This includes earlier detection of animal health and welfare problems and providing a basis for standard operating procedures (SOPs).

#### 2.3.1.1 Farmer's tasks and schedule

The traditional milking systems require physical labour in order to harvest the milk and handle the animals (Spahr & Maltz, 1997). Automatic milking systems negate this labour requirement. They lead to a complete change in farmer tasks and increase the flexibility of the farmer's schedule (Rossing, Hogewerf, Ipema, Ketelaar-De Lauwere, & Koning, 1997). With the use of automatic milking systems a farmer's task becomes one of management and supervision (Spahr & Maltz, 1997). A large part of the manual labour saved must however be spent on the observation of cows, due to the reduced farmer contact with animals and increased risk of disease in a confined system (Dijkhuizen, Huirne, Harsh, & Gardner, 1997; Kuipers & Van Scheppingen, 1992). However with the use of a MIS this task can be completed very efficiently (Kuipers & Van Scheppingen, 1992). The information received and sorted by the MIS can help the farmer make faster and more informed management decisions (Sonck, 1996).

Greater emphasis is also required for shed hygiene in the farmer's management schedule. Hygiene in the feeding and resting area of a confined AMS system is an absolute priority to maintain animal health and milk quality (Armstrong & Daugherty, 1997). As a result of reduced farmer interaction with the animals during milking time it is possible that damaged or overly dirty teats may go unnoticed by the AMS robot until data from the MIS indicates that there is a problem. To keep the udders and teats as clean as possible, shed hygiene and cleanliness is required to be maintained and monitored on a daily basis (Rodenburg, 2012).

Staff competency is another important factor influencing the farmer's tasks and schedule. AMS equipment can be complicated and requires staff to be educated in the maintenance of the technical machinery as well as confident with computers. Automatic milking systems often require regular monitoring or adjusting to keep them operating correctly (Dijkhuizen et al., 1997). Management staff also needs to be educated in the use of the MIS in order to decipher the collected data correctly and make properly informed decisions.

#### 2.3.1.2 Feeding management

Dairy cows' grazing pasture is recognised as a key driver of New Zealand's image of sustainable dairy farming. The use of AMS in grazing systems is however limited to the capacity of the automatic milking systems (Devir et al., 1997). Grazing narrows down the milking frequency possibilities and thus decreases the efficiency of the robot (Kuipers & Van Scheppingen, 1992). In a study by Parsons and Mottram (2000) on pastoral based automatic milking systems it was found that it can be difficult to tempt cows from fresh pastures to visit the robot for milking. This can have a negative impact on milking frequency; however Jago and Burke (2010) found that with the right management these systems can still be feasible. In an Australian study on the effect of pasture allocation on milking interval and milking frequency Lyons, Kerrisk, and Garcia (2013) found that splitting the grazing management into 3 breaks per day instead of the traditional 2 breaks per day reduced milking interval by 31% and increased milking frequency by 40%. This highlights the importance of feed management in these systems. Consideration of the practical and economic disadvantages of incorporating automatic milking systems into pastoral systems is important in the adoption of AMS technology (Heikkilä, Anna-Maija, Myyrä, & Pietola, 2012).

Due to the implications of maintaining feed efficiency and utilisation on pastoral systems, when adopting an automatic milking system, transition will often occur to limited grazing, zero grazing or summer feeding. In an experiment where cows were on a mixed diet of pasture and mixed rations, Artmann and Bohlsen (2000) found that in a study of confined AMS farms in Germany, when cow traffic was controlled (i.e. the cow has to pass the AMS if it wants to go to the basic ration feeding area) there was no significant effect to either milking or the number of visits to the robot compared to cows with free access to the feeding area. In a study of 29 AMS farms in Spain, Castro, Pereira, Amiama, and Bueno (2012), found that grazing had to be limited to a maximum of eight hours to still obtain similar efficiencies of the milking robot to that of zero grazing systems. Greater control of animal diets with mixed rations also ensures that cows are producing to their maximum potential. The adoption of an AMS may not be the only reason for limiting grazing. Environmental regulations may also play an influence on the choice of management system, for instance the capping of nitrate leaching could lead to the necessity for limited grazing.

### 2.3.2 Factors affecting AMS adoption

#### 2.3.2.1 Economic factors: expected profitability and financial situation

**Expected profitability**

As expected the adoption of AMS technology is much more likely if the investment is profitable. The economic impact of automatic milking system adoption has been defined by a number of authors as depending on the following factors:

- The capacity of the system: The efficiency of the system (the utilisation of the AMS and the milk yield per robot per day) determines its overall capacity and thus the profit relative to a conventional system. A higher capacity makes the robot economically more attractive (especially on large-scale farms) and more flexible (Sonck, 1996).
- Changes in milk production: After making a number of assumptions, Arendzen and Scheppingen (2000) found that the likelihood of investment in AMS technology increased by about 48% when milk yield per cow increased by 10%.
- Current housing infrastructure or the development of cow housing in the future.
- Availability of quality educated labour or the ability of staff to adapt to new technology.
- Current labour requirement and forecasted labour requirement: A change in labour requirement has been found to have a significant effect on the room for investment (Arendzen & Scheppingen, 2000).
- Current and proposed feeding systems and crop rotations.
- Herd health and cow genetics: It is recognised that in order to maximise the benefits of the AMS, that the parameters of the cow must also be considered (Dijkhuizen et al., 1997).

In a model constructed by Jago et al. (2006) a milk solid price of $4.25 was used to compare a conventional rotary milking system to a pasture-based automatic milking system for a standardised 450 cow operation. It was found that "automatic milking systems have a 27% higher production cost structure compared to a traditional rotary batch system. This was deemed to be due to "higher interest, depreciation and service contract costs". However, savings were identified in "reduced labour, cow health and dairy costs" (Jago, et al., 2006, p. 265). A sensitivity analysis showed that there is a requirement for a "seventy percent decrease in capital cost, or a more than two fold increase in the cow throughput per robotic milking machine was needed for the automatic milking system to be as efficient as a traditional rotary milking system" (Jago, et al., 2006, p. 266).

Due to the uniqueness of each farm system the individual costs of the above-mentioned factors are difficult to predict. Their contribution to the change in farm profits is determined by the specific situation on the farm and by the management capacities of the farmer. The ability and extent to which the farmer can exploit the benefits of the AMS is an important factor (Arendzen &

Scheppingen, 2000). This will depend on the farmer's knowledge about and experience with the system. (More about the factor 'human capital' can be found in section 2.3.2.2.). To be cost-effective, cows will need to be motivated to visit the robot as frequently as possible (Parsons & Mottram, 2000). Considering the amount of factors playing a role, it is clear that there is considerable variation possible in profitability following the adoption of automated milking systems.

A number of studies on the profitability of AMS expect that dairy farmers renovating a farm building, or building a new shed are the main group for whom the decision for the introduction of the AM-system arises (Arendzen & Scheppingen, 2000; Dijkhuizen et al., 1997; Kuipers & Van Scheppingen, 1992; Parsons & Mottram, 2000). These studies compare AMS adoption with the purchase of a traditional system, as they assume that the producer is at a point where the existing milking system needs replacing or requires modernisation. In addition, these studies always apply to a very specific set of assumptions and farm characteristics, making it difficult to generalise their results. This is supported by research by Jago et al. (2006) where there were a number of factors identified as influencing AMS profitability in New Zealand. The most important of these being capital investment and increased operating costs.

Using a simulation model, based on data from 80 UK AMS farms to test the costs and benefits of different management regimes for AMS farms, it was found that zero grazing AMS operations can be competitive with conventional milking systems at a low price of milk quota (Parsons & Mottram, 2000). This was assuming that the AMS technology shows the same reliability as conventional milking systems. Dijkhuizen et al. (1997), estimated that the break-even level of AMS adoption on a 125-dairy cow farm in the Netherlands and the USA was nearly double that of a herringbone parlour system with similar data collection ability. A sensitivity analysis showed that the break-even level was particularly sensitive to changes in wage rates. Labour and human capital requirements are further discussed in section 2.3.1.1.

The profitability of the automatic milking system can also be expressed using the maximum acquisition value (MAV), i.e. the amount of capital that may be invested in the system to achieve the same net farm result as with a traditional milking parlour. If the investment exceeds the MAV, net farm results will be smaller (Kuipers & Van Scheppingen, 1992). In that case, farmers who base adoption solely on the perception of how the new technology or equipment will increase the profitability of the dairy farm, will not invest in the robot (Armstrong & Daugherty, 1997). Alternatively farmers who are not necessarily looking for gains in profitability, but instead are interested in labour savings, more freedom and flexibility and increased cow welfare, etc. will only invest if they expect the lower profitability will be compensated by the fulfilment of their alternative expectations.

The MAV depends highly on the desired alternative for automatic milking. Capital which would normally be invested in renovation or replacement of a traditional milking parlour can be invested in an AMS (Kuipers & Van Scheppingen, 1992). In practice, it can be expected that farmers considering the purchase of an AMS would also prefer a high degree of automation for the layout of a traditional milking parlour. The difference in investment with an AMS will therefore be smaller. For farmers who would decide in favour of a cheaper and lower-tech alternative-milking parlour, the step towards an AMS is bigger.

**Farm size and structure**

Farm size and structure is an important factor influencing the efficiency and viability of automatic milking systems and subsequently a key driver of the adoption of this technology. Automatic milking systems will have the highest efficiency when herd size is matched to the optimal capacity of the robot (Kuipers & Van Scheppingen, 1992) or, conversely, on farms where the farmer is willing to invest in the adequate amount of infrastructure to support the number of cows present. Milk yield per cow and the milking frequency are important factors in determining the number of cows that can be milked with an automatic milking system. The system's capacity (if expressed as number of cows per milking unit) also depends on whether the equipment is used efficiently (Devir et al., 1997). Under optimal conditions, the maximum capacity of one robot is thought to be 60 cows when the average daily milking frequency is assumed to be 2.8 to 3.0 milkings per cow (Castro et al., 2012). In practice the milking frequency on commercial farms is 2.6 to 3.0 milkings per cow per day on average in confined systems and 1.4 to 2.3 for grazing systems (Davis, Fulkerson, Garcia, Dickeson, & Barchia, 2008; Jago, Davis, Copeman, Ohnstad, & Woolford, 2007). To maximize the use of AMS in pasture dairies, it may be more effective to increase the number of cows per AMS (Jago et al., 2007).

For larger herds (150 cows or more), there are a number of logistical and practical problems that also have to be solved to optimise cow traffic and feeding when adopting an automatic milking system (Parsons & Mottram, 2000). Such farm sizes are increasingly common in New Zealand as dairy farming has expanded and milk prices have increased. Armstrong and Daugherty (1997) studied the factors driving the slow adoption of AMS technology on large-scale American dairy farms (800+ cows). While the suitability of current infrastructure or the need to modify current systems was identified as a limiting factor, the key factor influencing AMS adoption was the cost. Due to the large costs of the robotic technology and the need to invest in the required number of robot units for the number of cows being milked, efficiencies of capital use are limited.

The ability to use existing infrastructure is also an important factor influencing AMS adoption. In the past, new technologies in milking systems have been more readily adapted by dairy farms when it could be used in existing facilities (Armstrong & Daugherty, 1997). Traditionally AMS have been designed to best suit free stall barn systems. For farms which do not have such facilities, the investment in an automatic milking system may be less attractive (Kuipers & Van Scheppingen, 1992). The number of AMS pasture based systems has increased over recent years, however the major interest is in smaller scale farms. Walking distance and seasonal climates can limit these systems and reduce the efficiency of the robots (Armstrong & Daugherty, 1997). Previous studies show that milking frequency, milk yield and grazing times decrease as walking distance from the grazing area to the dairy increases (Sporndly & Wredle, 2004 as cited in Jago et al., 2007). The point at which walking distance becomes a problem is however not yet known. The maximum limit will depend upon farm layout and desired milking frequency Jago, Jensen, Ridsdale & Ohnstad (2013).

**Increase in milk yield per cow**

A key driver for adoption of AMS technology is likely to be the aim of increasing milk production per cow. This can be either to keep down variable herd costs and improve efficiencies or to increase overall production. Most farmers however, do not intend to reduce their herd size as this can be seen as a step backwards, but instead tend to aim for growth and enlargement.

Production increases with automatic milking systems are achieved through increased milking frequency and greater control of individual cow diets (Devir et al., 1997; Kuipers & Van Scheppingen, 1992). Kuipers and Van Scheppingen (1992), assumed that with the right nutrition, a 10 to 15 % higher milk yield per cow to be possible when comparing confined systems. These values have been reached on experimental farms, but on commercial farms production increases are generally lower only realising a 5% increase in production. Moreover, this production increase can have a significant amount of variance (Dijkhuizen et al., 1997) and research on the influence of milking frequency on milk production is minimal for pasture based systems (Lyons, Kerrisk, & Garcia, 2014).

Not all of the high milk production as a result of increased milking frequency is realised financially. Increasing milk frequency often results in a reduction in the milk solid component of the milk. This is an important factor to consider as current milk prices in New Zealand are based on kg of milk solids. Dijkhuizen et al. (1997) reported that there may be up to a 0.15% reduction in fat content with automatic milking systems where cows are being milked between 2.8 and 3.0 times a day in confined systems. There may also be an effect on protein content, but this is less apparent at 0.05% on average. These lower fat and protein percentages may result in a slight decrease in the milk price per litre of milk produced for the farmer. This however may be negated if the increase in overall production is large enough.

**Financial situation**

The availability of finance has a strong influence on the readiness and willingness to adopt AMS technology. Finance availability and the readiness to take on debt vary significantly between dairy farming businesses and dairy farmers (Kuipers & Van Scheppingen, 1992). For those with a favourable financial situation, the possibility of introducing an automatic milking system is higher. If a farm is already highly leveraged, the addition of additional debt may put the business financially at risk. In these cases the AMS with its high capital requirement is likely to be less attractive (Dijkhuizen et al., 1997). Moreover, depending on the farmer's situation, the increased debt may result in excessive stress being applied to the farm business and the farmer (Sonck, 1996). The willingness of a farmer to take on extra debt is often related to their age, experience and current state of their business. A survey of rural decision makers in different New Zealand regions by Brown et al. (2013, p. 35) suggested that as well as representing past strategic and entrepreneurial behaviour the strength of a farm business also represents the farmer's future capacity for generating agricultural income. The willingness to invest in new technologies based on a farmer's financial situation is very hard to estimate, as there are a number of other personal factors influencing the decision.

### 2.3.2.2 Non-economic factors: human capital, labour and social welfare

Farmers may be interested in automatic milking systems for a number of non-economic factors. This includes the attraction of something new and revolutionary as well as a way for farmer's to improve their quality of life and pleasure at work. The conflict between security and trying something new is influential in the decision of adopting an automatic milking system.

Hoefman (1998), as cited by Kuipers and Van Scheppingen (1992) distinguished three groups of dairy farmers:

1) Farmers who choose to adopt AMS technology despite an expected decrease in farm profits, because of their high appreciation of the expected labour reduction, or the expected increase in flexibility, in milk production, in cow health, etc.;

2) Farmers who only choose to adopt AMS technology if they expect farm profitability to stay equal or to increase;

3) Farmers who do not choose to adopt AMS technology because they prefer to control the milking process themselves, or for other reasons.

The adoption of automatic milking systems is not suitable for every farmer. Its success largely depends on the specific farm situation as well as the farmer's goals and objectives (Kingmans, 1999). Early AMS technology often did not live up to its expectations and was deemed unreliable. This is supported by the findings of Artmann and Bohlsen (2000) that highlighted that early adopters were disappointed with a number of factors around automatic milking systems. This included a lack of reduction in labour requirement, milk quality problems, inability to relax knowing that the robot might fail at any time of the day, and high maintenance and electricity costs. The unfulfilled expectations or undesired implications of early AMS adoption may have been due to 'teething issues' of the system or due to the fact that information on the consequences of adoption was still scarce at the time. Fewer reports of these problems have been recorded in recent literature.

**Labour**

The expectation of a reduction in labour is a key reason why a dairy farmer may be interested in automatic milking systems. The change in labour requirement after adoption is however difficult to estimate. Labour requirement varies significantly from farm to farm and is largely dependent on the chosen management functions, namely the system of cow traffic and the feeding system (Devir et al., 1997). Also the reliability of the technology, the skill level of the labour, the herd size and the portion of the herd that cannot be milked automatically play a role. Artmann and Bohlsen (2000) found that the labour time required on four confined AMS farms in Germany ranged from 127% to 54% in comparison to conventional milking in herringbone parlours. Although this study was only across a small sample of farms, it does indicate the extent of variation of labour requirements with AMS technology. This is supported by Rodenburg (2012) who in a review of AMS literature found that the labour time gained for other activities was even more variable in sole charge operations.

With proper management and the full exploitation of AMS technology, a reduction in labour requirement is however possible. According to Artmann and Bohlsen (2000), a confined automatic milking system with a fully functioning facility and with consideration of a higher level of animal monitoring, can result in about two-thirds of the labour time needed, compared to a similar conventional milking system. This is supported by a study by Sonck (1995), which found that an automatic milking system with human-controlled cow traffic applied during the whole year and with an average milking frequency of three times a day resulted in physical labour savings for milking of up to 38% (or 470 hours/year). Sonck (1995) also found that with computer-controlled cow traffic and cows kept indoors the whole year, a labour reduction of up to 66% (or 821.3 hours/year) is achievable. These percentages however excluded time needed for repair or unexpected trouble shootings. Other studies also mention potential labour savings of between 300 and 950 hours a year or as much as 2.6 hours a day for confined systems with a herd size of 125 cows (Dijkhuizen et al., 1997; Rodenburg, 2012).

It is generally accepted that the physical workload will decrease after adoption of an automatic milking system. Milking is classified in the category of light to moderately heavy labour (Rossing et al., 1997). With the milking component of labour tasks removed, health complaints from milkers of back, neck and shoulder pain are likely to be reduced by the introduction of an automated milking system (Rossing et al., 1997). This may be a key factor when considering the adoption of AMS technology, especially if age, health and the availability of labour are issues in the current farm business.

**Schedule**

Labour organisation is an important factor in the decision of adoption of automatic milking systems. When milking in the traditional way, a farmer is tied to fixed milking hours 7 days a week; however with automatic milking systems this tie to the milking parlour is broken (Rodenburg, 2012). Traditional milking hours are considered to be socially unfavourable, with early starts and late finishes. With AMS, the farmer has more freedom during the day, more flexibility and the opportunity to have a life-style more in line with that of people working in other industries. To some farmers this may be of great importance allowing them to have what is accepted as a “normal” social life. This may also be appealing to labour candidates that in the past have dissociated themselves from the dairy industry due to the unfavourable work hours and nature of the work.

Automatic milking systems however require someone to be available 24 hours a day. Periodic breakdowns or abnormal cow behaviour disrupting the activity of the AMS can result in assistance being required at any moment. These disturbances and breakdowns can disrupt the daily labour planning and even social activities of the farmer. This can cause stress, especially when high priority activities are interrupted. The reliability of the AMS technology plays an important role in minimising this stress. However the fact that one can get called into work at any time of the day can be seen as more stressful than traditional milking programmes (Sonck, 1995, 1996). Farmers that are more comfortable working to a strict schedule i.e. milking in the morning and in the evening might struggle to adjust to an automatic milking system.

**Nature of the work and work climate**

Contact with the cows is expected to be less intensive in automatic milking systems (Sonck, 1995). This may have an influence on the adoption of such systems. Some farmers consider the contact with their animals of major importance for their pleasure at work and see it as the loss of a major element in their ‘stockmanship’ to give away the milking task to a robot.

However, when automatic milking systems are managed properly, contact with and control of the cows remains very important for the health of the herd and consequently for production itself (Rodenburg, 2012). A survey among Belgian AMS farmers showed that most farmers did not feel that they had less contact with their cows. On the contrary, thanks to the robot they had more time to observe their cows and that over all the cows were happier, healthier and friendlier (Artmann & Bohlsen, 2000). Furthermore, routine checks can be made when it best suits the farmer and more attention can be paid to any issues without the constraints of milking.

Less time being spent in a milking parlour may also be a favourable aspect of automatic milking systems. Physical environmental elements such as light, noise and climate can be unfavourable in conventional milking parlours. As the AMS farmer will spend less time in this unfavourable environment, the automatic milking system may benefit the health and wellbeing of the farmer (Sonck, 1996).

**Human capital**

Automatic milking systems require a different calibre of labour to extract the best results from the technology. Labour must be capable of analysing and interpreting the data delivered by the MIS. This requires a different kind of knowledge and insight with the need to develop a feel for technology and sense for animal observation (Artmann & Bohlsen, 2000). Due to the improvements in work schedule, and the nature of work expected with the adoption of AMS, this technology has the potential to attract a whole new labour pool. It is predicted in the future "robotic milking will become increasingly common due to skilled staff becoming increasingly difficult to source" (Jago & Woolford, 2002, p.39). The time needed to learn and enhance the new management skills before and immediately after adopting the AMS technology however should not be underestimated (Dijkhuizen et al., 1997).

Some farmers doubt the reliability of a MIS to monitor the milking of the cows and to detect animal health problems. This technology therefore may not suit farmers who prefer a more hands on approach (Dijkhuizen et al., 1997). From this it may be suggested that particularly young, dynamic farmers with a higher education level would be more likely to readily adopt this new technology or that farmers looking to attract their sons back to the family farm may use this as an incentive.

A greater understanding of animal nutrition and behaviour is also important. In pasture-based systems this may require a greater level of management to maintain pasture quality and feed allocation. Greenall, Warren, and Warren (2004) suggest that the key to motivating cows to visit AMS in a pasture system is flexible farm management and a broad understanding of cow behaviour and dietary needs. Thus, in grazing situations, managers need to constantly evaluate and manipulate the cow's access to the various dietary components available to make the farm successful.

**Strategic plan of the farm**

An automatic milking system must be compatible with a farmer's strategic objectives (Kuipers & Van Scheppingen, 1992). Before adopting an automatic milking system a farmer should first outline a strategic plan (motivations and goals) for the farm. The plan must take into account the farmer's needs and wishes and the available facilities, possibilities and constraints (Devir et al., 1997). For the plan to be successful it must also have a solid financial base (Arendzen & Scheppingen, 2000).

The robot is more likely to be a justified investment for intensive farms with a clear growth strategy in combination with limited availability of labour (Heikkilä et al., 2012). The key driver in these situations is likely to be saving costs by automating the daily milking and feeding routine (Devir et al., 1997). The aim is to keep income high by increasing scale and by increasing labour productivity and production efficiency (Devir et al., 1997). For these farms, the availability of capital can play a key role in the decision for adopting an automatic milking system.

The use of AMS technology is also a possibility for organic farmers. While organic farming is expected to be more nature minded, it is also very labour demanding. The use of AMS technology does not necessary conflict with the principles of organic farming and may be very beneficial for mitigating potential labour shortages (Oudshoorn & Boer, 2008). Oudshoorn, Kristensen, Zijpp, and Boer (2012) identified that a large number of organic farmers in Denmark are already using AMS technology in order to improve productivity.

#### 2.3.2.3 Animal welfare and environmental considerations

**Cow health and welfare**

Milk yield per cow has increased with the improvement of cow genetics. Subsequently the long intervals between traditional milking sessions may no longer be optimal for the welfare of high yielding cows (Rossing et al., 1997). The higher milking frequencies possible with AMS can mirror the natural pattern better when a comparison is made with the frequency of suckling in beef herds (4 to 6 times per 24 hours) (Day et al., 1987). Shorter milking intervals reduces discomfort due to udder pressure as a result of milk accumulation (Kuipers & Van Scheppingen, 1992), decreases stress on the udder ligaments by reducing the maximum accumulated milk present in the cow’s udder and decreases the time for growth of mastitis organisms (Spahr & Maltz, 1997). More frequent milking also leads to increased lying times due to the reduced udder tension offering the cow more comfort to lie down (Rodenburg, 2012; Sonck, 1996). However, the increased total milking time can cause extra stress on the teats and result in an increased number of teat end erosions and eruptions (Rossing et al., 1997; Sonck, 1996).

Through the integration of sensors in the automatic milking system and with the aid of MIS, cow monitoring is continuous, more consistent and faster than human observation. Deviations and diseases may be detected earlier resulting in improved animal health and welfare (Sonck, 1996). However this requires farmers to be able to interpret data produced by the MIS, which may require some training.

Increasing milk production by a higher milking frequency also has an effect on energy demands and on its complex relation with body reserves balance (Devir et al., 1997). Feeding systems have to be adapted accordingly, not only to attain full benefit of multiple milking but also to maintain cows' health (Spahr & Maltz, 1997). Farmers' attention must move to herd hygiene and management, such that the cows are regularly milked and the system can function optimally. This is particularly important with confined systems, where cows stay inside all year round.

Cows on farms with automatic milking systems appear to be happier and less stressed than in traditional farming systems. Farmers have reported less stress among the cows, less hierarchical battles within the herd and more peace in housed systems as a result of AMS technology (Rodenburg, 2012). Low dominance cows are able to adapt their visits to the milking robot and the feeding gate to periods of low traffic when they are less likely to be pushed around by more dominant animals (Rossing et al., 1997).

**Replacement rate and animal selection**

Not all cows are able to adapt to automatic milking systems. Udder shape is an important factor determining whether the sensors of a milking robot can guide the cups into place. Other cows may not voluntarily visit the robot or struggle during the milking process, reducing the efficiency of each robot (Artmann & Bohlsen, 2000). Armstrong and Daugherty (1997) found that when it comes to "large" confined systems, in general farmers are willing to replace 5% of the herd to be able to utilise new labour saving technology, but they resist replacement rates of 10% or more. Cows in their third lactation or more are the least likely to adapt to an automatic milking system with research by Artmann and Bohlsen (2000) showing that 78 to 84% of cows in their third or more lactation struggled to adapt to the robot. Old cows with ill shaped, deep udders and wide teats may need to be culled for a lesser degree of defect than is the case with conventional milking systems (Spahr & Maltz, 1997).

The importance of uniformity of the herd increases with an automatic milking system. This is due to the greatest profit being achieved when cows are optimally suited to be milked by the robot. The uniformity of the udder shape is one important characteristic for smoother robot functioning (Kuipers & Van Scheppingen, 1992). Milking velocity can also be influenced by breeding and selection (Castro et al., 2012).

**Energy consumption and environment**

Increased attention of the impact of dairy farming on the environment and of energy use on dairy farms is a key driver of any technology adoption in the industry. In this respect, it is of interest how automatic milking systems influence energy balances of a farm business.

Production and conservation of feed are the major energy consumers in dairy farming. With automatic milking systems, feed requirement per individual cow is higher. The higher milk yields per cow and the fact that supplements are used as bait for the cows to come to the robot are the main reasons. The required amount of feed per quantity of milk produced is expected to however remain the same (Kuipers & Van Scheppingen, 1992).

For reasons of efficiency, the adoption of automatic milking systems favours a transition to limited grazing, zero grazing or summer only feeding of pasture. When animals are housed year round, or during limited pasture growth periods, nitrate leaching can be reduced and in some cases pasture production increased. Klein, Paton, and Ledgard (2000), found that strategically removing animals from pasture for 3 or 5 months during the autumn/winter period can reduce nitrate leaching by about 20% or 35–50%, respectively. This is a direct result of reducing nutrient loading during periods where the level of nutrients being deposited is greater than the uptake by plants and soil. Klein et al. (2000) also estimated an increase in pasture production of up to 5% as a result of reduced pugging and pasture damage.

### 2.3.2.4 Risk considerations

Automatic milking systems require a substantial capital investment in machinery, management systems and staff training and in some cases barns. Generally the introduction of AMS technology also requires an adaptation of existing facilities as well as modifications to feed management. In most cases this creates more costs than originally expected when considering adopting automatic milking systems (Artmann & Bohlsen, 2000). The reliability of the technology will strongly determine the socio-economic effects as well as the effects on aspects of labour (Sonck, 1996).

The high investment cost of AMS technology can be an adverse factor effecting adoption rate (Armstrong & Daugherty, 1997; Kuipers & Van Scheppingen, 1992). According to Parsons and Mottram (2000), who assessed herd management aspects of AMS on UK dairy farms, an automatic milking system will need to sell at a lower price to be competitive with current conventional milking parlours. A price reduction of the robot over time, as occurs for most technological innovations, will favour the diffusion of automatic milking systems. To make it possible to spread the investment over more litres, manufacturers are searching for systems that can handle more animals per robot unit (Castro et al., 2012).

## 2.4 Conclusions and area of research

Innovation adoption has been widely studied with theories often inconsistent, particularly across research disciplines. It has however been found that despite different disciplines and different theories, when looking through a cross-disciplinary lens, the perspectives and emphases of many research traditions appear to complement one another.

While there has been extensive research on the principles of technology adoption, automatic milking systems have had little exposure. This is most likely due to the age of this technology and the limited number of farms using these systems. While there has been some level of research for these systems the current literature on the socio-economic factors and implications effecting AMS adoption is found to be limited to simulations and case studies. This makes it difficult to generalise their results, as each individual case is different. A few studies have included, but not focused on pastoral automatic milking systems, and further research in this area would be beneficial for New Zealand applications.

The balance between the direct financial costs and benefits of AMS adoption is also hard to determine as there are a number of non-financial costs and benefits which influence farmers' decisions, making it difficult to measure. These are generally related to the farmer's goals and objectives and include increased flexibility of the farmer's working day, impact on animal welfare, availability of suitable labour and willingness to take on risk.

Overall, there is a lack of information available on the drivers, planning and implications of AMS adoption, particularly for pastoral based systems. Where models have been used, the assumptions used to create the models have been largely based on housing systems with existing infrastructure, and may not best represent New Zealand applications. More information on the key drivers, establishment and results of AMS adoption in New Zealand is required.

# CHAPTER 3
# METHODS

## 3.1 Introduction

As shaped by the findings of the literature review, the aim of this study was to provide an analysis of the adoption of AMS into pasture based and confined New Zealand dairy farms. To achieve this, a case study approach was used where six AMS dairy farmers were interviewed using semi-structured interviews, and both quantitative and qualitative data was collected. This section outlines the methods that were used for data collection and justifies the chosen methods. The timeline and budget of this research are included, and limitations of the research method will be discussed.

## 3.2 Research questions

1) What type of robotic farm systems are run by the case study farms?
2) Why was AMS adopted by the case study farmers?
3) What were the key aspects of the planning and establishment stage that facilitated the success of adopting AMS?
4) Does current adoption theory suit AMS adoption in New Zealand?
5) What were the key benefits and limitations of the systems adopted?
6) What is the future for AMS in New Zealand dairy farming?

## 3.3 Type of research

The method of inquiry deemed most appropriate for this research is a qualitative approach. Qualitative research paradigms seek difference and divergence, as well as identifying common elements, and have greater ability to interpret rich data collected than is the case with solely quantitative research (Davidson & Tolich, 2003, p. 127). Accordingly, this research is set out with open research questions rather than specific hypotheses to test. Consistent with this, the numeric data will not be subject to inferential statistical analysis. The numeric data will be collected in the form of farm records, farm accounts, budgets, and production statements and is purely for information purposes.

## 3.4 Case Study Method

A case study approach was identified as the qualitative research method most suitable for obtaining comprehensive answers to the research questions. A case study provides an in depth examination of some social phenomenon i.e. a farming population (Babbie, 2013, p. 309). “The essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a decision or a set of decisions: why they were taken, how they were implemented, and with what result” (Schramm 1971, as cited in Yin, 2003, p. 12). This will give a broader understanding of the drivers and outcomes of AMS adoption.

Yin (2003) provides the following definition of a case study:

> 1) “Investigates a contemporary phenomenon within its real-life context especially when the boundaries between phenomenon and context are not clearly evident.”
>
> 2) “Copes with the technically distinctive situation in which there will be many more variables of interest than data points: and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion; and as another result, benefits from the prior development of theoretical propositions to guide data collection and analysis.” (pp. 13-14)

Due to the complexity around the adoption of innovation and the multitude of independently interacting variables driving the decision pathway it was necessary to look at the broader picture to better understand the adoption of AMS. Case studies helped facilitate the collection of such information and allowed for analysis of the entire farm system prior to and following the adoption of AMS. Case studies also allowed for personal attributes and farmer goals to be identified, which were integral in determining the key drivers of adoption. Collection of information by survey or database was not considered due to the limited number of AMS farms in New Zealand and the lack of such methods to extrapolate an in depth understanding of motivations and opinions of farmers.

Case studies were conducted on each of the 6 farms selected. Multiple case studies allowed the researcher to make comparisons between cases to determine what was unique about particular farmers’ motivations and success. The ability to make comparisons between case studies allowed for more accurate conclusions about what drives AMS adoption and the benefits and limitations of these systems. Multiple case studies also allowed for both confined and pasture based systems to be included in the study. This provided an opportunity to compare and contrast the principles of adoption in both systems, further expanding the representation of the study.

## 3.5 Sample selection

Purposive (judgemental) sampling was used to select participants for the case studies. Purposeful sampling is a non-probability sampling method in which the sample to be observed is selected on the basis of knowledge of a population, its elements, and the purpose of the study (Babbie, 2013, p. 190). Due to the limited number of farmers that have adopted AMS in New Zealand it was important that the sample selected was able to provide the greatest amount of insight towards the purpose of the study while still maintaining a degree of diversity. For this to occur, participants were profiled and chosen based on their potential to adequately contribute to the research. The parameters of this selection included having successfully adopted AMS and completed at least one season of production. The one exception to this is farmer F who while not having completed an entire season since adoption was identified as being a valuable source of information for the study. Participants were also selected based on their farm system ensuring that a wide range of systems were represented in the study.

The low number of cases selected is due to time constraints and makes purposive sampling all the more important. The highly investigative nature and level of information required means participant co-operation and enthusiasm was key to the researcher's success. Initial contact with the participants was made through Lincoln University and DairyNZ networks. By involving referrals from sources not involved with the study during the participant selection process, researcher bias was minimized.

## 3.6 Data Collection

Each case study was visited once with data collected via semi-structured interviews. Interviews with farmers A, C, D and E were run in conjunction with Hamish Clarke who is also currently completing research on AMS at Lincoln University. Any further questions were asked via phone or email so as to minimise disruption to the farmer. A verbal, face-to-face interview was deemed as the most accurate way to collect the qualitative information desired. This was due to the importance of understanding the individual decision-making process and key focus areas of the farmers. Questions or prompts were non-leading to ensure that the results were non-biased and representative. Interviews occurred in the farmer's natural setting i.e. in their home or office. Interview times were set at a time and date that suited each of the participants. In most cases the interviews were with the farmer alone, however input was encouraged from partners and farm managers.

Two types of information were collected. The primary form was qualitative data in order to develop an understanding of the farmers' motivation and decision making process. This was supported by quantitative or numeric data, relating to physical and financial success for each case study. All data was collected with the aim of increasing understanding and drawing insights, as opposed to being collected for use in statistical tests such as used in quantitative studies.

Minimal notes were taken during the interviews. Instead information was collected by a digital recording, which allowed conversation to flow, and information to be re-examined. In some cases, the interview involved a farm tour, which helped with understanding the farmer's story.

## 3.7 Data processing and analysis

After conducting interviews with the farmers, important information from the digital recordings was transferred to a Microsoft Word document. Information was sorted based on theme, for example 'key drivers of adoption'. This process provided a review of each study so as to identify differences and commonalities between farms. Due to the minimal amount of numerical data collected, this information was also entered directly into the Microsoft Word document in its related fields, e.g. 'production or environmental impact'.

## 3.8 Researcher position

I am an Honours student completing a Bachelor of Agricultural Science in November 2014. I have a wide background in agricultural undergraduate papers and experience on both Canterbury and Waikato dairy farms. I had no special prior knowledge of AMS farms, although farm systems and technology are of a personal interest. My background, having no prior affiliation to AMS farms but knowledge of dairy farms in general, may or may not have been a disadvantage to getting quality data in a study of this type.

## 3.9 Farmer consent and confidentiality Issues

Participants were made fully aware of the nature of this study when being invited to take part. Initial contact was made by phone, explaining the background of the study and goals of the research. At this stage, most farmers indicated whether they were happy to participate in the study. This phone call was followed up by an email and a secondary phone call in which the potential participant was asked if they had any questions further to what was explained previously, and to set an interview date and location.

Farmers have been assigned a letter to identify them within the study, e.g. "Farmer A‟. While every effort has been made to keep the participants identities confidential, it may be possible for them to be identified by those with close knowledge of the farm or participant. At the beginning of the interview, farmers were formally presented with the study information and given the researcher's contact details (Appendix A).

Under clause 6.2.3(2) of the Lincoln University regulations, students conducting research as an honours project for their undergraduate degree do not need to apply for human ethics consent in situations where the farmers will be interviewed solely in their professional capacity. Clause 6.2.3 (2) states that "activities ordinarily exempted from review include research projects involving interviews with and/or observations of public figures or professional persons in the areas of their duties or competence, provided that this is in accordance with the provisions of the Privacy Act". This was the nature of this research and therefore application for human ethics consent was not required.

## 3.10 Health and Safety

Health and Safety risk was mainly isolated to that of the researcher while carrying out interviews. With interviews being carried out on farm, normal farm hazards such as stock and machinery were managed in a practical and common sense way. Similarly, travel to and from farms was completed sensibly, leaving plenty of time to reach the destination.

## 3.11 Research method limitations

Davidson and Tolich (2003) conclude that there is no such thing as one best research method. A case study approach was selected for this project as it had been identified as the most suitable method for achieving the research aims while reducing limitations that may interfere with the results.

Case studies require an in-depth level of analysis, which achieves insight and understanding, but it did limit the number of participants that could be interviewed considering the short time frame of the study. This may have reduced the representativeness of the research outcomes as only a small proportion of the targeted population are acknowledged. It is therefore unlikely that this research identifies all the key drivers, benefits and limitations of AMS adoption. Accordingly, the study findings relate specifically to the purposively selected farmers, and any generality to what is being achieved by broader populations has been avoided.

# CHAPTER 4
# CASE STUDY PROFILES

## 4.1 Introduction

This chapter provides a brief overview of the case study farms and summarises the interviews with the farmers. It includes a brief description of the farm system and personal experiences and opinions on the adoption and success of robotic farming. These farmers have been identified as having a large amount of experience in their field and as part of their interview were given the opportunity to provide their opinions for the future of AMS in New Zealand dairy farming. All farms are located either in Canterbury or the Waikato. To maintain anonymity, each farmer has been allocated a letter, which is used throughout the entirety of this report.

## 4.2 Farm A

### 4.2.1 Farm Overview

Farm A is an indoor AMS farm located in Canterbury. Currently the farm is milking 180 Friesian cows through 4 robots in a 300-cow shed. The fully irrigated 80 hectare (72 effective) property was originally used as a run off block for the farming business's other dairy enterprises. The property, which has been in the business for over 12 years, was converted and commissioned as an AMS operation in 2012. All of the available land is now used as support for the indoor system with a mixture of crops grown and harvested for feeding in the barn.

The barn is set up as a free flow system with controlled exit. Cows are collected 3 times a day in order to maintain a milking frequency of around 3 milkings/day. The current diet is based on a pasture mixed ration consisting of predominantly lucerne silage, wheat silage and 'waste' bread. This is fed out twice a day as well as grain and molasses available in the robot. Feed is closely monitored in the barn in order to increase cow visits and reduce wastage. Cows are calved all year around with mating based on stage of lactation as well as production. Planned length of lactation is between 12 and 14 months with an average dry period of 60 days.

### 4.2.2 Key Drivers

<u>Production</u>: Farm A's key drivers for adopting AMS are predominantly production based. Effort has been put in to breeding a cow that produces more milk over the years. The farmer is very passionate about maximising per cow production and getting more feed through fewer cows. This is perceived as a more efficient way to farm and difficult to achieve through grazing alone. The farmer believes that in NZ, cows have been bred for production which can no longer be met by a solely pasture diet.

Labour: In order to maximise production the farmer realised he would have to increase the number of milkings per day and improve the diet. Finding labour, that will milk cows more than twice a day, is difficult and the farmer was not interested in doing it himself. Pasture based systems have proved difficult for maintaining a milking frequency of three so the decision was made to go for a confined system.

Cow comfort: Farm A has always winter-milked cows. The condition of milking cows outside, on pasture over winter, has always been a concern. Cows also prefer routine and benefit from consistency. With the confined AMS system it is much easier to control the diet and maintain a comfortable climate for the animals.

Succession: Farmer A highlights that succession also played a role in adopting AMS. The novelty and technicality of the system was seen as an incentive to attract the younger generation back into the business. After farmer A's initial interest in robotics 10 years ago it was his son who drove the research and helped make the idea a reality.

The challenge: There was a degree of uncertainty on how the adoption of AMS would go, however after seeing it working on other farms they were confident it could work in their system. The aim was to do the best they could and make the operation financially viable. With this comes an element of proving that AMS is a viable investment.

### 4.2.3 Planning & Establishment

Farmer A's interest in AMS began 10 years ago, however at this stage it was deemed unfeasible due to high start-up costs and a lack of knowledge in New Zealand. Upon farmer A's son retuning from studying, the idea was revisited with the son driving the research. The majority of the original research was based on magazine articles and overseas information. Visits to existing New Zealand AMS farms and consultation with the AMS manufacturers were beneficial during the next stage and the decision was made to build a barn.

Farmer A also travelled overseas to look at other AMS operations and see how they functioned. The best information was identified as coming from overseas. Once farmer A and his son had seen AMS in operation overseas they were confident they could make it work given they had similar systems and cows. Cow selection was identified as a critical component of the planning stage with genetics and udder conformation essential to maximise the benefits of AMS.

### 4.2.4 Benefits

Animal health: While animal health costs have not been that different from farmer A's other dairy farm, cow condition is much better. Cows are noticeably less stressed and quieter. After a season of production farmer A noticed that cows even "begin to follow you around". The level of data collection from the robots also allows farmer A to closely monitor cow health and quickly identify changes in cow behaviour, production or condition. Lameness is basically non-existent in the enclosed system. Somatic cell count has not been an issue, however severe cases of *E.coli* mastitis are more common.

Production: Farmer A believes the greatest benefit of AMS is higher production. Farm A is achieving on average 3 milkings a day and 50% greater production than farmer A's traditional dairy farm. They are currently aiming for an average daily production of 40 litres per cow. However this is thought to be a result of the change to the whole system with more milkings, less stress and better nutrition. Farmer A believes that AMS facilitates greater production compared to solely confined systems. This again comes down to a greater number of milkings and less animal stress, but also includes the potential to house more animals. Because cows are able to have their own routine (milking, standing up, feeding, having a back rub, etc.) it is possible to house more animals as not all the cows will be lying in the beds at one time.

Feed: Farmer A identifies the benefits of better feed control and utilisation in the confined AMS system. Feed utilisation is estimated to be in the 90 percent range with the majority of wastage being in the way of spoilage in the silage pit. What isn't utilised in the barn is fed to young stock in troughs.

### 4.2.5 Limitations

Labour: Farm A found that there were no real labour savings in their system. There is a similar workload to other dairy farms, however it is a different "easier" type of work. A large amount of time is spent making sure robots are working properly and maintaining them. Sourcing experienced AMS labour is difficult; however sourcing capable labour has not been hard. The majority of employees are young people with no prior experience.

Cost: Farmer A identified cost as the biggest barrier to the uptake of confined automatic milking systems. A high level of capital is required to establish such systems and as a result of a lack of knowledge around confined AMS in New Zealand, securing funding can be difficult. Farmer A's other farming enterprises were essential to securing money for the AMS venture. Running costs of the robots are also slightly higher with increased power consumption and servicing costs.

Establishment: Farmer A experienced a number of teething issues following the commissioning of the robots. These were considered to be annoying but have since settled down. Transitioning cows to the robots was also time-consuming. Cows were transitioned onto the robots as they calved over a two-month period. This required farmer A to spend from 5am to 8pm in the shed every day during this time. Farmer A believes it would have been easier to transition an entire herd mid-season and compress the training period, however as this was not an existing dairy farm this would have been difficult to achieve.

Professional help: While there is plenty of knowledge overseas, Farmer A identified a lack of professional help around robotics and confined systems nutrition in NZ. Robotic systems require diets to be balanced in order to optimise cow flow. Farm A relied heavily on overseas consultants both during the establishment stage of the system, as well as for day to day balancing of the feed rations. Getting good advice on balancing the pasture mixed-ration fed in the barn, with that of the protein being supplemented through the robot is seen as critical for making the system work.

On call: While the hours of work are not as demanding as traditional dairy systems, Farmer A highlights that you are on call 24/7. On average someone will get called out 5-6 nights a month to attend to a fault with the robot. This takes half an hour on average to repair and is particularly annoying if the issue is minor.

Risk: Farmer A highlights that confined systems are particularly vulnerable to fluctuations in milk payout and feed cost. Feed costs are a large portion of farm A's working expenses (in excess of $3.50/kgMS) and do not necessarily correspond with payout. Confined systems are also at particular risk to rapid spread of disease due to the animals' close proximity. Farmer A also identified public perception as a business risk. There is a lot of misconception around the condition that cows live in, in confined systems. However most people are pleasantly surprised when they visit the property. Neighbours will however complain if the barn produces any noticeable smell.

Environmental regulation: Farmer A identified the difficulty of determining the environmental impact of confined AMS. The environmental impacts of these systems are currently not able to be modelled by governmentally recognised modelling programmes such as Overseer. This can make it difficult to get resource consent, in regions like Canterbury, where there are restrictions on nitrate leaching.

### 4.2.6 Future of robotics

Farmer A strongly believes there is a future for AMS in New Zealand dairy farming. Family farms are seen as the most likely adopters with the market driven by lifestyle choices. Farmer A also identified the opportunity for multiple farm operations and integrated farming systems. Having multiple dairy farms was seen as an advantage when establishing the AMS property as it allowed for cows to be moved between farms if they would not settle into the barn system. Having the other farming enterprises also helped when it came to securing financial backing. Crop farms looking to diversify income could establish a confined AMS enterprise and integrate crop production with milk production reducing feed costs and wastage. Lifespan of robots is not seen as an issue with all components replaceable and upgradeable. Farmer A says, “In 10 years’ time it will basically be a new robot”. Original robots in Europe are still in operation after 20 years of use.

## 4.3 Farm B

### 4.3.1 Farm Overview

Farm B is an indoor AMS farm located in South Canterbury. Originally established with 4 robots, Farm B now milks 300 cows through 6 robots in a 300 stall barn. Traditionally sheep and beef farmers, the originally 100 hectare predominantly irrigated property has always been part of the farming business. Over the years the property has had a number of farm systems including techno bull beef and intensive heifer grazing. The property was converted and commissioned as an AMS dairy farm in early 2013. All 100 ha and 30 ha of newly purchased land, of which only half is irrigated, are now used as support with a mixture of supplements grown and harvested.

Farmer B's cows were sourced from a traditional spring calving European Holstein Friesian herd. These cows were already being fed a high level of supplements due to their breed. Cows are calved all year around with all mating done by AI and based on a cow's production.

### 4.3.2 Key Drivers

Income diversity: Farmer B is a 3rd generation sheep and beef farmer with no prior dairy farming experience. The current AMS block has always been a part of the farming business and traditionally has been used as a way to diversify income including techno bull beef and intensive heifer grazing. Farmer A identified dairy as a good way to broaden his portfolio, however, when running the numbers, the property was seen as too small to be a financially viable traditional dairy farm. The property however was identified as being ideal for AMS.

Production: The added production expected from the confined AMS conversion was seen as the key driver of the conversion feasibility. Farmer B was particularly interested in increasing the system's efficiency with an interest in maximising production through the barn. Being able to get more milk from fewer cows in conjunction with growing more feed from crops was very appealing. Some of the new land purchased was also deemed too costly to irrigate due to having to pump water up hill. A confined system meant that this land could then be used to grow lucerne, which is then harvested and fed in the barn. Also given farmer B's background in intensive pastoral farm systems it was identified at the time of conversion that pasture management achievable with an AMS system would be too inefficient.

Sustainability: Farm B borders a river and as a result of recent nitrate leaching restrictions in Canterbury it would have been difficult to obtain consent for a traditional dairy conversion. A confined AMS system was seen as being more environmentally sustainable given that all effluent is contained and spread on to the land in a controlled manner. This removes the impacts of nitrate loading caused by cows grazing on pasture.

Opportunity cost: Due to the high cost of land in Canterbury, farmer B identified that it was cheaper to invest in robots and a barn than to purchase the land required to sustain the same amount of production. It was expected that twice the amount of land would be needed. It can be argued that they have invested in infrastructure, which will depreciate while land is expected to appreciate. Farmer B believes that time will tell if this proves to be the case or not.

Succession: Succession was an important driver behind AMS adoption on Farm B. Farmer B's son graduated Lincoln University and was always interested in farming and technology, however he did not want to go into the sheep and beef industry. Farmer B says it would also have been difficult to convince his son to work in a traditional dairy system given the unfavourable working hours. Farmer B believes that if they hadn't adopted AMS they would probably have sold up and bought an arable farm in mid Canterbury.

Early adoption: Farmer B identifies himself as an early adopter. An irrigation system was installed on the AMS block in 1985. Shortly after a techno bull beef system was adopted, which was one of the first of its kind in the South Island. Farmer B is not afraid to take risks when it comes to innovative technologies and enjoys the challenge of making new ideas work.

Self-sufficiency: Farmer B identified self-sufficiency as a key driver with a long-term goal of growing all the feed to be fed in the barn on the property. This will reduce business risk by shielding it from fluctuations in feed cost. Some feed is currently imported from the other farm, but farmer B identifies an opportunity to improve efficiencies on the AMS block.

### 4.3.3 Planning & Establishment

Farmer B's interest in robotics was sparked when a connection in DairyNZ identified that the property was ideally suited for a pasture based AMS operation. This grabbed farmer B's son's attention, who then pursued the idea. Following a visit to other South Island pastoral AMS farms farmer B identified a number of limitations of pasture based systems and decided to go for a confined system.

Farmer B did not spend any time overseas, opting to visit other confined systems in the South Island in order to get a better understanding of shed designs and layout options. Farmer B identified that there is no “correct” layout or design, as ways to improve cow flow are continually being developed. As a result farmer B’s shed design is slightly different from that of other examples in the country. A lack of professional knowledge in this field was identified by farmer B and with no prior dairy experience they had to learn a lot themselves. The most important planning and establishment factors were identified as site selection, farm layout and feed storage space.

### 4.3.4 Benefits

Labour: Farmer B found that the system attracts a different pool of labour and has not had any issues finding staff. The more socially acceptable hours of work has helped as well as the spread of labour intensive jobs. All year round calving reduces the peaks in labour demand as experienced in traditional calving systems. Working with technology has not been found hard to pick up, particularly for the younger generation.

Animal health: Farmer B identifies a reduction in stress on the cows in this system. Cows are never hungry and are able to be milked whenever they desire. As a result cows are in excellent condition. The level of technology also allows farmer B to monitor what is going on carefully, and identify any changes in cow behaviour quickly. This helps reduce animal health issues with cows treated earlier and problems identified sooner. Longevity of cows is also superior and as a result of improved cow condition the sale value of cull cows is increased. Farmer B’s last line of cull cows sold for between $800 and $1200 each.

Environmental Impact: While nutrient modelling programmes such as Overseer currently do not have the capability to model the environmental impact of confined systems, farmer B estimates that nitrate leaching is reduced. By running parallel systems through Overseer it is estimated that the current system only leaches 14 kgN/ha while the techno bull beef system leached upwards of 20kgN/ha. This is a result of all effluent being contained and spread evenly over the property during low risk periods.

Production: Production has been higher than expected in this system. Farmer B originally budgeted on producing 550 kgMS/cow in the first year and as a result only installed 4 robots. Actual production was closer to 700 kgMS/cow, requiring another 2 robots to be installed soon after commissioning. Some of this may be explained by the quality of the cows that were purchased, however this level of production is still much higher than that expected in a traditional pasture based system. Confined systems are not limited by grass growth and as a result production curves do not follow such a seasonal pattern. This also allows cows to be mated based on production and target weights;

subsequently improving efficiencies. Farmer B also identified the potential for much greater feed production off cropped land compared to pastoral land. This is then complemented by improved feed use efficiency in the barn and the ability to conserve feed during high growth periods.

### 4.3.5 Limitations

Professional help: Farmer B identifies a lack of knowledge and advice on confined AMS in New Zealand. There are currently no independent advisors for robots or barn systems. This however is expected to change as more people adopt the technology and experience grows. Farmer B found that economic drivers were hard to determine, as there was no one in the country that could peer review them. The only advisors at the time of the development were attached to the robot manufacturers which farmer B believes do not have an independent view. A lack of knowledge around establishing these systems in terms of shed layout and transitioning cows was also identified. The majority of shed alterations were suggested by an overseas consultant.

Labour: Farmer B under budgeted when it came to staff requirements. He believes that it is a popular misconception that robots will halve your labour requirements. This however is not the case. The labour requirement is still there but the nature of the work is shifted. There is a greater emphasis on cow care, keeping the environment clean, maintaining robots and mixing feed. Farmer B believes that labour expenses would be similar to that of a traditional pasture based farm.

Transition: The first six months following the robots' commissioning was identified as a difficult time. The extent of this was compounded by the lack of experience in dairy farming and the absence of professional advice. Getting cows to use the bed was identified as the hardest part. Because farmer B didn't have another dairy farm to return slow adopters to, he had to persevere with these animals. Now that cows are using the beds it is easier to introduce new animals to the system as they copy the other animals. Older cows took some time to adapt to the robot, as they were not accustomed to the robot arm coming in from the side. Carry over cows were used to commission the robots with late calvers purchased at a discount rate in order to spread the calving. Farmer B also identified a number of animal health issues during the transition period, which were believed to be linked to nutrition. Since then he has employed an overseas nutritionist, which seems to have helped solve the problem.

Risk: Negative public perception increases the level of risk to the business. There is a negative image of cows living indoors as it is seen as an animal welfare issue. However farmer B strongly disagrees with these accusations highlighting that when cows are dry and not in the barn it is not uncommon for them to jump fences in an attempt to return to the barn. There is also a perception that dairy farming in NZ can only be competitive with the use of cheap grass. However farmer B believes this is no longer the case once you take into account the cost of inflated land prices.

Cost: While farmer B did not find it hard to secure funding, he highlighted that this was likely a result of the strong financial position of the business and ownership of two properties. He believes that this could be a barrier to adopting AMS for people early in their career.

### 4.3.6 Future of robotics

Farmer B sees a strong future for confined AMS systems in New Zealand dairy farming. These systems offer an environmentally friendly option for intensification and increased production. This will be particularly important as environmental regulations are tightened and land use restrictions are put in place. There is potential to run these systems in conjunction with cropping enterprises looking to diversify income, as well as properties with limited irrigation. This would reduce the distances cows have to walk and allow the land to maximise production through unirrigated crops such as lucerne. Uptake from existing dairy farms is likely to be slow due to the money already invested in milking facilities. Farmer B highlights that these systems are still developing and that once they are better understood they can easily be replicated elsewhere.

## 4.4 Farm C

### 4.4.1 Farm Overview

Farm C is a hybrid split calving AMS farm located in the Waikato. Currently farm C milks 300 cows through 4 robots in a converted 20 year old, 20 aside herringbone. The 72 hectare (68 effective) was converted from a traditional dairy farm to an AMS operation in 2012, when the original dairy shed was gutted and the pit filled in to make way for the robots. Farmer C has been involved in the dairy industry for over 20 years, converting a number of farms and milking a large number of cows initially in the North Island and then in the South Island.

The decision to build a free stall barn was made in order to sustain a split calving without having to purchase more land. This allows farmer C to take advantage of premiums from winter milk contracts. Cows are still grazed on pasture all year round but have free access to the barn in the morning and night during winter. Farmer C is experimenting with using the barn during the day over summer as a method of reducing heat stress and maintaining production. Cows are averaging 2.3 milkings a day with the best cows achieving nearly 4 milkings a day. All cows are artificially inseminated with spring calving starting at the beginning of August and autumn calving at the beginning of April. Average dry period is 65 days. Farmer C aims to calve 50% of the herd in spring and 50% of the herd in autumn.

### 4.4.2 Key Drivers

<u>Lifestyle</u>: Farmer C was tired of being tied to the milking shed after over 20 years of dairy farming. AMS was seen as a way to maintain involvement in the dairy operation while being free from the routine of twice a day milking. Farmer C chose the Waikato due to property limitations in the South Island as well as for family reasons and the warmer climate.

<u>The Challenge</u>: Farmer C identifies himself as someone who enjoys the challenge of establishing farms and trying innovative ideas. Pastoral robotic systems drew on this interest, as there is no proven correct method. There have been a number of critics who thought the system couldn't work and farmer C wanted to prove that it is not just possible, but also financially feasible.

<u>Property limitations</u>: Farmer C could have adopted robotics in the South Island on his original property but believed that cow flow would be comprised by the centre pivots crossing raceways. He decided that he would find a property in the Waikato that would suit the system and "show the Waikato something different".

### 4.4.3 Planning & Establishment

Farmer C looked at robotics roughly 6 years before adopting it. From here he spent a few days on a robotic farm in Southland helping with the commissioning of the robots. He also spent some time looking at existing farms in the North Island and Australia. Once he was sure he could make the system work, farmer C then focussed on getting the barns' design right, visiting a number of barns in the South Island. He believes that you learn more from getting in the field and visiting farms than you could ever do sitting down with a designer. Initially the robot manufacturers tried to dictate the shed design but, farmer C argued that if they couldn't fit into his system then he would go elsewhere. This highlighted that you do not need to just do what the manufacturers suggest. He also highlights the importance of doing things right the first time and to keep things simple. Thinking like a cow is important as they are the end users of the system and any changes further down the track are likely to confuse them.

Farmer C brought 110 cows up from the South Island and in hindsight should have picked the best cows in the herd. He then bought another 30, which were chosen on teat placement and age. Of these cows only 2 cows didn't transition and this was due to teat placement or udder conformation. Farmer C highlights the importance of balancing the number of cows per robot. Initially the property was established with 3 robots which was not enough and once the 4$^{th}$ robot was installed the heifers increased production by roughly 4L/day. Consistency such as keeping paddock changes to a set routine is important in these systems. Feed allocation is important to maximise cow flow, however if cows are over fed they will eventually return to the shed to be milked. All paddocks were split in half during the conversion so that they were roughly 1 ha in size in order to ease pasture management.

### 4.4.4 Benefits

Production: Farmer C believes the biggest benefit has been the lift in production. Farm C has achieved 520 kgMS/cow and is targeting an average of 600 kgMS/cow with the combined use of the barn. Farm C has also experienced a higher milk solid percentage, which may be a result of improved nutrition. Cows are supplemented with between 3 and 8 kg of grain in the robots depending on stage of lactation. Pasture management has not been an issue due to the farm's high stocking rate and only once has the farmer had to top pre-grazing. Farmer C believes that cows are frequently underfed in the Waikato and this hybrid system facilitates a greater fulfilment of genetic potential. Milking frequency is also higher accounting for some of the lift in production. Robot efficiency is also maximised through split calving in that fresh calvers will be milking upwards of 3 times a day while late lactation cows may only be milking 1.5 times a day.

Animal health: Cow condition on farm C since the adoption of AMS has improved. Animals appear to be less stressed and are never hungry. This season cows have had free access to the barn over summer during the afternoon and at night. Farmer C has been surprised by how early cows are opting to return to the barn and believes it is an indication of heat stress. When the temperature is 29 degrees outside, in the barn the temperature can be as low as 21 degrees. Farmer C believes this increases cow comfort and promotes higher feed intakes. As a result of less stress, farmer C also believes that cow longevity will be increased.

Labour: Farmer C believes these types of systems attract a higher calibre of labour into farming. Work hours are regarded as more socially acceptable with employees starting at 7:30 am and finishing just after 5:00 pm.  Farmer C has never had a problem obtaining staff and staff retention is high. Farmer C does highlight that you do get called at night, but that the alarms that are critical can be controlled. The current system can handle one unit going down at night if the problem isn't serious. Robot manufacturing companies also provide excellent service when required.

Use of existing infrastructure: Farm C is a good example of using the existing infrastructure of dairy farms in an AMS conversion. Farmer C spent $150,000 retro fitting the existing dairy shed, which already had its own effluent system. This reduced the consents needed, further reducing the cost of the conversion. Farmer C does however; highlight that a larger pre milking holding pen would have been useful and that there were some limitations in design as a result of working round existing infrastructure..

### 4.4.5 Limitations

Transition: Farmer C believes that the transition period is the most difficult factor of AMS adoption. The first spring was extremely stressful with the farmer spending nearly 24 hours a day in the shed for the first 3 weeks. Some of this was identified as being a result of being used to having control of cows milking twice a day, and spending a lot of time pushing cows through the robots. Eventually farmer C realised that in order for the system to work the cows need to be in charge and to let them do their own thing. This is identified as a difficult concept to get your head around, particularly for someone with significant experience in traditional dairy systems. Farmer C now only trains cows for 3 days with the cow left to its own accord on the 4$^{th}$ day. Herding is also an issue during the transition phase with cows used to batch milking. As a result cows will move together causing congestion at the dairy shed. Farmer C reduced this by introducing 6 cows at a time and using paddock changes to ease congestion and maintain cow flow. Training cows to the beds in the barn was difficult and took a good part of a month. Heifers tend to learn faster as they are smaller however it can still be difficult because unlike Europe where cows spend their whole life in a barn, heifers are not introduced into the barn until they return to the farm as 2 year olds.

Congestion: Farmer C identifies that cows will hang around the cow shed waiting for the paddock to change and that the constant flow of traffic can make a mess of races entering the shed. There is currently no solution for the issue. If he were to pour more concrete, the extended run off would then have to be contained and the effluent system expanded.

Mating: Farmer C currently artificially inseminates all animals, as running bulls in this system was difficult. Bulls tended to block races and stop cows returning to the shed reducing milking frequency. This increased animal stress and reduced productivity. Farmer C is currently looking at a way to draft low genetic cows into a bull paddock as a way of incorporating bulls into the system.

Cost: Farmer C highlights that these systems require a large investment and this is likely to hinder people's ability to adopt. Operating expenses such as feed costs and electricity bills are also higher in this system. Farmer C has worked to contain the latter by installing solar panels on the roof of the barn, which can power the farm during the day. This is expected to halve the power bill as the property still runs off the grid at night. Farmer C believes given the cost of electricity today, the turn around on investment will be as little as 6 years.

### 4.4.6 Future of robotics

Farmer C believes there is a future for hybrid AMS in New Zealand dairy farming. High capital costs are likely to slow the rate of adoption in the near future, however the number of farms will continue to grow. Farmer C believes that these systems are well suited for smaller Waikato and Taranaki farms and that the potential to double the production from cows is both financially and environmentally enticing. Lifespan of the robots is not seen as an issue with all parts replaceable and upgradable. A lifespan in excess of 25 years should be achievable. Farmer C believes that a lot of people don't realise how far the industry has come in recent years. Field days are, however playing an important role in demonstrating the potential of these systems and showing how they work.

## 4.5 Farm D

### 4.5.1 Farm Overview

Farm D is a hybrid, split calving, pasture based AMS farm located in the Waikato. Currently, farm D milks 180 cows through 3 robots in a specially built dairy shed in conjunction with an existing uncovered feed pad. The 70 hectare (65 effective) property was originally part of an existing larger dairy operation milking 320 cows. The decision to downsize resulted in the existing dairy shed being sold with the rest of the farm. The new downsized block however had an established feed pad and old herring bone infrastructure. It was decided to completely replace the old milking shed with a specifically designed AMS shed and incorporate the existing feed pad into the system. Cows have free access to the feed pad during winter in order to maximise feed intake but are restricted to predominantly grass during summer.

Farmer D currently sells all progeny and buys in 3-4 year old replacements in order to maximise milk production. This also removes the cost and hassle of grazing young stock. Spring calving begins at the start of August and autumn calving begins in the middle of March. Roughly 100 cows are milked over winter including carry over cows. The average dry period is 6 weeks and average live weight of cows is 560 kg. There is no topping done on the farm, instead paddocks are locked up for silage if cover gets too high. Farmer D does not use an independent nutritionist and instead relies on his feed company to balance diets.

### 4.5.2 Key Drivers

Shed upgrade: Following the downsizing of the operation, farm D was left without a functioning dairy shed as the existing shed was sold with the rest of the farm. Still interested in milking cows, farmer D decided to explore his options for either renovating the old milking shed on the property or building a new shed. This provided farmer D with the opportunity to look at AMS. The retired milking shed site already had the feed pad attached and a suitable race system feeding into it.

Production: Improved cow nutrition and increased per cow production was a key driver for adopting AMS. Farmer D doesn't understand why you should milk more cows just to pay for more debt. AMS was seen as a way to increase the farm's production without having to buy more cows.

Lifestyle: Farmer D identified the stress of having to milk cows as another key driver for the adoption of AMS. Farmer D and his wife are an older couple and decided that they wanted a change from the stress of physically milking cows. Both keen dairy farmers, they were however not ready to give up on dairy farming and enjoyed the animal side of the business. Farmer D's son wanted to put a herring bone on the property, however farmer D could see himself ending up back in the shed and was not interested.

Winter milk premiums: Farmer D also saw AMS as an opportunity to exploit the extra premiums of winter milk contracts. If possible, farmer D would like to have a higher percentage of autumn calvers than spring calvers. This would mean that a higher percentage of production is going towards winter milk contracts and earning more income. Farmer D however realises that the cost of feeding cows over winter must also be considered and aims to rely on pasture as a feed source as much as possible.

### 4.5.3 Planning & Establishment

Farmer D looked at robots around 10 years ago and identified that they were too expensive. Since then he has kept an eye on the development of the technology and visited local farms that have adopted them. Following the visits to functioning AMS farms, farmer D decided he could make it work. From here he sat down and designed a purpose built shed and layout that would fit the existing site. Farmer D highlights the importance of getting the initial design right and to not cut corners. After attending an AMS conference in New Zealand it was determined that there is no one correct design, with everybody running different systems.

Feed allocation is important for cow flow. Paddock size is therefore an important aspect of the planning and establishment stage. If overestimated, there will be a likely reduction in milking frequencies and subsequently production. Matching the number of robots to the number of cows is also an important factor in regards to maximising cow flow. Eighty cows per robot is seen as a feasible ratio for maintaining a milking frequency of three visits a day. Farmer D bought a number of cows from a semi-automated rotary system and noticed they transitioned much quicker to the robots than cows from a herringbone. This is thought to be a result of them being used to a single bail high input system. Farmer D aims to buy cows in autumn when they are cheaper to purchase and identifies udder conformation as a key selection trait.

Farmer D believes that there are a lot of systems out there that people make too complicated. The robotic system can run itself if you have the right attitude and design. There is a need to keep the system simple as the more you interfere, the more complicated the system becomes and the greater the work load.

### 4.5.4 Benefits

Labour: Farmer D also believes that these systems attract a wider selection of potential employees and makes room for a more intelligent labour pool. Farmer D believes this is a result of the reductions in physical stress. Work hours are more socially acceptable with later starts (8am) and not being tied down to a timetable. While the work is still there, staff are not restricted to a routine dictated by milking times and instead can work to their own schedule. This allows staff to increase the variety of their work during the day and do things when they want. While AMS theoretically reduces the amount of labour required, farmer D opts to employ a farm manager in order to free him from being tied to the farm.

Challenging: Farmer D believes this system has given him a new enthusiasm for farming due to its challenges and uniqueness. He no longer feels like a slave to the farm and instead looks forward to finding ways to tweak and improve the system. The level of data collected is tremendous and aids in the decision making on the property. Support from the robot manufacturer has been excellent with most issues able to be fixed over the phone or remotely.

Animal health: Animal health has improved and cows are less stressed and in better condition. Farmer D has noticed that the pecking order has reduced as a result of cows being able to have their own routine. There are still some signs of herding but the size of groups is a lot smaller. Longevity of cows has improved and selection pressure for culling has had to increase due to it being harder to identify culls. Cows that were on the cull list on the old farm are now in the top 10% of cows on the robotic farm. The high level of data collection and projections helps to identify problems remotely and allows for a quicker diagnosis and treatment. Cows never appear to be hungry with little bellowing or running between paddocks.

Production: Per cow production has increased in this system. While aiming to keep as pasture-based as they can, farm D has increased cow production from 430 kgMS/cow to 500 kgMS/cow in the first year of production. Farmer D highlights that cows appear to hold production levels for longer in this system. This is aided by increased milking frequencies with an optimum milking frequency of 2.7-2.8 milkings/day identified. The robots also allow for accurate drying off, with drying off groups determined on calving date and production. Cows that don't get in calf are continued to be milked and carried over until the next mating period.

### 4.5.5 Limitations

Perception: A lot of people don't see how AMS can work and doubt that it can work in a pasture-based system. Farmer D says even his wife doubted it would work originally and that you have to physically see it to believe it.

Transition: Farmer D identifies the transition period as the hardest part of adopting AMS. Farm D was commissioned by introducing autumn calvers from the original farm to the robots in May. Cows were trained in groups with patience a key factor for successful training. This period was stressful and time consuming, but now cows will walk straight into the robot when they calve. The shed is set up with training gates to help during this period. Farmer D only had to get rid of 3 cows that wouldn't settle into the system with teat placement playing a major role. He believes it took the people longer to get used to the system than the cows, with his son struggling to grasp the concept of cows running the system. Farmer D received more milk quality grades, in the first year following AMS adoption, than ever before. This is thought to be a result of everything being automated and never really inspecting the vat to see that it has been cleaned properly. Vat selection was also identified as an issue with central draining vats not suiting the automated cleaning system.

Workload: There is a popular misconception that these systems will run themselves if left alone. Farmer D reiterates that this is not the case and that they have probably been on the farm more with this system than in the past. Workload however has shifted from physically milking the cows to monitoring the farm system and making sure everything is working smoothly. At the start farmer D got called out of bed quite often, however this has stopped as things have calmed down and non-critical alarms have been identified and switched off. This is all part of getting to know how the machine works and can be daunting initially. Farmer D however, says that everything is easy enough to pick up and that the computer system is very user friendly.

Cost: Farmer D identified the high capital costs of these systems as a potential barrier to adoption. Due to the lack of knowledge around the systems and their profitability, farmer D found it difficult to secure funding from the bank. He now says that a lot of the people that come and look at the system will bring their bank manager to show them that it is feasible. Operational costs are also higher with the biggest increase being the power bill. This is not necessarily driven by the robots but instead by the need to keep the cooling system running 24/7. These systems also require large generators to supply power when the mains power is obstructed. Often power companies will cut the power supply for line maintenance in the middle of the night when the wash is going through resulting in the robots needing to be reset.

Lack of research: Little research around AMS has come out of New Zealand since the DairyNZ Greenfield trials 10 years ago. Farmer D believes that this information is now obsolete and that new data is needed. Results from the Greenfield trials are often quoted in publications, which wrongly portray the current success of the industry. The technology as well as management has come a long way since the Greenfield trials were ended by DairyNZ.

### 4.5.6 Future of robotics

Farmer D strongly believes that robotics is the future of New Zealand dairy farming. While farmer D does not have a second traditional dairy farm to complement his AMS farm, he does see the potential of running an integrated system. Farmer D believes that robots are best used to maximise returns from a farm's most productive stock. This may mean robotics suit farms where herds get split and top cows are milked through robots while the rest of the herd is continued to be milked through the original parlour. Alternatively, heifers could be calved and milked through a traditional dairy shed before being transitioned to the robots in their second year of production when their production potential is higher. Farmer D identifies the target audience of such systems are smaller farms of around 60-100 hectare. He also believes that it will suit the older generation of farmers as older milking sheds require upgrading and these farmers no longer want to be involved in the physical activity of milking cows. Larger farms would be better off being split into smaller modules to ease management and reduce the distance cows have to walk. The life expectancy of the robots is not seen as an issue with all parts replaceable and existing robots overseas exceeding 20 years of age. Given the reduction in animal stress there is also the potential to sell the image of "Happy Cows" to consumers and produce differentiated products.

## 4.6 Farm E

### 4.6.1 Farm Overview

Farm E is a spring calving, pasture based AMS farm located in the Waikato. Farm E currently milks 320 cows through 4 robots in a purpose built milking shed. The 80 hectare (78 effective) property has been part of the farming business for 30 years and prior to conversion to AMS, in 2010, was a fully functional low input traditional dairy farm milking 300-350 cows at 4 cows/ha.

Farmer E opts for a spring calving system due to the extra feed that would be required to run cows through winter. Some thought however is going into transitioning to a split calving system on the back of milder winters and in order to chase winter milk premiums.

### 4.6.2 Key Drivers

Existing infrastructure: Farm E was identified as being an ideal candidate for AMS with the existing layout requiring little modification or development. Current farm infrastructure was beginning to limit the old milking system with paddocks too small for the number of cows. Smaller paddocks were seen as favourable for AMS, which meant that the existing fences and races could be used in the conversion.

Labour: Farmer E hoped that with robotics the labour demand of the property would be reduced. This would allow him to get rid of the need for a farm assistant and subsequently reduce the labour expenses.

Personal interests: Farmer E admits that the economics of the conversion were always marginal and that it was his personal interest in the system that drove the adoption. He enjoys playing with the system and the challenge of making it work.

### 4.6.3 Planning & Establishment

Farmer E first heard about robotics during the DairyNZ Greenfield trials over 10 years ago. It was this research that sparked farmer E's interest in robotics and from here he began to try and determine the feasibility of a pasture based AMS operation. As part of his research, farmer E visited the first AMS farm in Australia, which helped show that a conversion isn't simple but that it could be done. At the time there were very few AMS operations in New Zealand and nobody had quite got it right. Farmer E highlights that there is still no "correct" system with every farm running a slightly different system and operation. Farmer E spent a number of years playing around with shed design and layout before deciding on a final system. He says that DairyNZ and the manufacturing companies were very helpful in this area and that there was no shortage of advice.

Farm E was commissioned by initially transitioning 20 empty cows and then introducing small groups of cows into the system. This was seen as the easiest way to transition cows as it meant that new cows could follow experienced cows speeding up the learning period. This was also seen as a way to reduce the congestion caused by herding. Farmer E believes the most important parts of planning and establishment are getting advice, particularly around farm layout and shed layout, and selecting the right cows for the system (udder conformation, teat placement and teat size). Balancing the number of cows per robot is also an important factor for optimising milking frequency and cow flow.

### 4.6.4 Benefits

Production: Production has increased compared to the previous traditional system. Per cow production has increased from 360 kgMS/cow to 460 kgMS/cow. How much of this can be accounted for by the adoption of robotics is unsure, but farmer E believes he has learned a lot about cow nutrition as a result of adopting the technology. He believes that per cow production of 500 kgMS/cow should be possible with improved nutrition and an optimum milking frequency. Farmer E identifies that production begins to drop off at a milking frequency below 1.7 milkings/day.

Animal health: Farmer E has seen large improvements in cow health. Cows are in better condition and appear to be less stressed. Cows lower down the pecking order seem to build confidence and visit the robot on their own accord instead of hanging back. Cows are more relaxed and quieter, no longer associating human interaction with being pushed around. Farmer E identified an unexpected benefit of improved mating success with higher conception rates and lower empty rates. This is thought to be related to cow condition and reduced stress. Longevity of cows is also higher, with farmer E finding it harder to identify cull cows. This can make it difficult when it comes to balancing replacement rates with the need for continued genetic gain.

Management: Farmer E believes that one of the largest benefits is being able to treat cows as individuals. The large amounts of information gathered from each cow allow individual management systems to be designed based on their production and behaviour. Management is made easier with one herd that can have milking frequencies varying from 1 milking/day to 3 milkings/day. Cows are not limited to a set routine and cows that are identified as struggling can be preferentially fed by controlling paddock changes and being given preferential access.

Labour: Farm E has had no issues obtaining staff. However he believes that these systems probably attract a different type of person. The current manager enjoys the challenges of the system and the variety of work during the day. This system gives the staff greater flexibility, with work schedules not tied to milking times. Farmer E believes that these systems are best suited to people that aren't routine based or short tempered.

Repairs and maintenance: As a result of less stress in the system the level of damage in high traffic areas is reduced. Farmer E identifies that pasture damage is reduced particularly around gateways where in traditional systems cow will congest. Cows are also not being pushed around so there is less pressure and stress on existing infrastructure.

Environmental monitoring: Farmer E believes that current nutrient models are not capable of estimating the environmental impact of these systems. The level of data collection particularly around cow movement and production however are likely to be useful tools in identifying true environmental impact in the future. Farmer E believes that in these systems, cows spend less time hanging around in the paddock and are more efficient at producing milk, thus reducing their environmental footprint.

### 4.6.5 Limitations

Labour: The spring calving system can be stressful, as all cows have to be taught to use the robot during the same period. Workload over calving is particularly high as a result. During this period, robots also spend a large amount of time rinsing after colostrum cows, further slowing down the process. Staff will often work long hours over spring with the flexibility of work reduced due to the seasonal restrictions of the system. Farmer E identifies that work load would be reduced by going to a split calving system. Farmer E also highlights the stress of being on call 24/7 in case a robot breaks down. While this was expected, farmer E has now opted to settle with one robot stopping working in the middle of the night, as this is when cow flow is lowest. Farmer E will however remotely check everything is going all right before going to bed.

Transition: Farmer E identifies the transition period as challenging, particularly as cows came from a herringbone system. Farm E transitioned the existing milking herd mid lactation resulting in a 10% drop in production that autumn. This was an expected outcome as cows settled into the system. Cows that would not settle into the system were sent to the farming business's other dairy enterprise. The majority of these were a result of poor teat placement and slack udders during autumn. Farm E had at least 8 people working in the shed during the first day of transition. The first spring had a lot of hold up issues with plant breakdowns and other issues. Fidgety cows and slow milkers also pose an issue as they take up box time and reduce robot efficiency. Farmer E found more lameness in the first 2 years of AMS production, which may have been a result of new concrete and cows transitioning to the system.

Pasture management: Pasture management in this system is harder. Farmer E has to pay closer attention to feed allocation as this influences cow flow. As a result, a lot of pre-grazing topping is done to maintain pre-grazing pasture covers. In spring, farm E aims to feed up to 99% grass. This however can reduce production and milking frequency, as there is less incentive to visit the robot. Pasture allocation is a key element during this period. Milking frequency and cow movement at night is highly related to the amount of supplements being fed at the shed. Farmer E has found that allocating less than 2 kg of supplements results in more cows having to be collected from the paddock while allocating more than 4-5 kg of supplements can result in no collections. Farmer E says it is easy for things to go wrong with pasture-based systems and he can see why people get frustrated and move to feeding more supplements.

Milk storage: An unexpected disadvantage identified by farmer E is to do with milk pick up. Due to the constant supply of milk, a more complicated vat system is required where milk is diverted to a header tank while the tanker picks up the vat load and a wash goes through. This can cause issues with tanker drivers not following instructions. Farmer E also identifies that a larger vat capacity is needed with these systems to accommodate any hold ups with milk pick up. Milk flow is constant so if there is any hold up with the tanker the vat will keep filling and over flow.

Cow flow: One of the issues with pasture-based systems is maintaining cow flow through the night. Cow flow is slow between 2am and 5am with a rush of cows at daybreak. This can be somewhat manipulated with paddock changes and varying rejection parameters during these periods, however there is no research on optimal settings.

Cost: Farmer E identifies cost as one of the biggest barriers to AMS adoption. Robots require a large capital investment and result in higher operating costs. He highlights that any savings in labour costs are replaced with other expenses such as power and maintenance. He estimates that the power bill in the robotic system is twice that of the herringbone.

Perception: There is a negative perception that robots cannot work in a pasture-based system. Farmer E believes this is a result of the lack of knowledge around these systems and that further research is required.

### 4.6.6 Future of robotics

Farmer E sees a big future for AMS in New Zealand dairy farming. These systems have the opportunity to be less stressful for both the animals and the staff. With the inflated value of land there is potential for robots on smaller farms with more feed purchased. Farmer E believes that pasture systems can certainly work and that 'rolling farms' may be better suited, as there is greater isolation between grazing blocks. There is also potential for hybrid systems where 1 of the 3 breaks is on a feed pad or standoff area in order to reduce nutrient loading and further improve nutrition. Rotary robots are seen as a good midway point for farms that have already invested in rotary infrastructure. Farmer E believes that robots will not be limited by their lifespan as all parts are replaceable however, current robot efficiencies will need to be improved for robotic systems to be really successful.

## 4.7 Farm F

### 4.7.1 Farm Overview

Farm F is a spring calving pastoral based AMS farm located in Canterbury. Farm F currently milks 480 cows through 6 robots in a purpose built milking shed. The 154 hectare (130 effective) property has been part of the farming business for 12 years and prior to conversion to AMS in 2013, was used as a support block for the farming business's other dairy enterprises. Farm F is limited by a nitrate-leaching cap of 42 kgN/ha. The current system is 99% pasture based with the only supplementation coming in the form of grain fed through the robots.

### 4.7.2 Key Drivers

Profitability & scale: Farmer F believes that the continued consolidation of dairy farms is not the future for the dairy industry. He believes it is possible to make 500 cow farms profitable with this sort of technology. Farmer F wanted to prove that this system could be just as profitable as traditional systems.

Technology: Farmer F has always been interested in technology and identifies this interest as a key driver for the adoption of AMS. The level of technology in these systems aligns strongly with his interests. Through the use of cameras and sensors, farmer F hopes to reduce the physical reliance on staff to make sure the system is running smoothly. The ability to remotely monitor the entire farm system is a challenge that drives farmer F's interest in robotics. Currently none of the staff that works on the farm live closer than 15 km away.

Production: Production is not a key driver for farmer F, as this would require moving away from a solely pasture based system. He believes the fundamentals of dairy farming in New Zealand have not changed from eating grass when it's growing and turning it into milk. Farmer F believes that you can make it more profitable with supplements, but there is still the need to utilise the pasture. He is not interested in pumping feed through the system nor is he interested in increasing the milking frequency. The aim is to run the same system as a traditional pasture based dairy farm and maximise efficiency and profitability.

The challenge: Farmer F has converted a number of dairy farms and did not want to go down the same path again. The challenge of making the robotic system work excited him and is considered a good distraction from his other dairy enterprises that are currently going through family succession.

### 4.7.3 Planning & Establishment

Farmer F bought his first dairy farm in 1981 and since then has been involved in a number of dairy operations. Farmer F originally talked to the manufacturing companies 12 years ago but was talked out of installing robots at this time due to a lack of technical support in the South Island.

Farmer F visited a number of AMS farms in New Zealand and did a significant amount of research online before deciding on a shed design. The final design is based on circles to aid in the automation of the system. Circles allow farmer F to motorise gates and yard wash systems, which he is currently working on. Technical advice from DairyNZ and the manufacturing companies was regarded as very important during the planning stage. Farmer F identifies the importance of employing the right staff "as these systems require a different mentality with staff needing to be able adapt to cow behaviour". Farmer F highlights that one of his successes during the establishment of the system was using the glycol chiller to heat up water entering the hot water cylinder. This helps to reduce power usage in a system that uses a lot of electricity.

### 4.7.4 Benefits

<u>Animal health</u>: Farmer F has noticed a big improvement in animal health with only three cases of lameness last season, even though cows are walking longer distances and spending more time on concrete. Any problems are identified earlier with any change in production or cow behaviour identified by the robots. This allows for a more rapid response and earlier treatment. The robot triangulates data from a number of sources to determine if a cow should be monitored for issues. Data collected includes milk conductivity, production, blood in milk and milking frequency. Two of the six robots on farm F have also been equipped with somatic cell count readers allowing for further monitoring of certain cows. Longevity of animals is expected to be higher due to less stress in the system. This will help with profitability, as cull cows will be worth more money with the potential to sell them as budget cows to share milkers. The in-calf rate has also increased which again is thought to be linked to less stress.  Vets have already said that they are not going to get rich on this farm.

<u>Environmental</u>: While the industry accepted environmental modelling programme Overseer is not yet able to fully accommodate AMS operations, farmer F believes that nutrient losses will be lower. This is a result of cows spending more time in the shed and on raceways. Farmer F is currently looking into ways in which he can monitor cow activity in order to get some understanding of these concepts.

Production: While farmer F is not targeting per cow production, he believes that it is easier to obtain higher production levels in these systems. This season, farmer F is targeting an average of 500kgMS/cow on a predominantly pasture based system. Farmer F believes AMS naturally leads to more content cows making it easier to realise their production potential.

Something new: In the 30 years of farmer F owning and developing farms he believes this has to be by far the most fascinating dairy development he has completed. Farmer F would have been thoroughly bored if he had put another rotary on this farm and he believes there are enough challenges here to keep him busy for at least the next five years. He highlights that while this system is challenging it is also very rewarding. After only two months farmer F's wife said, "You would have to have a pretty good reason to convert to a conventional farm again".

### 4.7.5 Limitations

Seasonal workload: Farmer F identifies the biggest disadvantage is the workload over spring. This is a stressful period as cows are trained to robots. This takes a toll on the workers over these 6 weeks, however hours improve as the season goes on.

Robot downtime: Due to the seasonal nature of the production in this system the robots are left sitting idle over winter. Not only can this be seen as inefficient but last winter farmer F experienced a problem with rats chewing through wires. There is however no intention to move from a spring calving system as this is where his interests lie.

Cow flow: Cow flow through the robots can be hard to maintain. Most error notifications on farm F are a result of cows not exiting the robot as they try to lick the spilled meal off the ground. Currently farm F only uses an air jet on the back to encourage cows to exit the robot, however this does not seem to be working that well. Initially 400 cows were transitioned from the farming business's other farms three months after calving. These cows were already accustomed to a batch milking system resulting in herding issues. As a result, cow flow was difficult to maintain following the transition period with farmer F collecting cows at all hours of the day. This spring has been much better in terms of cow flow as animals are beginning to settle into the system.

Transition: Farmer F identifies the transition period as being difficult with long hours. He literally slept in the offices of the milking shed for the first 8 weeks following the commissioning of the robots. Farmer F would go and get cows 2 or 3 times in the night as they were used to batch milking. This took a bit of time to deal with; however this spring has been much better. A huge input is needed at the start, but farmer F believes that if you don't put the effort in then you will not get the results.

Cost: While farmer F identifies that there has been some labour savings with AMS, these savings are quickly offset by the cost of maintaining the robots and having them serviced.

Congestion: Farmer F identified some issues with cows hanging around on races by the milking shed and causing a mess. There is no current solution to this, as any concrete would need the runoff contained.

Milk pickup: There have been some issues with tanker drivers not getting used to the increased level of technology at the vat. While it is a simple 3-step process to remember, the number of return tanker drivers is low, resulting in a new driver every night and some confusion by those that are used to traditional methods.

Lack of research: Farmer F believes that the data that came out of the Greenfield trials is now out of date and that the trial should never have been shut down. There was a lot of opportunity for more information on automation to be produced. There is now a high demand for research on the efficiencies of robotics and how to improve them.

### 4.7.6 Future of robotics

Farmer F is confident there is a place for AMS in profitable New Zealand dairy farming. These systems are likely to best suit farms in the 300-500 cow range. Farmer F identifies the benefits of having a second traditional dairy farm for returning problematic cows. This reduces the stress of having to persevere with slow adopters and also provides the opportunity to run the highest producing animals in the robotic system. Farmer F believes that currently the biggest barrier to uptake of robotics is people's attitude and a fear of technology. The technology however is not hard to master with none of farmer F's staff being particularly computer savvy, but still able to work the system.

# CHAPTER 5
# CROSS CASE ANALYSIS AND DISCUSSION

This chapter compares and contrasts the results of the six case studies. Key drivers, aspects of planning and outcomes of AMS adoption are analysed and discussed. The findings are compared to existing knowledge of present farm systems in order to identify any key differences.

## 5.1 Summary of case study farms

### 5.1.1 Farm Systems

AMS has traditionally been adopted into high input confined systems in other countries due to the perspective that these systems are best suited for exploiting the full benefit of the technology in term of production and robot efficiencies. New Zealand dairy farming systems are however traditionally pasture-based, where milk production follows the pasture supply curve. Dairy farms in New Zealand are classified as system 1 to 5 based on the level of bought feed (including grazing off) used and fertiliser applied (DairyNZ, 2012). The suitability of this classification system to identify and compare robotic farm systems is however unknown.

Three different AMS farm systems were identified in the case studies. These included;

1) Year-round-calving confined robotic systems with all feed harvested and fed in mixed rations (Farms A and B);
2) Predominantly pasture based spring-calving systems where only small amounts of supplements are fed through the robot (Farms E and F);
3) Split calving hybrid systems where a feed pad or barn structure is used to facilitate winter milking or as a component of the grazing rotation (Farms C and D).

While confined and pasture-based robotic farm systems are well documented in the literature there is no mention of the hybrid systems identified in these studies. Hybrid systems differ from the confined and pasture-based systems in terms of management, production and capital expense. Similar systems have been identified in traditional NZ dairy farming by Pow, Longhurst, and Pow (2014) who also identify the need to define 'hybrid' systems separately. Results from this study propose that a third classification of robotic farm system is required.

### 5.1.2 Effective area & stocking rates

Effective farm area was smaller in all of the case studies across all robotic systems when compared to the traditional system averages of their respective regions (Table 5.1). This was particularly evident with the Canterbury case studies where two out three effective areas were less than half of the district average. All of the case study farmers highlighted the suitability and potential for these systems in smaller operations. There are a number of logistical and practical problems that have to be considered to optimise cow traffic and feeding as farms increase in size. Jago et al. (2013) highlight similar concepts indicating that AMS may become less attractive as farm size increases.

**Table 5.1 Comparison of case study farm systems and district averages sourced from New Zealand Dairy Statistics 2012-13 (LIC & DairyNZ, 2013)**

| Farm | A | B | C | D | E | F | LIC | LIC |
|---|---|---|---|---|---|---|---|---|
| Location | Canterbury | Canterbury | Waikato | Waikato | Waikato | Canterbury | Canterbury | Waikato |
| System | Confined | Confined | Hybrid | Hybrid | Pasture | Pasture | Traditional | Traditional |
| Effective Area | 72 ha | 114 ha | 68 ha | 65 ha | 78 ha | 130 ha | 228 ha | 110 ha |
| Calving | Year round | Year round | Split | Split | Spring | Spring | Spring | Spring |
| Robots | 4 | 6 | 4 | 3 | 4 | 6 | N/A | N/A |
| Cows | 220 | 300 | 300 | 180 | 320 | 480 | 786 | 323 |
| Cows per robot | 55 | 50 | 75 | 60 | 80 | 80 | N/A | N/A |
| Cows per ha | 3.1 | 2.6 | 4.4 | 2.8 | 4.1 | 3.7 | 3.4 | 2.9 |
| Milking frequency | 2.9 | | 2.8 | 2.7 | 1.7 | | 2 | 2 |
| Production/cow | 780kgMS | 700kgMS | 520kgMS | 500kgMS | 460 kgMS | 500kgMS | 382 kgMS | 330kgMS |
| Production/robot | 42900kgMS | 35000kgMS | 39000kgMS | 30000kgMS | 36800kgMS | 40000kgMS | N/A | N/A |
| Production/ha | 2383kgMS | 1842kgMS | 2294kgMS | 1384kgMS | 1887kgMS | 1846kgMS | 1317kgMS | 970kgMS |

Herd size is also below their respective district averages across all of the robotic systems (Table 5.1). The number of cows per robot limits AMS operations. In order to maintain robot efficiencies and exploit the production benefits of AMS, then the number of robots must match the number of cows. Armstrong and Daugherty (1997) previously identified the limitations of cost, in terms of AMS adoption for large dairy operations, given the requirement to purchase more robots as herd size increases. This suggests that economies of scale are greater in large traditional dairy systems as costs can be spread over a single structure. AMS however, may be better at exploiting economies of scale in smaller systems given that the costs are spread across the number of cows each robot can support. This is particularly important when comparing the investment of constructing a traditional milking facility on smaller operations with that of purchasing robot units.

Number of cows per robot varies between case studies and was influenced by farm system (Table 5.1). Number of cows per robot was highest in the pasture-based systems and lowest in the confined systems. This supports research by Jago et al. (2007) who found it may be more effective to increase the number of cows per AMS to maximize the use of AMS in pasture dairies. This is due to milking frequency, milk yield and grazing times decreasing as walking distance from the grazing area to the dairy increases.

Stocking rate of the case study farms varies between each farm and across all of the farm systems (Table 5.1). This is due to the different goals and objectives of the farmers. The level of supplements purchased also influences stocking rate. As the confined and hybrid systems rely on the use of supplements, of which the amount imported has not been quantified in this study, it is hard to compare true stocking rate.

### 5.1.3 Production

Production per cow, of all the AMS case study farms, is much higher than their respective traditional dairying district averages and highest in the confined systems (Table 5.1). This is thought to be a result of a number of factors including better nutrition, less stress and higher milking frequencies. Production advantages of the confined systems are hard to determine, in regards to other confined systems, given a lack of data on these systems in New Zealand. Production advantages in the pasture-based systems are however higher than those previously reported in the literature. Initial trials of AMS in New Zealand pastoral systems by Jago et al. (2007) found no production advantages when compared to a traditional rotary system. Little research has been completed on pasture-based AMS systems in New Zealand since the closure of these trials.

While Table 5.1 highlights similar per cow production of the hybrid and pasture-based systems, research by Pow et al. (2014) on hybrid traditional dairy farming operations, identifies the potential for these systems to also improve per cow production through less stress and better nutrition. Farmers C and D both highlighted that they were yet to determine the true production benefits of the hybrid system with farmer D preferring to rely on pasture as much as he can.

Production per robot varies across the farm systems and between the case study farms (Table 5.1). Production per robot is important when considering the efficiency of an AMS farm. Jago et al. (2006) found that the economic viability of automatic milking in pastoral systems depends strongly on the daily milk harvesting capacity and the number of cows milked per unit. Milking more cows through each robot and decreasing the milking frequency per cow may increase milk production per robot. While this may be true within systems, Farm A still had the highest per robot production despite having less cows per robot (Table 5.1). This may indicate that maximising robotic efficiency requires balancing the number of cows per robot and milking frequency, and is dependant on the farm system.

## 5.2 Key drivers of AMS adoption

The potential to increase production was identified as a key driver by three out of six farmers and was most evident in the confined and hybrid systems. Potential production increases were not a driver for the pasture-based systems with farmer F specifically highlighting that he did not aim to use robotics to increase farm production. Farmers A and B were identified as animal people with an interest in genetics and nutrition. They displayed pride in achieving the maximum production from their cows and were continually looking at ways to improve in this area. Farmers A and C both believe that the continued improvement of production genetics in the NZ dairy industry can no longer be realised by traditional farming systems.  AMS helps realise this potential by providing the opportunity for greater milking frequencies and improved nutrition.

A reduction in labour and a change in lifestyle was a key driver of adoption for four out of six of the case study farmers. The importance of labour reductions was most prominent in the pasture-based and confined systems with both farmers B and F specifically aiming to reduce labour costs. In the confined systems, farmers A and B both identified a goal of reduced labour requirement. This cost was however identified in terms of improving milking frequency. Finding labour that will milk cows more than twice a day was considered difficult by farmer A and the farmers were not interested in doing it themselves. Changes in lifestyle as a result of fewer ties to the farm were key drivers of the hybrid and pasture-based case studies. Farmer D identified that a change in lifestyle and physical workload was a key driver of AMS adoption as he ages. AMS was seen as a way to remain involved in dairy farm management while relieving the physical stress of milking cows.

Winter milk premiums and profitability were key drivers for all four of the confined and hybrid case study farmers. Farmer D identified the opportunity to exploit the winter milk premiums in the hybrid farm system and aims to have a higher percentage of autumn calvers than spring calvers. This would mean that a higher percentage of production is going towards winter milk contracts and earning more income. Farmer B as the only AMS adopter with no prior dairy experience also identified the increase in income diversity from milk production as important to his farming business.

The need to either update an existing dairy shed or build a new one was identified as a key driver by four out of six case study farmers. This was either a result of changes in the farm system or the development of non-dairy land into dairy production. In the instance of developing land into dairying, property limitations in terms of size or environmental regulations were a key determinant of the system adopted. Farmer B identified that it was cheaper to invest in robots and a barn than to purchase the land required to sustain the same amount of production in a traditional system. Also due to the location of the property, obtaining consent for a traditional pastoral dairy farm would have been difficult.

Personal interest in technology and the challenge of making the system work was seen as a key driver by four out of six farmers and across all three systems. The intricacy and challenge of the pasture based systems was a key attraction with farmers E and F both highlighting that they were determined to prove that these systems can work. Both farmers B and F identified themselves as early adopters with a passion for innovation and technology. The potential to remotely operate the farm system through sensors and cameras was seen as an attraction for farmer F.

Succession was a key driver of adoption in both of the confined system case studies. Farmers A and B both identified AMS adoption as a means to attract the next generation back into the farming business following their university studies. Farmer B believes that if they hadn't adopted AMS and their son hadn't returned back to the farm, that they would probably have sold up and bought an arable farm in mid Canterbury.

Figure 5.1 highlights the similarities and differences between key drivers of adoption based on the farm system adopted by the case study farmers. Similar drivers have been found by Verwoerd and Tipples (2007, p. 54) when looking at the adoption of once a day milking in New Zealand. In this study the farmers studied changed their system"…because they were looking for a better way to farm", which included "…better health for their animals, more sustainable use of the land, more production for less input, and above all, a better and more satisfying life for themselves and their families on the land." This highlights that drivers of AMS adoption may not only be related to the adoption of technology itself but the entire farm system as well.

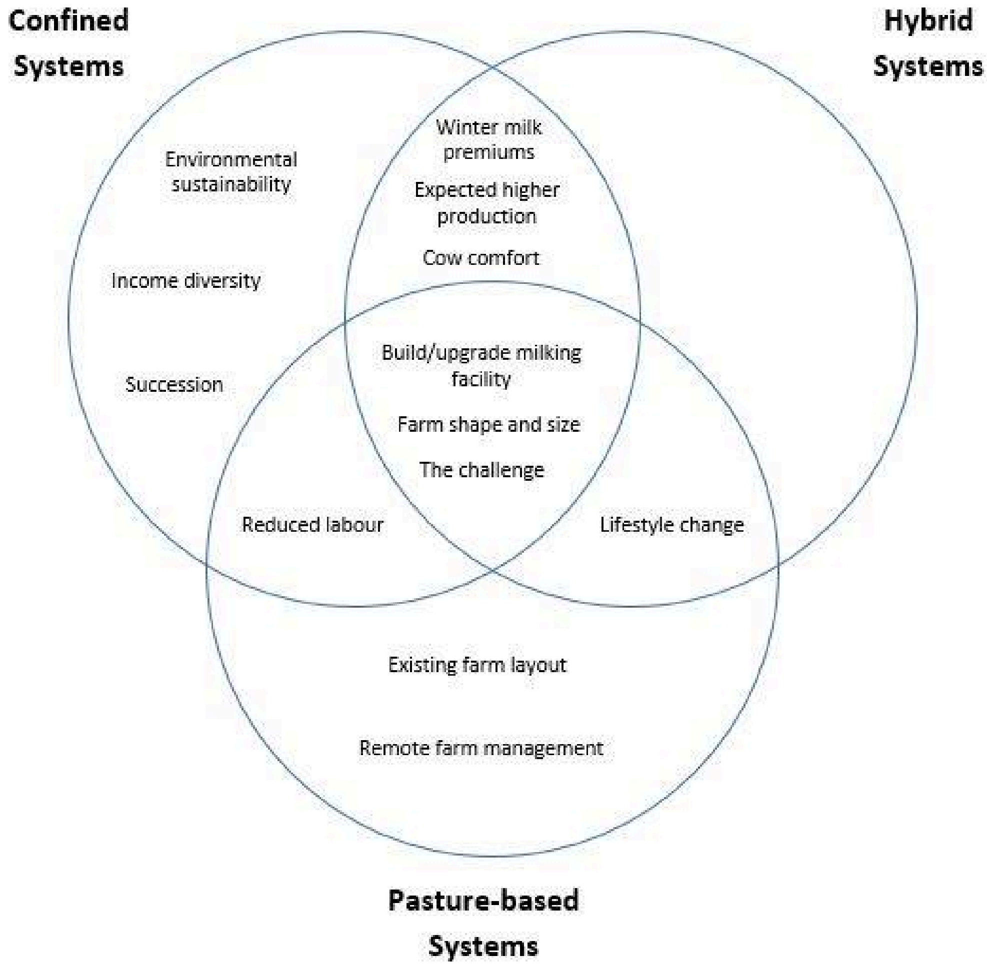


**Figure 5.1 Comparison of key drivers of AMS adoption between the three farm systems adopted by the case study farmers**

## 5.3 Planning & Establishment

Research and planning was identified as an essential part of successful adoption by all of the AMS farmers. Farmers A, D, E and F all began looking into robotics over 10 years ago when the first Greenfield trials began. Research predominantly consisted of Internet searches and overseas publications. All farmers visited existing operations before making the decision to adopt with farmers A, C and E also looking at examples overseas. The importance of visiting established operations overseas was highlighted to be less important as more examples of successful AMS farms are established in NZ.

Robotic manufacturers and DairyNZ were also identified as playing an integral part in the planning and development of shed layouts and farm systems. Robotic farm systems are continually developing and as a result no farm has the same shed layout or farm system. The most important aspects of the planning and establishment stage were identified as farm layout, cow to robot ratio, cow selection and system simplicity. Farmer D highlights that the robotic system can run itself if you have the right attitude and design. There is a need to keep the system simple as the more you interfere the more complicated the system becomes and the greater the work load.

## 5.4 Benefits & Limitations of AMS farm systems

A number of benefits and limitations of AMS adoption were identified by the case study farmers. This section compares and contrasts these outcomes between the individual case studyies and across the identified farm systems.

### 5.4.1 Benefits

#### 5.4.1.1 Animal health

The greatest benefit of robotic systems is the improvement in animal health and condition. Cows appear to be less stressed and are quieter compared to traditional systems. This was noticed early on by all the case study farmers across all three systems. This supports findings by Rodenburg (2012) who reported less stress and less hierarchical battles in confined AMS operations but also highlights similar outcomes in pasture based and hybrid systems. As a result of less stress there is also an expectancy of improved longevity of the cows. Farmers B, D and E all noted that they have had to tighten cull cow selection pressures due to the increased difficulty of identifying culls. This also has a financial benefit with farmers B and E noting that cows coming out the other end of the system are worth more money as they are in better condition and identified the opportunity for them to be sold as budget cows to sharemilkers. Farmer E also identified an unexpected improvement in mating success with a higher conception rate and less empties. This again is thought to be related to less stress and cow condition, but is also thought to be a function of more available time to be spent on correctly identifying cows to be mated. Higher conception rates are critical for seasonal dairy farmers as the technology on induced lactation is now outlawed.

Animal health is also improved by the ability to identify and treat sick animals quicker. All farmers noted that through the integration of sensors in the automatic milking system and with the aid of the MIS, monitoring of cows is continuous, more consistent and faster in comparison with human observation. This supports research by Sonck (1996) who identified the potential of detecting deviations and diseases earlier with the aid of AMS. The MIS triangulates data to quickly and accurately identify any change in animal behaviour or production and notifies the farmer. This can help reduce the spread of disease and help improve production by identifying even subclinical cases of disease.

#### 5.4.1.2 Production

The production of the case study farms, in comparison to district averages, has been previously discussed in section 5.1.3. All case study farmers highlighted the potential for these systems to improve per cow production. This is thought to be a result of a combination of factors including, higher milking frequencies and improved nutrition and less stress. The significance of this is most apparent in the confined systems; however the hybrid and pasture systems are still well above their respective district averages (Table 5.1). The production increases displayed in these systems are higher than those estimated in the literature, highlighting the potential improvements with traditional systems.

Production per hectare is also higher; however the relevance of this for the confined and hybrid systems is unknown given the high levels of supplements purchased into these systems. Further research is required to better understand the value of supplements in these systems.

#### 5.4.1.3 Work schedule, nature of work and human capital

An improvement in the nature of work and work schedule was also seen as a benefit of AMS. Farmers B, C, D and E all highlighted an improvement in staff morale due to more socially acceptable hours of work and the removal of the physical labour requirement associated with milking. Staff are no longer tied to routines dictated by milking times and have the freedom to control their work schedule. This flexibility is seen as an advantage when it comes to attracting staff. None of the farmers interviewed have struggled to obtain staff with the majority of them highlighting that AMS opens up an entire new labour pool of workers. Farmer D believes that it attracts more intelligent people with an interest in technology that have traditionally not been interested in dairy farming due to the association with early starts and long days.

#### 5.4.1.4 Environmental impact

The environmental footprint of these systems, while not yet quantified, is seen as a potential benefit by farmers B, E and F. The potential to reduce nitrate leaching by strategically removing animals from pasture and collecting effluent is well documented in the literature. There is however, a lack of research to do with the environmental impact of pasture-based AMS farms. Farmers E and F believe that as a result of improved production efficiencies and cows spending more time on raceways and in the milking shed that nitrate leaching will be reduced. The ability to closely monitor production and animal movement is seen as a positive progression allowing for more accurate estimations of nutrient movement around the farm.

#### 5.4.1.5 Management

Beyond the managerial benefits of monitoring animal health, farmers A and E also highlight the improvements in feed management and nutrition. Farmer A highlights that in confined systems feed utilisation is much higher and nutrition is easier to balance and control. Farmer E however highlights that feed management is improved in pastoral robotic systems. This comes back to cows being treated as an individual in the system and the ability to preferentially feed animals based on production, age and behaviour. Management is also made easier by having one herd, which is independent of milking frequency. Cows are not limited to a set routine and cows that are identified as struggling can be preferentially fed by controlling paddock changes and being given advance access to new breaks. Farmer E also identifies a reduction in pasture damage with cows not mobbing at gateways or displaying signs of being hungry.

#### 5.4.1.6 Uniqueness of the system

Farmers D and F both identified a rekindled enthusiasm for dairy farming as a result of adopting AMS. The challenges and uniqueness of these systems are considered a positive for those who want to try something different or enjoy a challenge. After large stints in the dairy industry both farmer D and farmer F were no longer interested in developing traditional dairy systems. Both farmers identified that due to the pleasure they have got out of setting up a robotic system, neither would ever look at building a traditional farm again. Farmer F identified that while the system can be challenging it is also very rewarding.

### 5.4.2 Limitations

#### 5.4.2.1 Cost

The large costs associated with establishing AMS is considered the biggest limitation, and potential barrier to adoption, by all of the case study farmers. Due to the lack of experience and information available in New Zealand, securing funding can be difficult. Being in a strong financial position and having other farming enterprises to borrow against was considered an essential element in securing funding by all of the farmers. Operation expenses were also found to be higher with farmer E identifying that any savings in labour expenses were soon offset by maintenance costs of the robots. Electricity costs were also found to be higher with farmer D highlighting that there is a high cost associated with having to run the cooling system 24/7. Farmer E estimates the electricity bill to be double that of his traditional herringbone system.

#### 5.4.2.2 Transition and Establishment

The transition and establishment stage was identified as being a difficult and high stress period by all of the case study farmers. During this time most farmers identified that their staff and themselves spent a large amount of time in the dairy shed with farmer F even opting to sleep there for the first 8 weeks. The majority of this time was spent pushing cows through the robots and maintaining cow flow. Farmer F identified a problem with herding, resulting in congestion at the milking shed, as cows were accustomed to batch milking when transitioned. Farmer E found it easier to transition cows from high input rotary systems as cows were already used to single stall systems.

All of the case study farmers experienced some sort of technical issues during the establishment phase. These seemed to become less prominent over time as the systems began to settle down and the farmers developed an understanding of the technology. Animal health issues were also experienced by farmers A and B in the confined systems. Farmer A found this to be a result of a technical issue with the robot while farmer B identified it as a nutritional problem and both problems seemed to have settled down.

#### 5.4.2.3 Labour

There is a popular misconception that adopting AMS will halve your labour demand, as cows no longer have to be milked. Farmers A, B and E highlight that this is not the case particularly in confined systems, where there is a greater labour demand for feeding out and cleaning. Farmer B emphasises that there is a similar workload to other dairy farms however; it is a different “easier” type of work with time spent making sure robots are working properly and maintaining them.

Farmers E and F highlight that the seasonal workload of spring calving pasture-based systems is particularly trying with farmer F identifying calving as the most difficult part of the season. This is a result of the difficulties of training heifers and recommissioning robots being concentrated to a single part of the year. Staff will often work long hours during this period with less flexibility. This can increase stress and reduce staff morale.

All of the farmers also highlight the limitation of being on call 24/7. Farmer A identifies that on average, someone will get called out 5-6 nights a month to attend to a fault with the robot. While this fault may be minor, it is still necessary for someone to be within a reasonable responding distance at any given time. Sonck (1995) highlights that being called into work at any time of the day or night can be seen as more stressful than traditional milking programmes. Farmers C, D and F highlighted that depending on the fault they will leave the issue to be fixed in the morning. Farmer F uses webcams to remotely check any issues with the robots before sending anyone to the farm.

#### 5.4.2.4 Professional help

A lack of independent, professional help was identified by both farmers A and B for confined systems and AMS. In these systems there is a need to accurately balance nutrition between the robots and the barn fed rations in order to maintain animal health and cow flow. Both farmers identified a lack of local knowledge in New Zealand and have opted to use overseas nutritionists and consultants. A lack of knowledge and help was also identified during the planning and establishment phase when it came to designing shed layouts to optimise cow flow. Again overseas consultants were used by both farmers during this stage.

#### 5.4.2.5 Perception

Four out of six case study farmers identified a negative perception of AMS technology. Farmers A and B noted that there is a negative image of cows living indoors as it is seen as an animal welfare issue. However farmer B strongly disagrees with these assertions highlighting that when cows are dry and not in the barn it is not uncommon for them to jump fences in an attempt to return to the barn. There is also a perception that dairy farming in New Zealand can only be competitive with the use of cheap grass. However farmer B believes this is no longer the case once you take into account the cost of inflated land prices.

Farmers D and E identified a negative perception of pastoral based robotic systems. Farmer D says there are a lot of people who don’t see how AMS can work and doubt that it can work in a pasture based system. Farmer E believes this is a result of the lack of knowledge around these systems and that further research and public demonstration is required.

#### 5.4.2.6 Risk

Farmers A and B both identified the sensitivity of confined AMS to fluctuations in milk price and feed costs. Feed costs are a large portion of Farm A's working expenses (in excess of $3.50/kgMS) and do not necessarily correspond with payout. Confined systems are also at particular risk to rapid spread of disease due to the close proximity of animals. Neither farmers A or B have experienced any significant disease outbreaks, however the potential for this is well documented in the literature.

#### 5.4.2.7 Lack of NZ based AMS Research

Little research around AMS has come out of New Zealand since the DairyNZ Greenfield trials 10 years ago. Farmer D believes that this information is now obsolete and that new data is needed. Results from the Greenfield trials are often quoted in publications, which wrongly portrays the current success of the industry. The technology as well as the management has come a long way since the Greenfield trials were ended by DairyNZ.

#### 5.4.2.8 Herding & Cow flow

Herding, as a result of batch milking prior to transitioning to AMS, was experienced by the pasture-based farmers E and F. Cow flow is an essential element of robotic efficiency. Both farmers struggled to maintain cow flow following the transition to AMS with farmer F highlighting that a large amount of time was spent collecting cows in the first season. Farmer E highlighted that one of the issues with pasture-based systems is maintaining cow flow through the night. Cow flow is slow between 2am and 5am with a rush of cows at daybreak. This can be somewhat manipulated with paddock changes and varying rejection parameters during these periods, however there is no research on optimal settings.

Farmer C and F also noted the negative impact of cows hanging around the dairy shed during periods of congestion. Farmer C identifies that cows will hang around the cow shed around gate changes and that the constant flow of traffic can make a mess of races entering the shed. There is currently no solution for the issue. If more concrete is used then the extended run off has to be contained and the effluent system expanded.

### 5.4.3 Summary

**Table 5.2 Summary of key outcomes of AMS adoption identified by the case study farmers**

| Benefits | Negatives |
|---|---|
| • Improved animal health/condition<br>• Greater per cow production<br>• Better work schedule and nature of work<br>• Wider potential labour pool<br>• Reduction in environmental footprint (unquantified)<br>• Improved animal and feed management<br>• New challenges | • Cost of establishment<br>• Increased operating expenses<br>• Stress of transitioning to AMS<br>• No saving in labour expenses<br>• Lack of professional help<br>• Negative perception of AMS<br>• Sensitivity to feed costs in (confined and hybrid systems)<br>• Increased workload during calving (pasture-based)<br>• Herding and inconsistent cow flow (pasture-based systems)<br>• Lack of AMS research in New Zealand |

The case study farmers identified a number of similar outcomes of AMS adoption. The key benefits were improvements in animal health and condition and the potential to improve animal production. The key limitations were the cost of AMS and the stress of transition and establishment. A number of outcomes specific to the type of robotic system adopted were also identified. These included the added stress to the seasonal workload of pasture-based systems and a lack of professional advice, particularly in the confined systems.

## 5.5 Adoption framework

### 5.5.1 Innovativeness of case study farmers

Farmers B and F both identified themselves as early adopters. However, based on the five categories of adopters identified by Rogers (1983) and outlined in chapter 2, all of the case study farmers can be classified as innovators. Five out of six of the case study farmers identified that their interest in AMS began over 10 years ago when AMS was first introduced into New Zealand. This eagerness to explore new ideas aligns strongly with Rogers (1983) identification of the venturesome attributes of innovators. The findings of this research indicate that the farmers who have adopted AMS technology enjoy the challenge of making the system work and are continually adjusting their systems in order to develop and improve them.

### 5.5.2 Information seeking characteristics

All the case study farmers used a number of different information sources when researching the concept of AMS. These included Internet searches, popular press, overseas research, DairyNZ publications, correspondence with the robot manufacturers and both local and international AMS farm tours. The most important of these were the physical visits to established AMS operations, discussions with the robot manufacturers and DairyNZ publications. A lack of independent professional AMS help was identified as well as a lack of current AMS research based in NZ. Murphy's (2014) theoretical adoption framework highlights the importance of information as a key factor in the decision making process of adopters. These current gaps in information sources identified by the case study farmers may have a negative impact on the rate of adoption.

### 5.5.3 Socio-demographics

Farmer's socio-demographics have a big effect on AMS adoption. These include farmer characteristics such as attitude to risk and personality, and farm business characteristics including farm size, number of farming enterprises and strength of the business. Five out of six of the case study farmers identified the importance of owning multiple farming enterprises when it came to the decision to adopt AMS. This is consistent with research by Brown et al. (2013, p. 35) which suggested that as well as representing past strategic and entrepreneurial behaviour; it also represents the farmer's future capacity for generating agricultural income from the farm and provides leverage for borrowing capital.

### 5.5.4 Innovation characteristics

The most important innovation characteristics identified by the case study farmers were higher production, data collection and the removal of the physical labour aspect of milking cows. The importance of each of these factors varied depending on the individual goals of each farmer and the robotic system they adopted. In general there was an interest in increasing milking frequency and improving production in the confined and hybrid systems. The pasture-based farmers however were more interested in labour reductions and changes in lifestyle. All farmers highlighted the importance of data collection and the ability to treat cows as individuals and monitor animal health closely as key innovation characteristics.

### 5.5.5 Contextual factors

The most important characteristics that were influenced by contextual factors are farm size, existing farm layout and the condition of the current milking facilities. All of the case study farmers identified the importance of farm size when adopting AMS with different criteria based on the system being adopted. Pasture based and hybrid AMS farms are generally smaller with shorter walking distances in order to maintain cow flow. Confined systems, tended to be dependent on their ability to grow enough food for the barn system with the aim of becoming self-sufficient. The adoption of robotics onto smaller scale farms contradicts findings by Yule and Eastwood (2012), which suggested that larger farms may have a greater need for technologies due to a scarcity of skilled labour and increased management complexity. This highlights that farm size is therefore likely to be influenced by contextual factors and is tightly linked to the socio-demographics of the farmer. Also of importance in pasture-based and hybrid AMS farms is the existing farm layout. Farmers B, C and D all highlighted that the ability to use existing infrastructure in the AMS system was an important driver of the adoption process.

## 5.6 Future of AMS

All the farmers interviewed identified a strong future for AMS in New Zealand dairy farming. Greatest potential was seen for smaller family sized farms in the 300-500 cow range. The ability to produce more off less land is a strong incentive given current inflated land prices. The potential to reduce environmental impact through hybrid systems is also likely to be of importance as environmental regulations are tightened. The majority of the farmers also identified the benefits of running AMS farms in conjunction with conventional systems. Farmer D identified the potential of complimenting systems, where only the highest producing animals are milked through the AMS. Farmers A and B both identified the potential of integrating cropping farms with confined AMS systems as a way to increase efficiency and income diversity. No robotic system was identified as better than the others with farmers highlighting that every farm situation and farmers personal objectives are different.

# CHAPTER 6
# SUMMARY AND CONCLUSIONS

This chapter briefly summarises the key findings and answers the research questions. Limitations of the study are addressed and potential future research is identified. The conclusions have been developed from six case studies, and these do not claim to represent all AMS farms in NZ.

## 6.1 The major findings of this study

### 6.1.1 Farm systems

This dissertation analyses six case study farmers, who have successfully adopted AMS technology. The case studies operate three different AMS farm systems. These include confined, hybrid and pasture-based systems categorised by their use of structures, level of supplementary feeding and calving. In this research hybrid systems are classified as a system where a feed pad or barn structure is used to facilitate winter milking or used as a component of the grazing rotation. Confined and pasture based-based systems are well documented in the literature, but there has been no previous reference to hybrid systems in AMS. Hybrid systems would benefit from their own classification, when it comes to AMS farm systems due to their unique management, production and use of capital.

Effective farm area and herd size of the case study farms are well below their respective traditional dairying district averages. Number of cows per robot was highest in the pasture-based case study farms and lowest in the confined case studies. Production per cow was highest in the confined case study farms with hybrid and pasture-based case studies showing similar levels of production. All of the case studies were producing more per cow than their respective district averages for traditional dairying systems.

### 6.1.2 Key drivers of AMS adoption

Key drivers of AMS adoption were linked to the individual circumstances of the participants and the physical resources of their farms. These also influenced the robotic system adopted with production focussed participants adopting confined and hybrid systems. The challenge of making the system work was a key driver across all of the farm systems. A number of other drivers were also identified including animal health, succession, the need to update existing facilities, environmental concerns and lifestyle changes. These drivers of AMS adoption are not only related to the embracing of AMS technology itself, but the entire farm system as well.

### 6.1.3 Planning and establishment

'Getting the system right the first time', is important for establishing a successful AMS farm system. The case study farmers used a number of different sources of information during the planning stage. The most valuable of these sources were physical visits to existing AMS operations both locally and overseas. As the number of AMS farms in New Zealand increases, the value of visiting overseas operations will decrease. Other key factors for successful AMS development were identified as farm layout, cow to robot ratio, cow selection and system simplicity.

### 6.1.4 Adoption theory

All of the case study farmers were identified as being in the innovator class of adopters due to their passion for developing these farm systems and the prior lack of established knowledge relating to these systems. The findings in this research support Murphy's (2014) theoretical adoption framework in terms of the interconnection of farmers' information seeking characteristics, their socio-demographics, contextual factors and the characteristics of the innovation on influencing the adoption decision-making process. Innovation attributes of complexity and trialability had a greater influence than compatibility and profitability when it came to dictating the rate of AMS adoption.

### 6.1.5 Key outcomes of AMS adoption

The key outcomes of AMS adoption included beneficial improvements in animal health/condition, high animal production and a change in lifestyle. Negative outcomes and limitations of the system involved large establishment costs, increased operating expenses and the stress of transitioning to the robotic system. Limitations of specific farm systems included, added stress to the seasonal workload of pasture-based systems and a lack of professional advice, particularly for confined systems.

### 6.1.6 Future of AMS in NZ dairy farming

Participants observed that the future for AMS in New Zealand dairy farming is positive, particularly for smaller farms, with opportunities to further improve current systems and integrate other farming disciplines. AMS is thought to have unquantified social and environmental benefits, which will have the potential to positively impact the industry.

## 6.2 Limitations of research

A limitation of this dissertation is the lack of quantitative data to back up the case study farmer's spoken word. Profitability indicators would have allowed for a greater comparison between the case studies and industry averages. Furthermore this data may have allowed a monetary value to be calculated for improvements in lifestyle and reductions in labour stress. Some of the case study farmers were unwilling to share profitability data due to the ‘newness’ of their systems and in other cases the farmers felt financial data would not fairly indicate the capabilities of their systems due to recent investment and developments. Lastly, due to the ‘newness’ of the industry and the limitation of time, only six case studies were selected for the study. Accordingly, the findings of the study relate specifically to the purposively selected farmers, and any generality to what is being achieved by broader populations has been avoided, as it may not be representative.

## 6.3 Future research

This dissertation highlights that there is a need for more research on AMS in New Zealand. Future research should include further investigation of the types of AMS farm systems that are currently being adopted in New Zealand. The collection of financial data and identification of key performance indicators for these systems may be necessary to determine the success of these systems. This would also allow the value of lifestyle improvements and changes in physical labour demand to be quantified. This research has highlighted the potential of AMS in smaller farming operations. Further research into the advantages of AMS compared to traditional milking systems in small-scale operations should be investigated. Production advantages of the case study farms were found to be greater than what has been previously identified in the literature. This is particularly evident in the pasture-based systems and further research is required to identify the drivers of this success. Potential environmental benefits were discussed, however evidence of the sustainability of these farms from a whole-system approach is a gap requiring further research. It is currently difficult to determine environmental footprints of AMS due to limitations of modelling software. The ability to reduce the environmental issues of dairy farming by adopting AMS has important implications for industry growth.

# Appendix A

## Case study participant information letter

**Dear AMS Farmer.**

I would like to thank you very much for giving me your time and the opportunity to get to know you and your business. I would like to thank all of your team for their support, and in aiding me with my research. I am very passionate about AMS, so it is a great privilege and an amazing opportunity to gain a better understanding of AMS farms. Your help with my research is very valuable to my studies and again I very much appreciate your support.

If you have any questions or queries with regard to my research, you are more than welcome to get in contact with me or my supervisors. Their contact details are as follows:

- Guy Trafford (guy.trafford@lincoln.ac.nz)
- Keith Woodford (keith.woodford@lincoln.ac.nz).
- Marvin Pangborn (marvin.pangborn@lincoln.ac.nz).

Just to remind you the goals of my studies are:

- To better understand why farmers are adopting AMS in NZ.
- To provide information on the benefits and drawbacks of indoor-based and pasture-based AMS farm systems in NZ.
- The identification of lessons-learned from early adopters of AMS in NZ.
- To provide information that will help future adopters of AMS technology in NZ.

In practical terms, I will be looking to publish the results of my studies towards the end of this year, or early into next year. I would like to reiterate that all farm data collected will remain confidential, and the property of Lincoln University, and that it will not be displayed on an identifiable basis, and will only be used to help build and justify models and trends or themes. However, I will make sure that you are given the opportunity for criticism of my work prior to any public display of the results and conclusions.

Thank you again for your help, your expertise and experience is invaluable to my research. If you have any further thoughts on my research project or questions in the future, please do not hesitate to get into contact with me.

Marc Brakenrig

Lincoln University Honours Student

Email: marc.brakenrig@lincolnuni.ac.nz

# Appendix B

# Interview guide for case studies

## Introduction and overview:

**Could you please tell us about yourself and how you became interested in robotics?**

- Introduction
- Farming experience/knowledge
- Source of robotic information
- Background research of robotics

**Could you please give us a background of this property?**

- Original farm system/use of property
- Constraints/limitations
- Existing infrastructure

**Why was the decision made to create and use a robotic milking system?**

- Goals/objectives
- Perceived benefits
- Who were the driving forces for the change

**Could you briefly describe the current robotic milking system used on the property?**

- Number of robots
- Number of cows
- New infrastructure (shed etc.)

**Has this system changed compared to the original robotic milking system which was created?**

- Why did they occur?
- What would you do different?

**Are there any other unforseen challenges that occurred?**

- Lessons learnt
- Changes to the original design
- Reasons for change

**Has adopting AMS achieved the goals you had hoped to achieve when implementing the system?**

- How or why not?
- Other benefits found

**What plans do you have for the future of robotics in your farm systems?**

- Expansion/efficiency
- Goals
- Succession

## Positive and Negative Questions

**What are the key benefits you found in establishing a robotic milking system in New Zealand?**

- Expected or unexpected

**What are the main disadvantages/limitations have you found (if any) of the use of robotic milking systems in New Zealand?**

- Expected or unexpected
- Ways to mitigate

**How do you think robotic milking systems in New Zealand compare to a traditional milking system?**

- Benefits
- Negatives
- Similarities

**What do you see as the biggest barrier to the uptake of robotic milking systems throughout New Zealand?**

- Ways to mitigate (if any)

## Summary questions

- **What are the most important aspects of robotic milking systems during a New Zealand properties planning and establishment phase?**

- **In the future where do you think robotic milking systems fit within the New Zealand dairy industry and why?**

- **Why do you believe more New Zealand farmers have not taken up robotic milking systems?**

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