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An evaluation of the viability of two 'AMS' farm systems in Central Canterbury

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AN EVALUATION OF THE VIABILITY OF TWO 'AMS' FARM SYSTEMS IN CENTRAL CANTERBURY.

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SUMMARY

The New Zealand (NZ) dairy industries 'twice per day' batch milking system, is creating a labour shortage in NZ, as it is "not attractive compared to other industries" (Tipples, Hill, & Wilson, 2008, p. 159). The NZ dairy industry is challenged with lifting its overall environmental performance, while simultaneously, maintaining or increasing profitability (Macdonald, Scrimgeour, & Rowarth, 2013).

However, a mechanical innovation is available which can "automate all the functions of the milking process and cow management currently undertaken in conventional milking by a mix of manual and machine systems" (Jago, Jensen, & Berdell, 2008, p. 1). This innovation is Automatic Milking Systems (AMS), and "no other new technology since the introduction of the milking machine, has aroused so much interest and expectations among dairy farmers" (Koning & Rodenburg, 2004, p.1).

Currently, the commercial economic and environmental factors are relatively unknown for both pasture-based and indoor-based AMS farm systems within the New Zealand dairy environment. The goal of the proposed study is to provide information, which will help future adopters of AMS technology in New Zealand, to choose whether indoor-based or pasture-based AMS is best suited to them. As the evaluation of the viability (the economic and environmental aspects) of AMS, is essential for future adopter's decision making. Therefore, the hypothesis for this study is that: - *indoor-based AMS farm systems are more viable than pasture-based AMS farm systems.*

The methods that have been chosen for this study are a qualitative case-study approach for the collection of data, and quantitative farm system modelling for data analysis. Within the collection of case-study data, a semi-structured interview technique will be used as outlined by Perry (1998). These methods have been chosen if order to produce a wealth of detailed data about a small number of people and cases as described by Patton (1987).

Within the analysis of the data, a variety of techniques will be used. These techniques consist of Microsoft Excel Solver® (Linear Programming), Farmax Dairy Pro®, Accounts Analysis, Discounted Cash Flows, and OVERSEER®. These techniques will be used to evaluate and compare the viability of both indoor-based, and pasture-based AMS farm systems, based on the scale and physical limitations of the Lincoln University Dairy Farm. These models will be based on real case-study data, to give a more accurate evaluation of the potential of these AMS farm systems in Central Canterbury. This will give better information to potential adopters, removing some uncertainty from the outcomes of adopting pasture-based and indoor-based farm systems throughout New Zealand.

INTRODUCTION

"Dairy farmers in New Zealand are challenged with lifting the overall environmental performance and compliance of their farm systems" (Macdonald, Scrimgeour, & Rowarth, 2013, p. 1), but simultaneously, the New Zealand dairy industry needs "to maintain or increase productivity and profitability" (Macdonald, et al., 2013, p. 1). However, this is not a straight forward process, as the New Zealand dairy industry is exposed to changing product prices (the milk payout) and input prices (feed and supplies) (Greig, 2012).

To combat this traditional New Zealand (NZ) dairy systems have become renowned for being highly efficient and low cost (Jago & Burke, 2010). However, the traditional 'twice per day' milking system that is widely adopted in New Zealand relies on physical labour for the activity of milk harvesting in batch milking systems, as well as many other farm management tasks. Yet, currently it is being widely publicised in NZ agricultural media that the NZ dairy industry has an industry wide shortage of skilled labour.

Woolford, Claycomb, Jago, Davis, Ohnstad, Wieliczko, (2004) confirm that New Zealand's 'twice per day' batch milking system, was the main contributing factor to this labour shortage. As the New Zealand dairy industry is "not attractive compared to other industries" (Tipples, Hill, & Wilson, 2008, p. 159). As twice per day batch milking systems are labour-intensive, and require labour to work "long and unsociable working hours for up to 300 days per year" (Woolford, et al., 2004, p. 280).

These long hours, lead to high staff turnover rates, which have led to industry wide employee recruitment and retention issues, as well as the high industry accident rates due to employee fatigue (Tipples, et al., 2008). The NZ dairy industries average staff turnover-rate can be quantified as 22-43% between 1999 and 2008, which was significantly higher than the NZ national average of 15-20% (Tipples, et al., 2008). However, a mechanical innovation is available, an innovation which can remove the requirement for physical labour completely from the process of milking dairy cows.

This mechanical innovation is Automatic Milking Systems (AMS). Such is the potential of AMS that Koning & Rodenburg (2004) states that "no other new technology since the introduction of the milking machine, has aroused so much interest and expectations among dairy farmers and the periphery" (Koning & Rodenburg, 2004, p. 1). AMS is "a technology that has the potential to reduce the labour cost associated with milking, and improve the lifestyle and work environment for farm staff" (Jago & Burke, 2010, p. 109).

Automatic Milking Systems (AMS) is defined by Jago, Jensen, & Berdell (2008), as *"a system that automates all the functions of the milking process and cow management currently undertaken in conventional milking by a mix of manual and machine systems" (*Jago, et al. 2008, p. 1). However, AMS requires a farm system change. As unlike conventional milking, "where humans bring the cows to be milked at regular times (usually twice a day), AMS places emphasis on the cow's motivation to be milked in a self-service manner several times a day by a robotic system without direct human supervision" (Koning & Rodenburg, 2004, p. 2).

AMS technology is already being used within commercial dairy farm systems across New Zealand, but NZ AMS farm system research is in its infancy, and at this stage has not continued beyond the initial early adopters. This uptake of AMS technology in New Zealand is a part of a much broader trend towards dairy intensification. There have been dramatic changes in New Zealand dairy farm systems over the last decade. This is supported by Greig (2012), who found that in NZ "there is evidence that the basic grass dependent dairy farm systems are becoming more intensive with greater amounts of supplementary feed" (Greig, 2012, p. 217).

The following document looks to build on these ideas, and build on the conclusions and unanswered questions that have been put forward by the previous researchers of AMS's role and potential within the NZ dairy industry. The document will explain a detailed outline of a proposed study to test the hypothesis that; - *indoor-based AMS farm systems are more viable than pasture-based AMS farm systems.* It is hoped that this research will lead to the NZ dairy industry being given some of the data that it desperately needs on AMS farm systems for future adoption of the technology.

Figure 1: The first live demonstration of AMS technology in NZ, taken from Tipia (2014

PURPOSE OF THE STUDY

The 'triple bottom line' is a concept that is used to bring sustainability into business decisions making (NSW Government, 2014). The triple bottom line concept separates out sustainable business decisions into three components, people, planet and profit as demonstrated in the diagram below. The people aspect of AMS adoption is the most simple for adopters to understand. As AMS adopters can readily identify activities that would rather be doing, if the physical act of milking cows no longer had to be conducted.

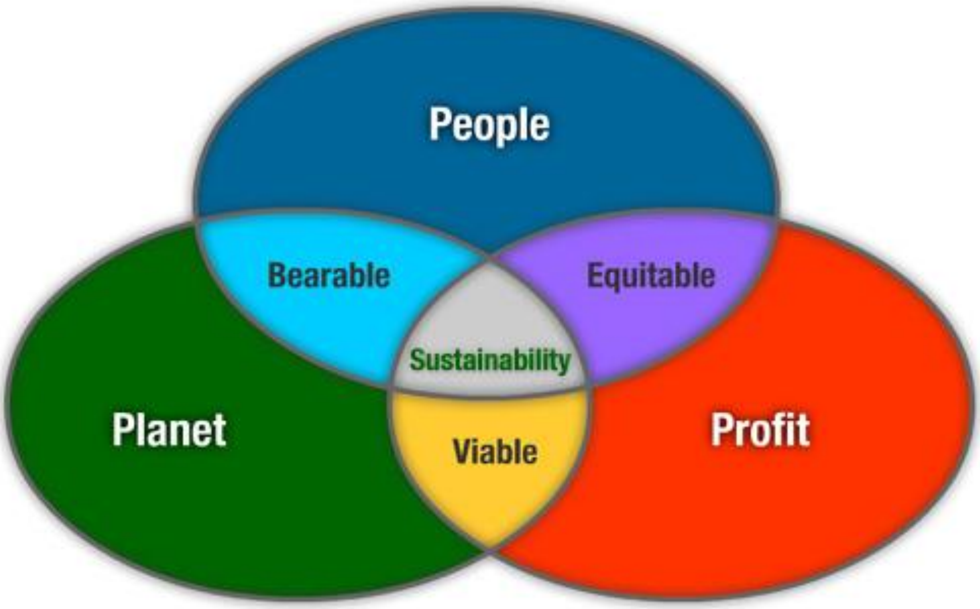

Figure 2: Diagram of the triple bottom line taken from NSW Government (2014).

However, the economic and the environmental factors of pasture-based and indoor-based AMS farm systems, in the NZ commercial dairy environment are unknown within the published literature. As demonstrated above, knowledge on both economic and environmental aspects of AMS farm systems is essential for the measurement of their potential as a part of a 'sustainable future' for the New Zealand dairy industry, and in particular the Central Canterbury region.

The purpose of this study is to evaluate the viability of AMS within the two farm systems that are already being used in NZ. However, the majority of this study will focus on evaluating the economic aspects of the two systems, as this has been identified by Marra, Pannell, & Ghadim (2003) as the main driver of technology adoption. As economic variables "are the major determinants of technological change and adoption of innovations" (Marra, et al., 2003, p. 217).

THEORY OF ADOPTION

Adoption is a process of technological change or technology substitution for improvement (Marra, Pannell, & Ghadim, 2003). This process "involves the acquisition of information and the process of learning" (Marra, et al., 2003, p. 222). In an agricultural context, adoption is a "multi-stage decision process involving information acquisition and learning-by-doing" (Ghadim & Pannell, 1999, p. 146), by people that "vary in their risk preferences and their perceptions of riskiness of an innovation" (Ghadim & Pannell, 1999, p. 146).

From a business perspective the rate of adoption and the ultimate adoption level, are "determined primarily by the actual benefits of adoption to the potential adopters" (Ghadim & Pannell, 1999, p. 150). However, on a personal level other factors that are likely to influence the rate of adoption are an adopter's age and financial situation, as this influences an adopter's personal discount rate, and time preference (Ghadim & Pannell, 1999).

Overall, the rate of adoption of a technology innovation can be explained primarily by its profitability and riskiness, but "risk, uncertainty and learning play a number of distinct roles in the process of adopting new technologies" (Marra, et al., 2003, p. 231). In the case for AMS in NZ, "the uncertainty about whether the investment will continue to pay off over the whole period covered by the fixed costs, creates an incentive to delay the adoption decision" (Ghadim & Pannell, 1999, p. 151), as it is not always possible to recover all investment costs of a failed specialised technology investment (Marra, et al., 2003).

In these situations, it is best to initially demonstrate an innovation on a trial or experimental basis (Marra, et al., 2003). Trialling an innovation has two benefits: skill improvement, and better decision making. Therefore an "adoption decision based on trial information may have a higher chance of correct interpretation" (p. 152).

However, in most agricultural situations, "learning and imitation are central to adoption" (Marra, et al., 2003, p. 222), as gains in the use of a novel technology, come from gains made through experience (learning-by-doing) (Marra, et al., 2003). To become familiar with a new technology, adopters often seek out information on the cost, operational capacity and the value of the innovation before deciding whether to adopt or not (Marra, et al., 2003). Therefore, this study is proposed to make that information available to the potential adopters of AMS technology in New Zealand.

LITERATURE REVIEW

The idea of AMS technology or the concept of milking cows with robots "was first initiated within Europe during the 1970's", (Woolford, et al., 2004 p. 282). By the 1980's, AMS milking technology was further refined, and in 1985 the first milking cup was attached during an experiment to a cow udder (Jago, Jensen, & Berdell, 2008).

The main quantified benefits of AMS technology are "reduced labour, a better social life for dairy farm families, and increased milk yields due to more frequent milking" (Koning & Rodenburg, 2004, p. 1). Koning & Rodenburg (2004) outline that AMS "can create a physical labour savings of 30 to 40 % compared with conventional milking" (Koning & Rodenburg, 2004, p. 3), but the most significant change is the nature of work required. "The physical work of machine based milking, is replaced with management tasks, such as frequent checking of attention lists" (Koning & Rodenburg, 2004, p. 3), and being 'on call' to deal with system failures at all times.

Prior to AMS technology adoption in New Zealand, indoor-based AMS systems had proven to be a commercial success internationally, and in 2007 there was "approximately 8000 AMS units in operation on farms in 22 countries worldwide" (Jago, et al., 2008, p. 1). Most of these are farms are family businesses that have between 1 - 3 milking boxes (Koning & Rodenburg 2004). However, the largest AMS operation acknowledged in the literature is an indoor-farm system, which is located in California, USA, which after completion. Will be made up of "32 milking boxes, within 4 interconnected barns, each with a central cluster of 8 milking units" (Koning & Rodenburg, 2004, p. 2).

The introduction of AMS technology into NZ pasture-based farm systems took place in early 2001, with the launch of the Greenfield Project, in Hamilton. The Greenfield Project was a joint venture, between Dexcel Ltd and Sensortec Ltd, and was developed with the aim of finding: "What a New Zealand pasture based dairy farm would look like, if AMS technology is going to improve its productivity and labour efficiency?" (Woolford, et al., 2004, p. 281).

Early on in the Greenfield Project trials by Jago & Woolford (2002), found that there is a fundamental difference between traditional batch milking systems and AMS pasture-based milk harvesting methods. As "AMS systems rely on cows using the milking stations throughout the day and night to achieve sufficient cow throughput" (Jago & Woolford, 2002, p. 39). The Greenfield Project trials showed "that the fundamental principles of profitable pastoral farming (i.e. high pasture utilisation and low levels of imported feed) can be maintained with automatic milking" (Jago, et al., 2008, p. 1), and that "cows are willing and able to do their part to make extensive pastoral voluntary milking systems work" (Jago, et al., 2008, p. 1).

However, the Greenfield trials were focused on extensive pasture-based systems, and recent studies have shown that there is evidence that the dairy farm systems of New Zealand, "are becoming more intensive with greater amounts of supplementary feed" (Greig, 2012, p. 217). This is demonstrated visually in the following diagram, which has been taken from Greig (2012).

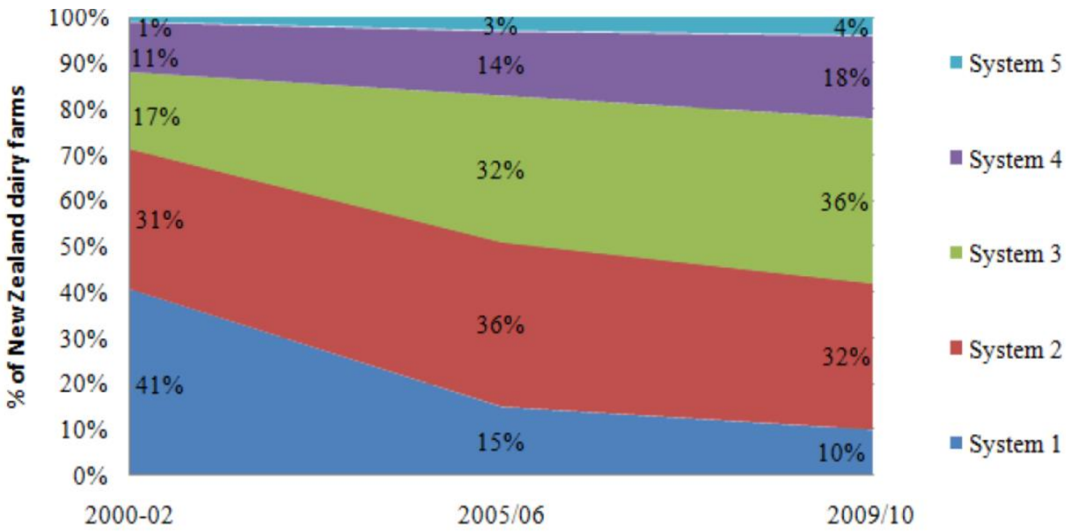

Figure 3: Graph showing the separation of the New Zealand dairy industry into the five DairyNZ systems, taken from Greig, (2012).

The above diagram demonstrates the trend of increasing system intensity in the New Zealand dairy industry. It has resulted in a further diversification of NZ dairy farming systems, with the largest increase coming in System 5 (300%), followed by System 3 (111%), and System 4 (63%), which has been created by a decrease of by 75% in System 1 (Greig, 2012, p. 220).

This trend of intensification is being seen within AMS technology adoption internationally, with "a large proportion of installations operating indoor feeding systems" (Lyons, Kerrisk, & Garcia, 2014, p. 103). "In these indoor feeding systems cows are housed and fed in barns for all or most of the year, and when in combination with AMS they are referred to as 'indoor-based AMS'" (Lyons, et al., 2014, p. 103).

However, indoor-based AMS is no longer just an international phenomena, it has arrived within New Zealand. This trend can be explained by the small amount of research which has been conducted into cow housing within New Zealand. This work shows that cow housing in New Zealand, can be used to achieve "cash positive farm systems capable of generating both increased production and environmental performance under regulation" (Macdonald, Scrimgeour, & Rowarth, 2013, p. 1).

Macdonald, et al., (2013) undertook an economic analysis of slatted floor housing systems in the Waikato. The study established that even if the capital cost of construction is debt funded, the investment creates a net annual increase in cash flow, "after borrowing and repayment costs, which equivalent to an annual return on investment of 7.20%" (Macdonald, et al., 2013, p. 5), or 9.55% over a 10 year investment preiod.

However, within New Zealand, investment in cow housing is seen as an alternative wintering strategy, and indoor-based systems have gone relatively unrecognised within the literature. Some work by Greig (2012), outlines that the use of higher input systems such as AMS indoor-systems, "may provide more consistency in production, but can be more complex to manage" (Greig, 2012, p. 227). However, indoor dairy systems may have other benefits such as:

1. Improved cow welfare.
2. Reduced environmental impact.
3. Improved feed utilization.
4. Reduced fertilizer use.
5. Improved cow performance (reproduction and milk production).

Yet, there is currently no published literature on the economics of indoor-based AMS farm systems in NZ to quantify Greig (2012)'s claims. However, research conducted by Journeaux (2013) into the economic benefits of wintering barns, gives a snapshot of some of the potiental economic benefits of indoor dairy systems in NZ.

The benefits of wintering bars were outlined by Journeaux (2013) are as follows:

1. Savings from grazing all cows on-farm over the June/July period (estimated to be $28 per cow per week, for an 8 week period).
2. A reduction in pugging and compaction (increased pasture utilisation of 20–40 percent, and increasing pasture yield to between 20–80 percent for 4–8 months).
3. Increased milk production from:
    a. An increased number of cows.
    b. A more intensive and balanced feeding regime.
4. Better cow condition (0.5 body condition score or 7.5 kgMS / cow) due to:
    a. A better feeding regime.
    b. A lower body maintenance requirement.
    c. A better body condition score at calving.
5. Increased milking period (3 weeks longer, at $10 per cow per week), due to:
    a. Better cow condition.
    b. A desire to re-coup costs.
6. Reduced dry/empty cows (2% improvement) due to:
    a. Better cow condition
    b. Better feeding regime
7. Saved cost of not applying fertiliser ($539/hectare applied)
8. While the main negatives of wintering-barns were identified by Journeaux (2013) as:
9. Increased machinery traffic (in conserving feed or topping pastures).
10. The system is very sensitive to supplementary feed costs.
11. The area required for effluent disposal increases.
12. The economic cost of the wintering barns is significant if:
    a. There was not an increased milk payout.
    b. The system as not intensified (more MS production).

In contrast, systems where the "cow kept outside and obtain over 50% of their annual requirements from grazed pastures or forages in combination with AMS, they are referred to as 'pasture-based' AMS" (Lyons, et al., 2014, p. 103). These farm systems physically exist as commercial farm systems in NZ, but there is currently very limited information available on the profitability of pasture-based AMS systems in New Zealand.

NZ pasture-based dairy systems "are not compromised with the introduction of AMS" (Jago & Burke, 2010, p. 114). Yet, compared to indoor-based AMS systems, "the integration of AMS and a pasture-based dairy farm system, created a new spectrum of challenges which are very different to those of indoor-based feeding systems" (Lyons, et al., 2014, p. 102). However, Jago and Burke (2010) indicate that "voluntary milking through automatic milking systems is not a barrier to harvesting large amounts of grazed grass" (Jago & Burke, 2010, p. 114).

As "grazing can be incorporated effectively into an AMS" (Lyons, et al., 2014, p. 106), but "it is the manager's ability to grow and utilise pasture that drives the profitability of pastoral dairy systems" (Jago & Burke, 2010, p. 113). However, even within Jago & Burke (2010)'s study benefits from the use of a more intensive system were seen. When an intensive pasture-based AMS farm system produced more milksolids (MS) per cow (53 kg), and more MS per ha (338 kg), than a lower input, highly extensive, pure grass based AMS system.

However, the primary economic disadvantage of the adoption of AMS technology, is the requirement of a large initial investment (Rotz, Coiner, & Soder, 2003). Jago & Burke (2010) calculated that because of this high level of capital, pasture-based AMS farm systems "are marginal at a milk price below $5.50/kg MS" (Jago & Burke, 2010, p. 114), but there is variation in the literature on this value. As an early model conducted by Jago, et al., (2006) calculated a milk solid price of $4.25/kg MS, as a breakeven base milk price, but these economic results of this experiment were based on 2010 AMS prices, and the early AMS adoption productivity levels, which may account for the variation.

Jago et al., 2006 went on to conduct a NZ pasture-based comparison between a 40-bail rotary batch milking system and a 5-unit Greenfield based pastoral AMS system. The study showed that one of the major changes associated with the potential adoption of AMS technology, is the large difference in capital investments. Jago & Burke (2010), found that building an AMS dairy requires a base capital cost of $253,000 for a single AMS unit or $223,000 per AMS for multiple AMS units. With the other major technological capital costs required consisting of two remote selection units at $30,000 per unit.

Table 1: Farm profile, milk harvesting system features, service and capital costs for a rotary dairy and 5 unit Greenfield System taken from Jago, et al., (2006).

	Rotary	Greenfield
Farm profile	450 cows 140 ha 3.24 cows/ha	450 cows 140 ha 3.24 cows/ha
Milk harvesting system	40 bail rotary	5 AMS units
	Cup removers Automatic drafting No in-bail feeding	6 selection units Automatic drafting In-bail feeding Automatic milk diversion
Service costs	$100/cluster/yr	$10,000/AMS unit/yr
Capital investment[1]	$577,000	$1,217,000

Therefore, "for a given herd, the initial equipment cost is often two to three times that required for a traditional milking parlour" (Rotz, et al., 2003, p. 4167). However, the other main economic differences between the two systems are the servicing and maintenance costs of the farm system are substantially increased, and low cow adaptation to AMS, which can have a significant negative impacts on an AMS farm systems first year economic performance (Jago, et al. 2006).

However, it was identified by Jago et al. (2006) that to be competitive with rotary milking systems in NZ, future AMS systems will require; a total of 112 cows to be milked per AMS unit, a 25% decrease in capital cost, a 10% reduction in system labour requirements, an equivalent level of milk solid production, and an increase of 10% in cost of labour (based on 2006 pasture-based AMS system productivity and milksolid prices).

This was due to AMS having 42% higher costs in the first year of production, and 27% higher in the second year onwards. Even when depreciation, interest and labour are included, this value only reduces to 25% over the period of the comparison (Jago, et al. 2006). Yet, due to the AMS system having "higher interest depreciation and service contract costs" (Jago, et al., 2006, p. 265), and savings from "reduced labour requirements, cow health and dairy costs" (Jago, et al., 2006, p. 265), a similar return on asset percentage of 4.2% and 4.1% was calculated for AMS and rotary pasture-based dairy systems respectably.

However, not all challenges that the NZ dairy industry are currently facing are economic. In New Zealand “heavier regulation and compliance structures have been placed on agriculture” (Macdonald, et al., 2013, p. 2). Therefore, the future success of the New Zealand dairy industry also relies on “the ability of dairy farmers to adapt their farm systems sustainably to proposed regulation” (Macdonald, et al., 2013, p. 5). As current New Zealand pasture-based dairy systems with high stocking rates are impacting the environment and are “causing a declining trend across key performance indicators such as nitrogen loss per hectare” (Macdonald, et al., 2013, p. 2).

“The need to adapt the NZ pasture-based dairy farm system to meet environmental compliance, and maintain its profitability is a driver of recent shifts by the dairy industry to incorporate cow housing systems (Macdonald, et al., 2013). As “cow housing systems have been identified as suitable infrastructure investments for maintaining or lifting profitability while reducing the loss of nutrient to both water and atmosphere” (Macdonald, et al., 2013, p. 1).

Recent research by Journeaux (2013), highlighted that with or without the use of cow housing, “nitrogen leaching increases again as the farm system intensifies” (Journeaux, 2013, p. 2), and that “phosphate run-off also follows a similar pattern” (Journeaux, 2013, p. 2). Therefore, it was identified that a wintering facility, without an increase in system intensity has “a significant impact in reducing nitrogen leaching, down to just above the required limit:” (Journeaux, 2013, p. 2). However, Journeaux (2013) concluded that if a farm system has to intensify, “in order to cover the cost of the wintering facility, the level of nitrogen leaching rises accordingly” (Journeaux, 2013, p. 2), to the extent that the increase in leaching rates was well above the proposed limits (Journeaux, 2013).

Therefore, the study should be based on the physical land resources of the Lincoln University Dairy Farm within the Selwyn—Waihora catchment of New Zealand. This area has been chosen as “the introduction of nutrient leeching limits on the scale proposed in the Selwyn Waihora catchment is unprecedented in New Zealand” (Environment Canterbury Regional Council, 2013, p. 36). As a part of this, the Lincoln University dairy farm will in the future have to meet a number of rules, which have been developed by the council for the Selwyn – Waihora Catchment.

Figure 5: A cow being milked in a Lely Astronaut A4, taken from Team Lely (2013).

The rules taken from Environment Canterbury Regional Council (2013), are as follows:

1. *Land users currently can intensify provided they are operating at GMP And intensification does not result in discharges exceeding 15 kgN/ha/year;*
2. *Land Users discharging more than 15 kgN/ha/year, are required to make about 15 - 20% Improvement on GMP Loss rates by 2022 and, if they are not in CPW, Can only intensify if this does not increase N loss.*
3. *Providing a N load to CPW to allow for intensification from 30,000 Ha new irrigation*
4. *Require all rural properties (larger Than 20 ha) to prepare audited farm environment plans (to Improve soil, nutrient (N and P), irrigation, wetland, riparian and cultural health management)*
5. *Reduce Phosphorus and microbial contaminants from the catchment by*
6. *Requiring stock exclusion (as per proposed LWRP) From streams, rivers, wetlands and lakes and applying the rules in the same manner to exclude stock from drains*
7. *Provide effective riparian margins on at least 850 Km of the lowland streams and on 1000 Km of the drains in the catchment*
8. *Enhancing and constructing wetlands to improve water quality, including spring - head wetlands*
9. *Improving management of macrophytes (aquatic "weeds") in drains*
10. *Managing sediment including through sediment detention and targeted in-stream sediment removal.*

(Environment Canterbury Regional Council, 2013, p. 2)

However, the key steps in the Planning Framework for managing effects of land management activities on water Quality in the Selwyn -Waihora Catchment for existing users are:

a) *Land users are required to make a percentage improvement on 2017 GMP by 2022;*
b) *Land users who are discharging less than 15 kgN/ha/year can change (intensify) land management or land use provided they are operating at GMP and the change does not result in discharges exceeding 15kgN/ha/year;*
c) *Requiring any new land use that will discharge more than 15 kgN/ha/year to operate at better than 2017 GMP from the start (as per above) and, if they are not in CPW, not to discharge more N than under the previous land use;*
d) *Requiring land users who cannot comply with a) above to submit a management plan to show how they will meet the requirements as soon as practicable and no later than 2037;*
e) *Providing a N load of 460 t/year to Central Plains Water to allow shareholders to change land use or intensify land management activities;*
f) *Developing a comprehensive support package, with industry, to implement the Sub---regional Section. Commentary*

(Environment Canterbury Regional Council, 2013, p. 37)

METHODS

Systems have been defined by different people in different ways Forrester, (1968) stated that a “system means a grouping of parts that operate together for a common purpose” (Forrester, 1968, p. 1). While Spedding, (1979) found that “a system is a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks” (Spedding, 1979, p. 18). Spedding (1979) went even further to simply define that a system is something that can be identified by its behaviour, as a system should respond as a whole, in response to stimuli to any section of the system (Spedding, 1979).

To create “an agricultural system, there is a requirement for inputs, outputs, a system boundary, a system environment and a feedback system” (Spedding, 1979). A system’s inputs are the pre system interaction components which are placed into the system, while a system’s outputs are the post system interaction components which are produced by the system (Spedding, 1979). These are contained within a systems boundary, which is the researcher’s perceived border to where the system is self-contained and has no outside influences (Spedding, 1979).

Jones & Street, (1990) believe that a system approach is a belief that a successful system gives synergy or the sum of its parts is worth more than then each individual aspect. This means that the study of individual components which make up the system is inadequate to understand the entire system and more importantly how the outputs are produced. Farm management fits this description, as it is a skill which is used to manage farm systems, because farm management is choosing between alternative prospects or identifying the best system (Jones & Street, 1990).
The study will focus on simple hard systems. These systems are often best described by diagrams; this is due to the diagrams identifying the different bodies within the system and the different interactions within the system (Spedding, 1979). Hard systems research are often best used in decisions regarding resource allocation, such as financial resources or technological resources. Hard systems are often used when there is a quantitative knowledge of both the biological elements and the economic elements of the system (Jones & Street, 1990).

In hard systems experiments on long term trends of farm systems, it is virtually impossible to conduct physical experiments, because it is virtually impossible to make observations over a large enough sequence of years or seasons (Jones & Street, 1990). Therefore, hard systems research is now conducted through the computer based modelling of systems (Jones & Street, 1990).

Rossing, Zander, Josien, & Groot, (2006) describe the use of modelling in farm management, as being a strong and unique attribute “that exceeds the analytical capacity of the human mind” Rossing et al., 2006, p. 6). As modelling can cost-effectively and easily identify or quantify system outputs, system relationships, and potential risks of large complex systems. Modelling is very cost-effective, as it is possible to construct farm system models for multiple purposes (FAO, 2012). One basic system model is created and then adapted into different versions of the same system by identifying and modifying several sub-systems of the larger generic system, (Rickert, Stuth, & McKeon, 2000).

However, a qualitative approach will be used for the collection of data for this evaluation. Under this approach data starts as raw descriptive information. In regards to this study, qualitative methods allow for the selected systems to be studied in depth and detail. Patton (1987) confirms this by stating that "qualitative methods produce a wealth of detailed data about a much smaller number of people and cases" (Patton, 1987, p. 8).

A case study approach technique is suited to the collection of data within this research as there are a very limited number of cases available for research, but the cases (farm systems) available to be studied are rich in information. This is due to the high level of detailed data recording from the AMS technology, and the complex nature of each farm system. Therefore, the use of a case study technique has been identified as the best means of data accurate of the examples of the farm systems.

Therefore, within this study a case study approach has been identified as the main technique of qualitative data collection as described by Perry (1998), because they are particularly effective when there is a requirement for one particular problem or situation to be studied and analysed in great depth and cases rich in the required data or information can be identified (Patton, 1987).

However, unlike traditional case study methods, such as those mentioned by Perry (1998) and Eisenhard (1989), a specific case study orientation been chosen for this study. This study will follow a similar method to Langford (2009), to choose at minimum 3 examples of each farm system. This is due to the lack of examples available for analysis.

Therefore, a modelling approach has been chosen for data analysis, rather than traditional forms of case study analysis, as the interviewer's goal is the collection of numeric data, which will be then be used to under pin the data put into models to extract further information. The modelling section of this study, will use a variety of techniques, which will be conclusively identified once the initial case study data has been collected. However, a number of techniques have been identified as having a very high chance of being used. These techniques consist of linear programming, Farmax Dairy Pro® modelling, discounted cash flows and OVERSEER®.

Linear Programming (LP) is described by Baitzing (1991) as being a "mathematical technique used in computer modelling (simulation) to find the best possible solution in allocating limited resources (energy, machines, material, money, personnel, space, time, etc.) to achieve maximum profit or minimum cost" (Baitzing, 1991 p. 2).

The purpose of the use of LP within this study is twofold. Firstly, LP will be used as a tool to link the hard system physical model to economic returns, while simultaneously optimizing the farm system so that the best possible system outputs are created and compared. Thus removing management error from the system evaluation and the inter-system comparison. Secondly, LP will be used to identify a number of economic transactions that occur within the system, which will be needed within the following discounted cash flow section of the study.

It is proposed that Farmax Dairy Pro® (commercial modelling software for NZ dairy systems), should be used as a tool to evaluate and compare the two AMS farm systems, which are being evaluated within this study. Farmax Dairy Pro® is a *"whole-farm decision support model that uses monthly estimates of pasture growth, farm and herd information to determine the production and economic outcomes of managerial decisions (Bryant, et al., 2010, p. 13).*

Farmax Dairy Pro® has been chosen for this study as it can be used to accurately "predict animal, farm and financial performance for different management scenarios" (Bryant, Ogle, Marshall, Glassey, Lancaster, Garcia, & Holmes, 2010, p. 13). The accuracy of Farmax Dairy Pro® was demonstrated by Bryant, et al. (2010) who concluded that Farmax Dairy Pro has "a high degree of accuracy" (Bryant, et al., 2010, p. 13).

A financial modelling technique that will be used for long term modelling of the farm system is Discounted Cash Flow (DCF). DCF is a valuation method, which is used to estimate the attractiveness of investment opportunities. This technique has been chosen, because a "discount rate is a critical component of cost benefit analysis" (Journeaux, 2013, p. 3), as "a discount rate will reflect both the cost of capital, and a premium for risk over time" (Journeaux, 2013, p. 3).

Finally, OVERSEER® nutrient budget modelling is proposed to be included within this study, to analyse the ability of the pastoral AMS farm systems to meet the Canterbury Water Management Strategy (CWMS) for dairy systems within Central Canterbury. OVERSEER®'s nutrient modelling software will be used, to assess the nitrogen leaching of both the AMS farm systems on the Lincoln University Dairy Farm.

OVERSEER® has been selected as it contains "a decision support model to help users develop nutrient budgets" (Wheeler, Ledgard, De Klein, Monaghan, Carey, McDowell, Johns, 2003, p. 191). It is believed that OVERSEER® is very suited to this study as it "enables the user to examine the impact of a range of specific on farm management scenarios to increase the efficiency of resource use and decrease environmental impacts" (Wheeler, et al., 2003, p. 193).

Figure 4: An international indoor-based AMS barn taken from Lely (2014)

CONCLUSION

It can be concluded that there a desperate need for further research to be conducted within AMS farm systems in New Zealand. In particular the viability of the two systems (indoor-based and pasture-based) that have been outlined within this document. To achieve this the author has proposed the following research topic; *an evaluation of the viability of two 'AMS' farm systems in Central Canterbury*.

This topic is cemented by framework within the published literature on the process of adoption and thus a need for detailed economic analysis of the two AMS farm systems. However, there is also a need for investigation into the environmental feasibility of these AMS farm systems, as shown in the literature review and by the triple bottom line 'business sustainability' framework.

Therefore, it is proposed that research should be conducted that builds on the earlier work conducted by Jago and Burke (2010), which showed variations in AMS farm system outputs, from changes in system intensities under farmlet 'experimental conditions' in New Zealand. This can be achieved by testing the hypothesis that; *'indoor-based AMS farm systems are more viable than pasture-based AMS farm systems'*. As this will shed light on the commercial farm systems that are currently operating within New Zealand, and explore the economic and environmental aspects of these AMS farm systems.

The proposed study is essential to the future decision making of the Central Canterbury dairy industry. Dairy farmers throughout New Zealand need to know the capability of these two AMS farm systems, if they are to successfully undertake their current challenges in sourcing labour, and meet environmental regulations, while maintaining a profitable business enterprise. As it seems to be a matter of when not if AMS will have a significant place in the New Zealand dairy industry.

For this to occur, there must be case study data collection on the small number of systems examples that are already operating in New Zealand. This data must then be used in modelling exercises, which will show the key drivers of the systems, the system's ability to respond to change, the financial outputs of the systems, and the efficacy levels of 'resource use' of the systems.

When these models are built it will be possible to evaluate and compare the financial outputs of the two AMS systems, and their environmental feasibility under proposed new regional legislations. This will lead to practical conclusions that will have significant implications within New Zealand commercial agricultural industry. Therefore, it is essential that the research proposed is within this document is conducted in a detailed manner and shared with the wider agricultural public of New Zealand.

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