A Theoretical Study of the Environmental and Economic Sustainability of a Dryland Dairy System in Canterbury

A dissertation
submitted in partial fulfilment
of the requirements for the Degree of
Bachelor of Agricultural Science with Honours

at
Lincoln University
by
Peter Cornelis Smit

Lincoln University
2015

Abstract of a dissertation submitted in partial fulfilment of the
requirements for the Degree of Bachelor of Agricultural Science with Honours.

A theoretical study of the environmental and economic sustainability of a dryland dairy system in Canterbury

by

Peter Cornelis Smit

The New Zealand dairy Industry has had rapid expansion over the past 20 years. The intensification of farm systems and change of land use towards dairying is recognised as an important contributor to a range of environmental problems. The build-up of nitrate in ground and surface waters is a headlining issue and has been confronted through government policy. Leaching limits for the Selwyn-Waihora catchment area requires dairy farms to reduce nitrogen (N) losses by 30% by 2022, with discharge limits of <15kgN.ha^{-1} by 2035. Meeting these N limits requires the urgent development of sustainable farm systems. In addition to this, over allocation or river and ground sourced water has reduced the options for irrigation in Canterbury to reliance on 'schemes' for water supply. The nature of these schemes means water rights are expensive and so with N leaching restrictions the economics and acceptability of conventional systems are becoming suspect. This forms the basis for this project, of exploring the profitability of a dryland dairy system that meets proposed N leaching limits.

This study developed a dryland dairy model suitable for the Canterbury region and examined both the environmental and economic feasibility of the model. The proposed model utilises partial housing as the main N leaching mitigation strategy. Lucerne, diverse pastures and fodder beet are also incorporated into the system because of their N mitigation benefits, and suitability to the dryland environment. An autumn based calving has been used rather than the traditional winter/spring calving period. Autumn calving is thought to provide drought management benefits, as well as advantages with winter milk premiums.

Linear programme (LP) and Farmax Dairy Pro® modelling produced an optimal scenario for the 200ha property, with base details including a peak herd size of 450cows (2.25cows/ha), 100ha of ryegrass pastures, 80ha lucerne pastures and 20ha of fodder beet, and 670t.DM of imported maize and pasture silage supplements.

Overseer analysis predicted the nitrogen leaching losses from the property to be 11kgN/ha/yr. This is well below the proposed limits for the Selwyn-Waihora catchment of <15kgN/ha/yr by 2035.

Financial analysis concluded the model would provide a return on asset (ROA) of 7.2%. Base assumptions included a land value of $20,000/ha, milk price of $6.00kgMS/ha, contract winter milk premium of $3.00/kgMS, and a total farm working expense of $3.80/kgMS. Investment analysis was done on the conversion of a typical Canterbury sheep breeding and finishing property to the proposed dryland dairy system. The post finance and tax internal rate of return (IRR) for the dryland dairy system was 9.3% compared to the sheep model of 2.1%. Marginal return analysis suggested the post finance and tax marginal return on the investment was -0.6%. The negative marginal return showed the investment wouldn't provide a return over the 15 year project life due to the high capital investment required. The working life of the development is likely to be longer than 15 years, and an increased investment period is likely to provide a positive marginal return. Sensitvity analysis analysed the models vulnerability to drought scenarios, varied milk price, varied milk production and increased farm working expenses.

It is concluded that the proposed dryland dairy model in Canterbury is environmentally and economically viable. However developing a typical Canterbury sheep breeding and finishing property into the proposed model is unable to provide a positive return within a 15year investment period.

Acknowledgements

Writing this dissertation would not have been possible without the guidance and support provided by my supervisor Guy Trafford. Thanks for your time throughout the year, your guidance, knowledge and enthusiasm has provided the foundation from which I have been able to complete this project.

To DairyNZ (in particular Susan Stokes and Bill Barwood), thank you for the support, mentoring and networking opportunities you have provided throughout my studies at Lincoln. The financial support has also been a great help. To OneFarm and the Bay of Plenty Farmers trust, your financial support is hugely appreciated and has allowed me to have complete focus on my studies. Also, I would like to thank my parents, Corrie and Donna, their continued support has made this possible.

Finally I would like to thank the lectures at Lincoln University who have taught me during the four years I have been studying. This dissertation concludes my time at Lincoln University and I await the next chapter.

Table of Contents

List of Tables

List of Figures

Chapter1:
Introduction

1.1 Background

Traditionally dairy farming in New Zealand has been based on the better soils, in the more suitable climates of the country, Waikato, Taranaki and Southland. However over the past few decades the increase in dairy prices have led to the development of more land into dairy and pushed dairying into more marginal areas. The development of irrigation systems has enabled the growth of dairying in the east coast regions especially Canterbury. In Canterbury between 1980 and 2009 the land used for dairying increased from about 20,000 ha to nearly 190,000 ha (Pangborn & Woodford, 2011). It is expected that continued investment into irrigation will provide further opportunities for growth in dairy (Pangborn & Woodford, 2011). However with an over allocation of river and ground sourced water, the options for irrigation have greatly reduced, with the reliance now more on 'schemes' that save surplus water from winter and spring and use this water to irrigate over the drier months. This water and associated infrastructure comes at a cost, this cost along with tighter farming constraints around nitrogen (N) leaching means the economics and acceptability of conventional systems is becoming suspect. Dryland dairying is a lower input approach that could make farming profitably at low N leaching limits possible. Therefore, there is a need to investigate the feasibility of dryland dairy systems.

A major issue with dryland dairying is the potential impact of droughts. It is considered an autumn based calving would provide significant drought management advantages over the typical winter/spring calving period used on New Zealand dairy farms. Autumn calving also provides other financial incentives such as the premium paid for winter milk supply. For these reasons the use of an autumn based calving system is explored.

1.2 Research Objective

The aim of the research project is to use a whole farm systems approach to explore the environmental and economic feasibility of a modelled dryland dairy system based upon Lincoln University's 'Ashley dene' property in the Selwyn district, Canterbury. The development of a dryland dairy system will provide an alternative option for Canterbury farmers who don't have access to irrigation water or for farmers who are looking for an alternative to the high water charges and infrastructure cost associated with signing up with scheme water. The development of strategies for dryland dairy farms will have a high relevance to the rest of New Zealand, beyond Canterbury, with the majority of New Zealand dairy farms non-irrigated and subject to summer dry conditions. The project will also provide reference for Lincoln University's investment proposal to develop 50ha of the research farm 'Ashley Dene' into a dryland dairy system.

Chapter 2:
Literature Review

2.1 Introduction

The purpose of this section is to review existing literature with regards to dryland farming in Canterbury, with particular focus on environmental impact and economic factors. The use of stand-off facilities and alternative forages (lucerne, diverse pastures and fodder beet) will be explored as possible environmental, and dryland mitigation strategies. The process of linear programming will also be explored.

2.2 Dryland Pastoral Agriculture in New Zealand

New Zealand has a temperate climate which promotes its pastoral based agriculture systems (White, 1999). However, the east coast of New Zealand, from Gisborne down to Otago, are in a rain shadow of the central mountain ranges. The predominant westerly wind drops rainfall before making it to the eastern side. The east coast region can be grouped as a sub-humid climate (400-800mm rainfall) with dry periods restricting growth during late spring, summer and autumn months (White, 1999). The Canterbury region fits into this dryland zone, with low annual rainfall and potential evapotranspiration exceeding rainfall from September- April. Dryland systems are designed to utilise the reliable growth period over spring, with growth constrained at other times of the year by i) low winter temperatures and ii) summer drought. Droughts are difficult to manage as their duration and intensity is variable and unpredictable (Hoglund & White, 1985). Modelling the effect of drought is difficult with this nature of variability and unpredictability; as well various conditions such as soil properties, management and forage type can also have significant influence. Radcilffe & Baars (1987) state that spring and summer rainfall can account for 60% of the variation in annual pasture production on the east coast. Another study done by Rickard & Fitzgerald (1969), looked at 41 seasons (1927-1968) in mid-Canterbury and determined the worst drought in this 41 year period (88 days with soil moisture below wilting point) reduced annual perennial ryegrass pasture production by 40% compared to the average season on light Lismore soils. It was also noted that 1 in 4 seasons had on average a reduction in annual pasture production by 25% due to drought. The Lincoln University farm technical manual (Trafford & Trafford, 2011) provides pasture growth rates with a ± range of the potential pasture production. Pasture production using the minimum values between September-April at the Winchmore site (stony silt loam soil) resulted in a pasture production 54% lower than average.

Global warming is expected to having significant impact to dryland farm systems in the future. Climate change scenarios predict rising temperatures and decreased rainfall in the east of New Zealand as human activity adds more greenhouse gas to the atmosphere (NIWA, 2015). This means the eastern side of the country is set to experience more droughts as the 21st century goes on. NIWA (2015) suggests that by 2080, current 1 in 20 year droughts will be experienced every 10.5years when looking at the low-med end of the predictions and every 3.5years when looking at the med-high end of predictions. This will have significant impact to dryland farms in the future and will require development of new strategies and systems to manage.

2.3 The Environmental problem from dairy farms

2.3.1 Development of environmental issues

The New Zealand dairy industry has had rapid expansion over the past 15 years, with milk production almost doubling (Dairy statistics, 2014). This has come from an increase in land area in dairy by 30% and increased productivity of ~700kgMS/ha to over 1000kgMS/ha (Dairy statistics, 2014). Further intensification of agriculture land is required to feed the growing population, with the world population likely to reach 9 billion by 2050 (FAO, 2014). This intensification of farm systems and change of land use towards dairying is recognised as an important contributor to a range of developing environmental problems (Monaghan, Hedley, McDowell, Cameron & Ledgard 2007). Approximately 39% of monitored lakes and rivers in New Zealand have nitrate levels above the natural background levels, and a number have levels above that deemed safe for drinking by the New Zealand Ministry of Health (Baskaran, Cullen & Colombo, 2009). A study done from 1995-2008 by the Ministry for the Environment, on 973 sites, found that New Zealand has a national scale, ground water quality issue with the contamination of ground water with nitrate and (or) microbial pathogens. Nationally the median nitrate concentration exceeded the level for ecosystem protection at 13.2% of monitored sites. This was presumably from human or agriculture origin and occurred in all regions but especially Canterbury, Southland and Waikato (Daughney & Randall, 2009). Increased concentration of nitrate in ground and surface waters is a serious health hazard, as well as a factor in eutrophication (McLaren & Cameron, 1996). A high nitrate level in drinking water is linked with a disorder call methaemoglobinaemia (blue baby syndrome) and other health problems. Eutrophication of lakes and rivers is the build of nutrients, promoting algae and other aquatic plant growth; this creates problems for recreational activities and furthermore results in the depletion of oxygen in the water which causes the death of fish and other aquatic life.

2.3.2 Environmental regulation

Increased awareness of the developing environmental impact of farming has led to the development of legislation by the central government in the form of the National Policy Statement for Freshwater Management. Regional councils are set with the role of implementing the National Policy Statement for Freshwater Management and will set catchment scale targets in some if not all regions over the next few years (Ministry for the Environment, 2014). Minimal acceptable states for “Ecosystem health” and “human health for recreation” have been set as the national bottom line and councils must maintain or improve water quality above this level. The Environment Canterbury (ECan) Land & Water Regional Plan sets strict limits on nitrogen (N) and phosphorus (P) losses and Variation 1 of the proposed Canterbury Land and Water Regional Plan for the Selwyn-Waihora catchment area requires dairy farms to reduce N losses by 30% by 2022, with discharge limits of <15kgN.ha^{-1} by 2035 (Variation 1, 2014). For properties already <15kg N.ha^{-1} they will be unable to lift their nitrogen leaching above this level. This reduction in N loss is going to be extremely difficult to achieve and there is an urgent need to develop farm systems that are profitable at these N leaching regulations.

2.3.3 The urine problem

On New Zealand dairy farms it is common practice for cows to be outside grazing paddocks all year round (Di & Cameron, 2002). This is what gives the dairy industry its competitive economic advantage over producers in other parts of the world. However this is where the problem lies as the main source of N leached from dairy pastures is the urine N returned by the grazing animal (Di et al. 2002). Therefore the main focus on reducing nitrate leaching should be placed on reducing leaching losses from the urine patches (Di et al. 2002). A urine patch from a cow has a nitrogen loading rate of 500-1000kgN/ha, which is far in excess of what plants can readily assimilate (McLaren & Cameron 1996; Di et al. 2002). This causes an accumulation of nitrogen in the soil. Soil nitrogen in the form of nitrate, NO_3^-, is repelled from soil cation exchange sites due to its negative charge, and therefore is readily leached when water drains through the soil (McLaren & Cameron, 1996). Soil texture and structure affect the rate of water movement and so affect the rate that nitrate will be leached from the soil. Over 200,000ha of the Canterbury region has shallow stony free draining soils which are most vulnerable to nitrate leaching (Di et al. 2002).

De Klein, Monaghan, Ledgard & Shepherd (2010) recommends there are three promising options to reducing N leaching from cow urine patches: nitrification inhibitors that slow the conversion of ammonium to nitrite and so keep the nitrogen in a less mobile form for longer, the use of herd shelters to capture excreted N during high risk times of the year, and more closely aligning animal N demand with forage N supply by replacing N-rich pasture with maize or cereal silage. The use of dicyandiamide (DCD) nitrification inhibitors is currently prohibited on NZ dairy farms after traces of DCD were found in milk powder exports. The options of herd houses and alternative forages are explored.

2.4 The use of housing structures

2.4.1 Housing options

Concrete structures where excretal deposits from cows are collected and stored; to be applied to soil evenly and at a nutrient rate and timing that matches plant uptake is an effective method for reducing nutrient losses to the environment (Benton 2014; Brown 2014; Christensen, Hanly, Hedley & Horne, 2010; De Klein & Legard, 2001; De Klein et al. 2010; Monaghan 2012). A range of standoff/ housing options are explored in the literature, and have varied advantages depending on the farming situation. De Klein et al., (2010) suggest systems in New Zealand are most likely to be based on partial confinement (‘hybrid’ systems), rather than changing into total confinement systems typical in the Northern hemisphere, as the current low-cost grass/clover grazing systems will be loss under the total confinement option. In a partial housing system, cows only spend the ‘high risk’ part of the year inside, and graze on pastures outside for the other part of the year. Monaghan, De Klein, Smeaton, Stevens, Hyslop & Drewry (2004) reported that 60% of the total N leaching from a farm in Southland occurred during the winter, and so this is the most important period to capture urine deposits. Capturing N leached over this period using concrete structures would help meet new N leaching regulations and also be better utilised for plant growth when reapplied to the soil. De Klein et al., (2010) also suggest that when urine is applied to the soil strongly affects the amount of urine N leached. Late autumn and winter are considered the high risk period for N loses as N accumulates in the soil as the plant uptake of N is low due to low soil temperatures. Also soils are often near field capacity as low temperatures mean rainfall is often in excess of evapotranspiration. Hence N being deposited in urine that is not used by plants will eventually leach out of the soil profile and into waterways (De Klien & Ledgard, 2001; Di & Cameron, 2002; De Klien et al. 2010; Monaghan et al, 2004). By capturing the excretal deposits over this period, they can be stored and spread evenly at a rate and time in which conditions and grass pasture growth rates allow the nutrients to be either taken up by the plants or retained in the soil (Monaghan, 2012).

2.4.2 Nitrogen leaching losses using housing structures

A partial housing type system where cows are indoor from April- August, for a typical NZ dairy farm is modelled by De Klien & Ledgard (2001). It was found that the total simulated N losses to surface waters for the restricted grazing system was 25 kg N/ha/yr, this was compared to a fully housed system of 18 kg N/ha/yr and a conventional system where cows graze outside on pastures all year long, 42 kg N/ha/yr. Similar reductions in N leaching were obtained by Benton (2014) who modelled a partial housing system for the Lincoln university dairy farm and found N lost to water was reduced to 24kgN/ha, from 39kgN/ha in the current system. In the system proposed by Benton cows spent the high risk periods of the year in the housing structure; this was estimated to be 20% in March and April, 30% in May and August, 100% in June and July. Benton (2014) stated that the cost (capital and operating) of including a housing structure in the farm system was the main restrictive barrier to their incorporation on Canterbury dairy farms. Christensen et al., (2010) also studied a system where a stand-off facility is utilised to reduce nitrate leaching loses, describing it as a duration- controlled grazing. This practice involves limiting the time cows spend in paddocks by reducing grazing time and moving cows to housing or a feed-pad to receive supplementary feed (De Klein, Paton & Ledgard, 2000). Cows were given a grazing duration of ~ 4 hours for both day and night before being moved onto the stand-off facility. This procedure reduces the number of urine patches distributed to the paddock and hence reduces N leaching. Results from the first year of this trial suggest duration-controlled grazing reduced nitrate losses by 41%. This system utilises cows to harvest ~70% of the forage and so has a lower operating cost than a restricted grazing regime where cows are fed 100% of their diet on the stand-off facility. Journeaux (2013) simulated a similar system, with cows grazing pasture for four hours in the morning and evening before being removed to a housing facility over the months of February to May. Over the non-lactating period (June/ July) cows spent 100% of the time in the housing facility. Journeaux found N leaching losses could be reduced by 34% using this system, however this came at a significant cost. To ensure profitability of the system it had to be intensified above original level, which in turn caused N leaching to increase to a similar level as the original system.

2.4.3 Economics of housing structures

De Klien, Paton & Ledgard (2000) stated that the success of strategic de-stocking systems will depend on whether the increase in costs (capital & operating) can be compensated for by an increase in pasture and milk production. Benton (2014) and Journeaux (2013) stated operating costs increase with the use of partial housing systems. Benton had increased operating expenses by 20%, largely from greater depreciation, feed costs increased but this increase was off-set by the removal of wintering costs. Journeaux associated the increased operating costs with increased costs for: effluent disposal, feeding, labour, tractor and R&M. Building a housing structure is also large capital cost which is a major drawback to the system (De Klien, 2001). The cost of these structures varies greatly depending on the specific features, and whether existing machinery and effluent systems are adequate (Benton, 2014). Table 1 shows that the price of free stall housed barns without an effluent system can vary between $1500- $3320/cow depending on the structure.

Table 1. Cost of cow housing structures

	Benton (2014)	Journeaux (2013)	De Wolde (2006)
total cost	$239,500	$668,000	$750,000
cost per cow (max capacity)	$3,320	$2,000	$1,500

Journeaux (2013) stated a system utilising a housing facility provided the following financial benefits: reduced wintering costs, increased pasture and milk production, better cow condition, reduced dry/empty cows, saved fertiliser costs. De Wolde (2006) suggested milk production could be increased using a partial housing facility in Southland from increased lactation length by 55days to 305days. De Klien (2001) estimated pasture production to be 2-8% greater under a restricted grazing regime, where cows were held on a standoff facility from April to August, compared to a conventional grazing regime. This was from a reduction in 'pugging' and a more even return of animal excreta to the soil. Benton (2014) predicted fertiliser costs would also decrease as less N and P were loss by runoff and leaching under the proposed system.

2.5 Lucerne

2.5.1 Background of lucerne

The New Zealand dairy industry is largely based on perennial ryegrass (lolium perenne) and white clover (trifolium repens) pastures. The shallow root systems on both of these species limits their access to soil water, and can lead to water stress and reduced herbage accumulation and quality during dry summer and autumn periods (Hoglund & White, 1985). Mills & Moot (2010) suggest ryegrass and white clover are inappropriate dryland pastures in low rainfall environments (<750mm/yr) and in these areas lucerne should be considered as the first pasture option. Lucerne is a potential source of high quality feed in places that experience hot dry summers, due to its greater soil water extraction and so greater water use (Brown, Moot & Pollock, 2005; Mills & Moot, 2010). There is limited research available on the productivity of dairy cows grazing lucerne (Bryant, 1978), with much of the recent research on lucerne being focused on the use in dryland sheep systems (Mills & Moot, 2010). There are some New Zealand dairy farmers using lucerne as a direct feed, but the practice is not widespread (Moot, 2009). The low uptake of lucerne by NZ farmers is likely from its loss of support in the 1980's, with inappropriate management practices and various disease problems. The development of new cultivars and better management practices has since given farmers greater confidence (Campion 2011).

2.5.2 Production from lucerne pastures

A range of literature (Brown et al. 2005; Brown, Moot, Lucas & Smith 2006; Greenwood 1979; Kearney, Moot & Pollock. 2010; Hayman 1985; Mills & Moot 2010; and Moot 2009) agrees that lucerne is capable of greater dry matter production than traditional perennial ryegrass in low rainfall environments (<750mm). Greater dry matter (DM) production from lucerne is credited to its deep perennial taproot which is able to extract water from deep in the soil profile (>2m) (Brown et al. 2005). Brown et al. (2005) reported mean dryland lucerne yields of 21t/ha in the second year from establishment, progressively decreasing to 16.5t/ha in the sixth year, on a Wakanui silt loam soil at Lincoln University. Mean annual dryland yields of 6.5 t DM/ha were also reported on a very stony Lismore soil (Hayman, 1985) and again over 20.0 t DM/ha on a deep Wakanui soil (Brown et al. 2003).

The research available on dairy cows grazing lucerne coincides that the feed value of lucerne is not an important limitation to its use with dairy cows (Bryant 1978; Smith, Bryant & Edwards 2013). Smith et al. (2013) showed early spring milk production is the same when cows are given the same allocation of ryegrass as lucerne. It was recognised the higher ME from ryegrass was balanced by the higher CP content, faster degradation rate and more favourable volatile fatty acid ratio from lucerne. No long term trials have been conducted on lucerne under grazing with dairy cows. Long term production data is all based on sheep grazing systems. It is considered persistence and production under dairy grazing is likely to be similar to sheep systems as the rotational grazing management required suits that of a dairy system. Moot et al. (2003) states for successful lucerne stand management, animal and plant requirements must be balanced throughout the season. Campion (2011) advises lucerne’s growth pattern suits seasonal dairy farming, with the majority of production occurring over spring/ summer and a two month rest period required over winter. When lucerne supply doesn’t match animal demand like ryegrass options to make hay or silage exists.

2.5.3 Nitrogen losses from lucerne pastures

Lucerne is a legume and so has the ability to access atmospheric N through rhizobia bacteria on its root nodules. Lucerne therefore doesn’t require applications of fertiliser N, which has significant effect in reducing N leaching losses (Campion, 2011). Campion also states that deep taproot on lucerne plants allows it to clean up excessive nitrate deep down in the soil profile. Therefore lucerne pastures are likely to have lower nitrate leaching losses than ryegrass.

2.6 Diverse Pasture

2.6.1 Productivity of diverse pastures

Increasing plant species diversity in pastures has the potential to provide productivity and environmental advantages over the traditional perennial ryegrass/ white clover pasture mix (Gerrish 2001; Woodward, Waghorn, Bryant & Benton 2012; Woodward, Waugh, Roach, Fynn & Phillips, 2013). Woodward et al. (2013) found diverse pastures (pastures including grasses, legumes and herbs) had similar annual DM production to typical perennial ryegrass/ white clover pastures, but had increased growth over the summer period due to the lucerne and chicory components and so could be better suited to dryland conditions. Gerrish (2001) backed this up stating diverse pasture provided a more even distribution of DM and feed quality throughout the season. Woodward et al. (2013) also found that cows grazing mixed pastures produced at least as much milk as cows grazing standard pasture.

2.6.2 Nitrogen losses from diverse pastures

Indoor trials by Woodward et al. (2012) showed cows grazing diverse pastures portioned more of their feed nitrogen intake into milk (15% in standard pasture and 23% in diverse) and hence less nitrogen was excreted in urine (43% in standard pasture and 29% in diverse). The urinary N output from cows fed diverse pasture was half of the cows fed standard pasture (100g N/ cow/day vs 200g N/cow/ day). Diverse pasture can therefore be a useful tool in reducing nitrate losses from dairy farms. Further long term research is required to determine the persistence of species included in diverse pastures.

2.7 Fodder beet

2.7.1 Background

America and Australia are amongst other overseas grain growing countries that have held a competitive advantage over the New Zealand dairy industry through cheap grain prices. Gibbs (2014) suggests that fodder beet has the potential to be the equalizer. The use of fodder beet as a forage crop for winter was pioneered by the New Zealand dairy industry (Gibbs, 2014). Up until recently the use of fodder beet has been low. However advances in agronomy and feeding out management have developed the use and interest in fodder beet, especially in the

Canterbury region. Gibbs predicts the area of fodder beet in New Zealand has increased from 100ha in 2006 to around 15,000ha in 2014. This recent growth provides reason for the limited but growing availability of research on the use of fodder beet as a livestock feed in New Zealand.

2.7.2 Production and use of fodder beet

Fodder beet is suitable winter forage for dairy farmers as it is capable of producing large tonnage of high quality DM, that doesn't deteriorate during the winter feeding period. Mathew Nelson, Ferguson & Xie (2011) suggest yields of 19-35t DM/ha are achievable, with the crop expenses being 6-8c /kg DM and an energy content of 14.5 MJME/kg DM expected in the bulb and 10.7 MJME/kg DM in the leaf. Gibbs suggests target yields for dryland crops are at least 20t DM/ ha. The high energy content of the bulbs, upwards of 60% and low crude protein (<10%) and fibre content mean it can be problematic as a ruminant feed, with issue of rumen acidosis. This can however be managed through correct transitioning between feed sources.

Gibbs (2014) suggests fodder beet can also be used as a supplement during lactation, as a forage crop or harvested bulb. Spring sown bulbs can be harvested in autumn, stored outside for up to 5 months without the requirement of covering and can be fed out using a standard silage wagon. The leaf represents a small loss in DM through this process. Fodder beet provides a competitive alternative to maize as an autumn supplement, having the advantages of a higher ME value, excellent utilisation (>90%) even in wet weather and at a markedly lower cost of production (Gibbs, 2014).

2.7.3 Nitrogen losses using fodder beet

Limited research has been done on using fodder beet to reduce nitrate leaching losses, however a few characteristics of fodder beet suggest it could provide opportunities to reduce nitrate leaching. Indoor wintering systems are known to reduce nitrate leaching however the majority of farmers prefer outdoor forage crop systems due to their low cost. Indoor wintering systems have a higher cost partly because the majority of the diet is made up of silage (De Wolde, 2006). Harvested fodder beet bulbs can be used in indoor wintering systems and so provide a much cheaper alternative; hence improve the economics of indoor wintering systems. Fodder beet also provides the opportunity to use a restricted grazing system which is also known to reduce nitrate leaching, as Gibbs (2014) states that 5kg DM of fodder beet takes less than two hours for a cow to consume. Additionally fodder beet is a suited feed source from an environmental perspective as it has a low crude protein content so more closely aligns a cow's requirement for N, with the supply of N from the diet. Cabrita, Dewhurst, Abreu & Fonseca(2006) stated that the most gains in nitrogen use efficiency can be attributed to reducing protein content in the pasture or total diet.

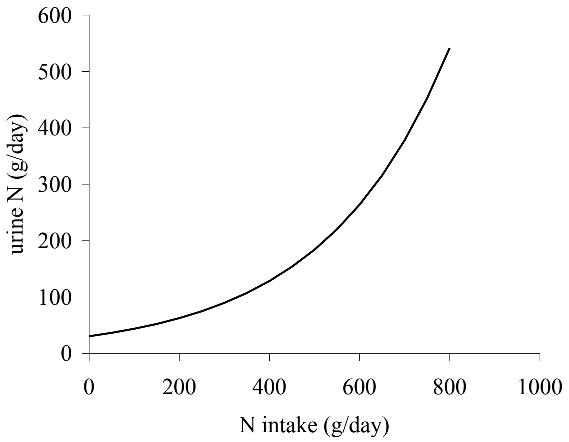


Figure 1. Relationship between N intake (g/day) and urinary N excretion (g/day)
Urine N (g/d) = 30.4 (e0.0036 N intake (g/d)) (R2=0.76) [Castrillo et al., 2000]

A cow eating 18 kg DM/day of 25% protein pasture has an intake of 720 g N/day and so using figure 1 would be expected to have urinary N excretions of 406 g N/ day. By supplementing the diet with fodder beet which has a crude protein content of <10% in the bulb, the N intake will decrease and so will the urinary N excretions. A pasture diet supplemented with 3kg DM of fodder beet bulbs at a crude protein content of 10% reduce the urinary N excretions to 313 g N/day or by 23%. With fodder beet use on the incline, it is likely more research will be done into its use on dairy farms and its potential to reduce nitrate leaching will become better understood.

2.8 Autumn calving

The traditional system of milk production in New Zealand is seasonal, with cows calving between winter and spring (Figueredo, 2003). On most pasture based systems this maximises pasture utilisation and minimises production costs, by aligning pasture supply with feed demand. The pasture supply curve on dryland Canterbury properties is largely dependent on soil moisture. Rainfall is evenly distributed throughout the year, however high temperatures, low humidity, and warm winds over the summer in association with a free draining soil, mean the effectiveness of rainfall during this period is greatly reduced. Subsequently plant growth over the summer period is limited and occasionally this extends into autumn and spring periods (Taylor, 1967).

An autumn based calving system can be used to manage the summer dry period, and risk of drought. Autumn calving allows cows to be dried off over the summer period, and feed demand minimised to maintenance levels. Lactation length is a key driver of annual milk production and autumn calving maximises the length of lactation prior to summer, providing advantages over the typical winter/ early spring calving system.

An additional advantage of an autumn calving system is that traditional seasonal supply causes inefficiencies in processing, as milk supply peaks in spring, and is virtually nothing in winter. On average only 54% of total processing capacity is used on an annual basis (Figueredo, 2003). Supplying milk over the winter period provides processing and marketing advantages and so producers receive a premium for this. Fonterra contracts set quantities of winter milk with farms to ensure sufficient milk is available for regulatory and market requirements. Winter contract milk premiums are paid for milk supplied between 16th May and 15th August in the South Island. The 2015 winter a premium of $3.80 was paid to farmers supplying the Christchurch plant. This price is before a transport deferential which depends on the supplier's location, and the supplier is liable to any damages caused by a shortfall in supply compared to their contract (Fonterra, 2015).

As well as receiving winter milk premiums, autumn calving systems have financial advantages with the opportunity to utilise empty or late calving cows from typical winter/spring calving farms. Milking through the winter period, means these cows can be milked through the typical lactation period to get in-calf for an autumn calving date.

2.9 Linear programming

Linear programming (LP) was first developed in the 1940's for military operations planning, but is now a widely used optimisation technique with many practical problems in operations research (Dent, Harrison & Woodford, 1986). For some farm planning problems the use of whole farm budgeting, partial budgeting or gross margin analysis are not feasible options to determine optimal activity levels. These methods involve a large number of tedious calculations for several plans to be compared and do not explore a rigorous combination of activity levels, nor do they follow a systematic procedure to arrive at the optimal condition. Linear programming can overcome these limitations allowing the user to analyse multiple solutions to a specific problem and arrive at the optimum allocation of resources. The linear programme method works on the assumption, that relationships linking resource use, resource cost, activity levels and activity returns are all linear (Dent et al., 1986).

Linear programming is a general methodology that can be applied to a wide range of problems. The following characteristics are required for linear programming to be a suitable method for solving a problem (Dent et al., 1986):

- A manager has the ability to select from a range of possible activities to put into operation;
- Various constraints prevent free selection from the range of activities; and
- A rational choice of a combination of activity levels is related to an objective that can be quantified (for example, profit).

Microsoft® Office Excel is capable of solving linear programme problems through the add-in "Solver". This software has been used to perform the LP process. The LP constructed will cover the whole farm system. Constructing an LP begins with making an inventory of the available resources. Following this the 'activities' are defined and their demand for the resources is specified (eg. The amount of MJME/cow /month). A system of equations is set out to allow the different activities to draw on available resources. Solving these equations determines the combination of activities that optimizes profit, given the limits on scarce resources and within financial and biological constraints that can be applied. The output from the linear programme model includes number of cows, area to plant in each forage type, amount of supplements to purchase, when and how much silage/ hay to make and fed out and the overall profit at this level of key resources.

2.10 Conclusion

The intensification and change of land use to dairying has had negative impacts on the environment, particularly the build-up of nitrate in ground and surface water. Government policy implemented by regional councils is putting limits on the amount of nitrate that can be leached from the land and so the development of systems that can meet new restrictions is required. The use of housing structures is effective at reducing the N losses from farm. However, this moves farm systems from pastoral based to a more high cost structure. Using restricted grazing strategies allows the pastoral based system to be maintained while achieving nitrogen leaching reductions. Alternative forages; lucerne, diverse pastures and fodder beet are suited to a dryland system and provide N leaching advantages over perennial ryegrass/ white clover pasture. These options will form the basis of the dryland dairy system to be modelled. The literature reviewed shows the need for farm systems to be developed that meet new N leaching regulations. It also indicates the potential for dryland dairy systems and lack of whole farm system modelling of dryland dairy systems.

Chapter 3:
Research Methodology

3.1 Introduction

The aim of the project is to model a dryland dairy system based upon Lincoln University’s Ashley Dene property and determine its economic and environmental feasibility. The system modelled is based on a partial housing system, where cows graze on pastures or crop for part of the day to be moved off and fed the remainder of their diet in a housing structure. The system will utilise drought tolerant forages (lucerne and diverse pastures) and will incorporate arable cropping throughout the lactation and winter feeding period.

3.2 Research Questions

- Can dryland dairying meet proposed environmental restrictions in Canterbury?
- Is dryland dairying able to achieve realistic returns on asset?
- Is dryland dairying a viable land use in Canterbury?

3.3 Ashley Dene

The Ashley Dene farm owned and operated by Lincoln University lies about 15km west of the Lincoln University campus, near Springston, in the Selwyn district (43°65’S, 172°32’E. 39m above sea level). Currently used for pasture and lucerne research, along with sheep, beef and winter dairy cow research and development. The farm currently consists of 120ha of irrigated land, 80 ha about to be irrigated and 155ha of non-irrigated land. It is proposed to use 190ha of the Ashley Dene property to establish a ‘Developmental Research Station’ comprised of two dairy farms. This Developmental Research Station will lead the way in new irrigated and dry-land partial-housed dairy farming systems that operate within the new stringent environmental limits, animal welfare standards and achieve profitability targets. The dry-land dairy system is proposed to be based on 50ha, milking 106 cows, using no irrigation (dry-land), continual supplementary feeding partial housing of cows and integration of arable cropping throughout the lactation and winter feeding period (2.5 cows/ha of milking platform; with target of 500 kg MS/cow/year). These leading edge farms will develop ‘better than best practice’ in environmental and financial performance, as well as provide a world leading resource for research, education and training in sustainable land use (Ashley Dene Business Case, 2014). The farm model will replicate this proposal at Ashley Dene but the proposed 50ha will be upscaled to 200ha to give the property sufficient scale and relevance to the wider Canterbury region, with the average farm size in Canterbury 210ha (Ministry of Primary Industries, 2012). The Ashley Dene site is of high relevance to the wider Canterbury region being based on the same shallow stony free-draining soils that cover 70% of the Canterbury Plains. The site is dominated by Lismore silt loam soils, with the sibling name Lism_2a.1 and soil classification Pallic Firm Brown Soil (S-MAP, 2015). This is a well-drained soil with 'very low' water-logging vulnerability and 'high' nitrate leaching vulnerability (S-MAP, 2015). Climatic data collected from Cliflo 30 year average data (NIWA) suggest the property has an average rainfall of 604mm/yr, average temperature of 11.9^{o}C and potential evapotranspiration of 912mm/yr. Ashley Dene sits atop the Te Waihora aquifer by 3-6m, this aquifers drains into Te Waihora lake 10kms to the south-east. Variation #1 of the proposed ECAN Land and Water Regional Plan indicate the properties in this Selwyn-Waihora catchment must operate within a nitrate leaching limit of <15 kg N/ha/yr leached nitrate across the whole farm area.

3.4 Research Approach

The limited number of dryland dairy systems in Canterbury and the desire to explore the use of lucerne and partial housing in such system meant a case study approach was not possible. Instead a quantitative research method approach was considered more appropriate. A linear programme was constructed and existing computer generated models Farmax Dairy Pro® and Overseer® (6.2) used to perform the quantitative research. The LP method is a profit maximisation process which determines the optimal mix of available resources, within financial and biological constraints. The LP was used to determine the level of key inputs because of its optimisation capabilities. As well as determining the level of some key inputs the LP was included to underpin the Farmax ® model. Farmax® requires the operator to select the input data and provides analysis based on this. It does not analysis the combination to determine if it is optimal and hence required the LP to be involved in the modelling process. The methodology followed was based on sourcing input data, building the LP, using outputs from the LP to get to an optimal solution with Farmax. Farmax due to its more complete modelling gives greater feasibility of the farm system mode. Once the farm system was finalised with the Farmax® technique, environmental analysis of the farm system was done using Overseer®. Financial analysis is produced from both the LP and Farmax® modelling tools. Farmax® produces an annual budget and key performance indicators will be calculated from this budget and used to analyse the profitability of the farm system. Further to this an investment analysis will be performed for developing the farm model on a typical dryland sheep farm in the Canterbury region.

3.5 Theoretical Model

The research approach is based on the theoretical model of profit maximisation. The use of linear programming enables the level of key resources where profit maximisation occurs to be determined. The style of LP suitable for this research is the standard LP/quadratic, known as the "simplex method". The canonical form of the LP matrix can be written as:

$\text{Max } Z = C1\ X1 + C2\ X2 + \ldots\ldots. + Cn\ Xn$

Z = objective to be maximised (profit)

C = contribution (gross) margin (+) or costs (-) of X

X = activities, choice alternatives or decision variables

The profitability is measured as the operating profit, also known as the economic farm surplus (EFS). This is calculated by the dairy gross farm revenue (milk and net dairy livestock sales, + other dairy income, +/- value of change in livestock numbers) less the operating expenses (Farm working expenses, +/- feed inventory adjustment, +/- owned runoff adjustment, + labour adjustment, + depreciation).

3.6 Linear programme

Linear programming involves using a mathematical approach to find an optimal solution to a managerial problem. Through this process the dryland dairy system is modelled and the optimal levels of key resources required in the farm system formulated. The most limiting factor of feed for production on NZ pastoral dairy farms is metabolisable energy (ME). For this reason feed supply and demand are measured in units of ME, mega joules of metabolisable energy (MJME). Land area and production/cow has been held constant, but livestock numbers are variable to match the supply of energy. The model is given the option to optimise cow numbers, the option to buy in supplement and the ability to move feed from month to month through making silage. Biological constraints are placed around the use of different crops to prevent a build-up of pests and disease and depletion in soil fertility and organic matter. Feed supply is restricted to a suitable utilisation of the total production of the crop or pasture to reflect the inefficiencies by grazing animals being unable to harvest all that is grown. The results produced from the linear program help the Farmax® process to reach an optimal solution and underpin the Farmax® model. The LP is limited in its ability to model a farm system and relies on the Farmax® model for input data.

3.7 Validating the Farm Model

Farmax Professional Dairy ® is a farm modelling software that has been developed to assist management in dairy systems. The software uses a network of complex calculations to model a farm as accurately as possible. It can be used to predict animal, farm and financial performance for different management scenarios. Bryant, Ogle, Marshall, Glassey, Lancaster, García & Holmes (2010) performed two farmlet trials to assess the accuracy of the model and found it predicted mean annual yields of milksolids (per cow and per hectare) to a high degree of accuracy. Bryant also found the monthly pasture cover predictions were accurate with a mean prediction error of 7%. The monthly pasture covers output from Farmax® are used to determine if the farm model is feasible. The pasture cover output from the Farmax® model gives a minimum pasture cover to achieve the set performance and compares this to an actual monthly pasture cover, produced from feed demand and feed supply balances. If the actual pasture cover drops below the minimum pasture cover the model is not considered feasible.

3.8 Financial Analysis

Financial analysis of the farm model will be performed through Farmax Dairy Pro® and Microsoft Excel™. Farmax® produces an annual budget for the farm, with production and input data linked to income and expenses. The annual budget will be used to analyse the profitability of the farm model and key performance indicators will be calculated from the budget. In addition to the annual budget a 15 year investment appraisal will be done for the model. The investment analysis is undertaken with the use of price assumptions to detail the annual cash flows for the 15 year period, in order to calculate an internal rate of return (IRR) and net present value (NPV) for the investment. This technique will allow the profitability of the model to be compared to an alternative land use of sheep breeding and finishing. Data from Beef and Lamb NZ for a Canterbury sheep breeding and finishing model will be used to produce and investment analysis for comparison.

3.9 Environmental Analysis

Environmental analysis is performed using the computer modelling programme Overseer®. Overseer® is a nutrient budgeting tool that was developed by AgResearch Limited, with support from the Ministry for Primary Industries and the Fertiliser Association of New Zealand. Overseer® is a mathematical model of the nutrients cycling within a farm system. The model considers nutrient inputs, transformations and outputs to produce a report of the nutrient flows within a farm system. The important output data for this project is the level of nitrate leaching from the farm system, referred to by Oveerseer® as 'nitrogen loss to water'. The level of nitrate leaching is the most important figure as nitrate leaching is currently the main environmental concern for dairy farming in Canterbury (Ministry for the Environment, 2014). Overseer® is an accepted method for determining nitrate leaching losses, with it being used by regional councils to implement the National Policy Statement for Freshwater Management. Farmers will be required to provide Overseer® predicted nutrient loss information to councils as part of reporting and compliance processes in the future.

3.10 Financial Assumptions

Milk Price

A long-term average milksolids payout of $6.00/kgMS has been assumed for the model. The Fonterra dividend was assumed to be $0.30/share. A winter milk contract premium of $3.00/kgMS was assumed for milk supplied between 16th May and 15th August.

Share Price

Fonterra requires suppliers to own one share per kg of milksolid supplied to the co-operative. The value of a share was taken from the NZX markets, where Fonterra's shares are listed as 'FSF' (Fonterra Shareholders Fund).
Fonterra Farmers Fund share value: $5.40 (NZX, 2015).

Depreciation Rates

Depreciation rates were sourced from Inland Revenue Department (IRD) standard diminishing depreciation rates (post 2006) as found on the IRD website. Depreciation rates are listed following:
-Cow shed 6%
-Housing structure 6%
-Machinery 13%
-Development expenses (fencing, water lines, and lanes) 20%

Cow Costs

The IRD "national average market values for specified livestock determination, 2015" was used to value mixed-age cows and rising two-year heifers.

Rising two-year heifers	$1,324
Mixed-age cows	$1,655

Housing Structure

The cost of the housing structure and effluent system was based on values sourced from Benton (2014). Benton's estimates were based on commercial quotes to build a 720 cow free stall barn. It is assumed the cost will be linearly proportional to the number of cows, allowing the costs to be estimated for a 500 cow free stall barn. It is assumed the barn will be built to hold a maximum capacity of 500 cows so that there is flexibility in the design to alter the future stocking rate on the farm. The structure design is based on two mirrored rows of free-stalls, with rubber bedding and 'scrapper lanes' in-between the rows to remove effluent. The bedding area is separated by a central feeding lane, which is wide enough for the tractor and feed-out wagon to drive down. Cow groups (dries, milkers, lames etc) can be separated by subdividing gates. Otherwise cows are able to move freely within the shed, to lie down, eat or socialise. The effluent system is built to hold 12 months of storage to ensure the effluent can be applied at the correct time.

Cost of fully enclosed housing structure with effluent system

$3678/cow (500cows) Total $1,839,000 Benton (2014)

Machinery Costs

Machinery values have been based on estimates provided by associated retailers (Askin & Askin, 2015).

105hp John Deere Tractor	$95,000
Giltrap side delivery 11m^3 silage wagon	$40,040

Cowshed

The cowshed cost has been based on a 40bail Herringbone. Milking 450cows peak, this is equivalent to 11.2 rows. Based on 10mins per row the milking time is slightly less than 2hours/milking with this size shed. REL dairy constructions suggests the costs of a herringbone shed including plant range from $15,000 to $17,000/bail depending on site conditions and specifications (Askin & Askin, 2014). This includes site works, building, milking platform, milking plant, refrigeration, yards and basic effluent system. It is assumed the milking shed will cost $16,000/bail or $640,000 total, with $145,000 of this associated to plant expenses.

Farm Working Expenses

Farm working expenses have been sourced from Benton (2014) who modelled a partial housing system on the Lincoln University dairy farm (LUDF). Farm working expenses that are considered to differ from Benton (2014) are feed costs, grazing costs, regrassing costs, weed/pest expenses, fertiliser costs and vehicle/ fuel costs. These are explained below.

Feed Costs

Maize and pasture silage are the only brought in feed sources. Both feed sources will be brought locally and prices have been estimated on price delivered (Smit, personal communication 2015).

Pasture Silage - $0.34/kgDM

Maize Silage- $0.36/kgDM

The costs of making silage has been estimated from the Farmax Dairy Pro® default values of $0.11/kg DM.

Grazing Costs

Grazing costs for young stock have been based on $5/hd/week from 3-9months of age, $8/hd/week from 10 months to 24 months of age. With calves leaving mid-August at 3 months of age and returning 1st May as in-calf heifers. All MA cows are wintered on farm.

Regrassing

Regrassing costs have been calculated by Farmax Dairy Pro® default values.

Fertiliser

Fertiliser costs have been calculated by using Overseer® modelling to determine maintenance fertiliser requirements. Fertiliser prices have been retrieved from Ravensdown price schedule and prices were excluding GST and spreading. (Ravensdown Fertiliser, 2015). Prices retrieved were as follows:

Urea	$575/t
Superphosphate	$320/t
Cropmaster DAP	$875/t
15% Potash Super	$382.65/t
Potassium Chloride	$695/t
Lime	$27.50/t

Nitrogen costs have been calculated by Farmax Dairy Pro® and is based on inputs 80kg N/ha across the ryegrass pastures in four applications. Maintenance fertiliser included Potash super 15% on the Lucerne block at 300kg/ha and superphosphate on the ryegrass block at 250kg/ha. In order to maintain a suitable soil pH, an annual lime application has been assumed at 1 tonne/ha.

Lucerne

Lucerne has greater weed management requirements than typical pastures. It has been assumed the extra costs associated with maintaining a lucerne stand will be $40/ha (Paraquat plus Atrazine) (Moot, personal communication 2015) plus application costs of \$22/ha (Askin & Askin, 2015). This has been added to the weed and pest expenses.

Vehicle and Fuel

The vehicle and fuel expenses have been increased due to the extra requirement of feeding out. Askin & Askin (2014) suggest the total variable and fixed costs associated with running a 90hp tractor are \$47.41/hour. It is expected that feeding-out will take 1 hour daily during lactation and 2 hours daily during the non-lactating period. A total of 432 tractor hours were considered attributable to the housing structure.

Extra Labour

It is expected the dryland dairy system will have a greater labour requirement than the LUDF as cows are wintered on-farm, increased labour requirement involved with feeding out, and cows are milked for a longer period.

Additional labour requirement: \$20,000

Contracting expenses

Contracting expenses are considered to have additional expenses from lifting fodder beet and spreading solids from the housed facility. Fodder beet expenses have been based on Farmax Dairy Pro® default values of \$2300/ha. A cost for harvesting fodder beet has also been included. It is estimated 185t.DM of fodder beet will be mechanically lifted for feeding dry cows at a cost of \$0.02/kgDM (Askin & Askin, 2014).

It is estimated that 800m^3 of solid effluent will be captured by the housed facility. Wilton contracting (Wilton, personal communication, 2015) quoted a spreading cost of \$8/t within 2km from the shed and loading cost of \$2/t. Total annual cost of \$8,000.

Inflation

The average rate of inflation is based on the average inflation rate for the past 5 years. Calculated from the consumer's price index, determined by the Reserve Bank of New Zealand.

Inflation rate: 2%   (Reserve Bank of New Zealand, 2015)

Capital gain rate

The Real Estate Institute of New Zealand (REINZ) determined the compounded annual growth rate of dairy farm land to be 3.7% for the past 10 years. Thus with inflation estimated at 2%, capital gain is assumed to be 1.7% (Farm Prices Steady but Sale Volume Falling, 2015).

Income development

The income development assumption is used to estimate the annual increase of product prices received by the business. It was conservatively estimated at 1.5% per annum. Income isn't expected to increase at the same rate as expenses (the rate of inflation) due to the classical cost price squeeze theory.

Tax rate

The tax rate used was 28%, which is the current tax rate for companies in New Zealand.

Canterbury sheep breeding and finishing model

A typical Canterbury sheep breeding and finishing farm is included in the investment analysis for comparison with the dryland dairy model. Sheep breeding and finishing is a typical land use for non-irrigated properties in Canterbury. The investment into dryland dairy is considered as an alternative land use for Canterbury sheep breeding and finishing farmers who are looking to increase the profitability of their farming enterprise. Figures for the sheep breeding and finishing property were sourced from Beef and Lamb NZ (2015). The sheep breeding and finishing model is based on a survey done on finishing farms mainly in the Canterbury and Otago regions. The survey covers mainly dryland properties, with some cash cropping and carrying capacities ranging from 6-11 SU/ha on dryland to over 12 on the irrigated properties. The only adjustment made to the models figures was the capital value of land, this was adjusted to $20,000/ha to better replicate agriculture land prices in the Selwyn district.

Loan

The funds required to develop the current sheep breeding and finishing property into a dryland dairy farm will be sourced from an amortised bank loan with a 25 year pay-back period. It is assumed the livestock from the sheep business will be sold, paying off the majority of the loan held by the sheep business, with the remainder of the loan carried forward to the dairy business.

Development costs

It is estimated that the cost of developing lanes, fences and water lines on the sheep property so it is suitable for the dairy operation will be $100,000.

Housing

It is estimated one extra house will be required on the property with the extra labour requirements of the dairy farm compared to the sheep enterprise. This is expected to cost \$2,000/m^2 and be 150mm^2 (Ashley Dene Business Case, 2014).

Chapter 4:
Linear program model

4.1 Introduction

This chapter describes the linear programme (LP) used to establish key data for the dryland dairy system. The linear programme was created to capture the key aspects of a whole farm system. The supply and demand for metabolisable energy set the base of the LP, and profit maximisation was the key driver behind the solution. The model was given the ability to optimise stock numbers, the option to buy in supplement and the ability to move feed from month to month through making silage. The linear program was linked to a number of background spreadsheets, including feed demand, feed supply and variable costs.

4.2 Input Data

4.2.1 Feed Demand

A comprehensive feed demand profile was included in the linear program shown in appendix B. Feed demand was formulated from requirements for maintenance, live-weight gain/loss, milk production and maternal status. The model was based on a crossbreed cow with mature liveweight of 450kg and annual milk production of 500kgMS/cow. Energy requirement calculations was based on work done by Nicol and Brookes (2007). Maintenance energy requirements was based on the equation 0.56 MJ ME/kg liveweight$^{0.75}$ and live-weight gain and loss was worked out on 38 MJ ME/kg gain and 28 MJ ME/kg loss. The data used to calculate energy requirements for lactation and pregnancy is shown in the following two tables.

Table 2. The metabolisable energy requirements above maintenance for lactation in dairy cows

	Milk Composition					
Milk fat (%)	4	4.5	5	5.5	6	6.5
Milk protein (%)	3.2	3.5	3.7	3.9	4.2	4.4
Milksolids (%)	7.2	8	8.7	9.4	10.2	10.9
	ME requirement					
ME (MJ ME/kg milksolid)	80	77	76	75	73	73

Table 3. The metabolisable energy requirement above maintenance for differing stages of pregnancy and the complete pregnancy in adult dairy cattle

Calf birth weight		**Weeks before calving**				
	-12	-8	-6	-4	-2	0
Kg		**MJ ME/cow/day**				
30	6	11	15	19	25	34

4.2.2 Feed Supply

The biological and management requirements of different forage species meant it was not easily possible to use the optimisation method of linear programming to find the ideal proportions of each forage species. Instead constraints were placed around the amount of different forages able to be grown to ensure biological and management constraints were meet. Lucerne has a greater yield than ryegrass, though its particular grazing management requirements mean the ideal situation is not 100% lucerne pastures. An area of lucerne similar or less to that in pasture was thought to be a good balance between maximising DM yield while allowing enough flexibility in the system to meet grazing management requirements. The investment proposal done by Lincoln University suggested a similar ratio. The area sown in fodder beet was set at 20ha as with a yield of 12t.ha^{-1}, this yielded enough to provide fodder beet as the main feed source for dry cows, a supplement in early lactation and for transitioning in late lactation. It was assumed of the remaining 180ha, 100ha would be ryegrass pasture and 80ha lucerne pasture.

A constraint has been placed on the LP model limiting the purchase of supplements to 600t.DM. This has been done to ensure the model is able to meet environmental regulations.
Annual pasture and crop yields have been based on the Lincoln University base assumptions for the investment proposal at Ashley Dene. These figures are 8t.ha^{-1} for ryegrass pastures, 10t.ha^{-1} for lucerne pastures and 12t.ha^{-1} for the fodder beet crop. Monthly growth rates have been calculated from annual yields, and follow supply curves typical under dryland conditions. Figure 2 and 3 shows the feed supply from lucerne and ryegrass pastures. The dryland sheep database on Farmax Pro® suggests annual yields of 6.7tDM/ha for ryegrass pastures. The increased soil fertility of the dairy land and application of effluent from the cowshed and housed facility are expected to increase annual yields above that on a sheep property, justifying the greater annual yield assumption of 8t.DM/ha for the ryegrass pastures.

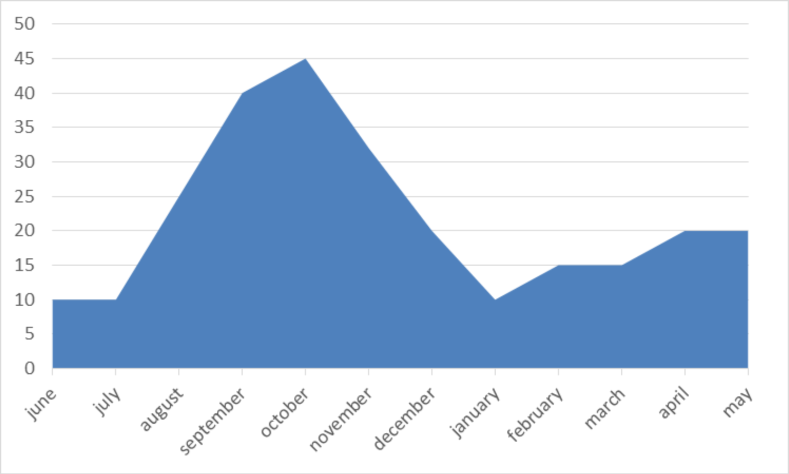
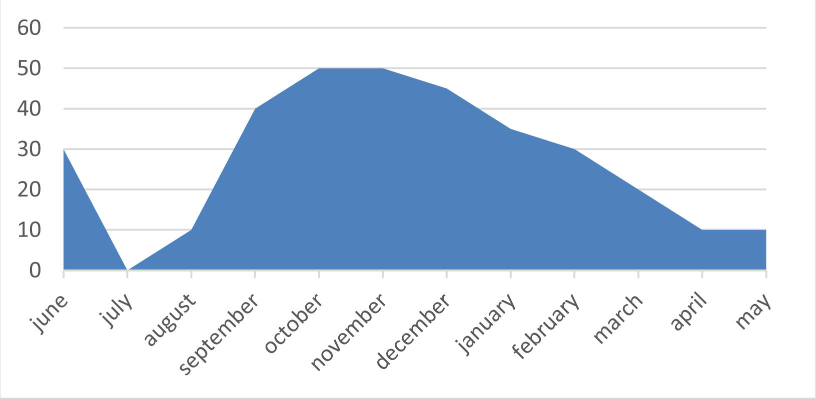


Figure 2. Ryegrass feed supply curve

Farmax Dairy Pro® is unable to model lucerne pasture accurately and so the lucerne pasture has been inputted into the programme as a typical ryegrass pasture. With this the lucerne monthly growth rates have been adjusted to satisfy the unique grazing management requirements. As shown in figure 3 below the sward has an abnormally high growth rate in June, this has been done to allow the lucerne sward to be grazed hard in this month. July has no growth and August only 10kgDM/ha to ensure the sward is given adequate rest over this period.

Figure 3. Lucerne pasture feed supply curve



The Farmax Pro Dairy® database has been used to provide estimations of the energy content in mega joules of metabolisable energy per kilogram of dry matter (MJME/kg DM) for all of the feed sources on a monthly basis. The LP is not able to make specific allowances for the effect of pasture height and age on pasture quality. It does however apply a cost to pasture being carried from one month to the next to reflect a loss in quality and to encourage the model to utilise pasture in the month it was grown. Farmax Pro® doesn't contain a database for lucerne pastures due to the limited use of lucerne in dairying. The metabolisable energy of the lucerne pastures has been assumed to be the same as the ryegrass pastures. This was justified as literature reviewed suggested milksolid production from lucerne pasture was equal to that from ryegrass pasture when cows were fed the same amount of dry matter (Smith et al. 2013)

Table 4. Metabolisable energy of ryegrass and lucerne pastures (MJME/kgDM)

Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
11.0	11.0	11.4	11.3	11.2	11.4	11.6	10.2	10.4	10.4	10.8	11.0

Utilisation rates have been estimated at 100% for the ryegrass and lucerne pastures and 75% for the fodder beet crop. No wastage has been assumed with pastures, as the housing facility and free draining soils mean cows will be removed from pastures when conditions are not suitable and so optimal utilisation can be maintained throughout the season. Table 5 shows the default utilisation values from Farmax®, which also uses an utilisation figure of 100% for 7 months of the year. The fodder beet crop has an assumed utilisation of 75% which is the default value from Farmax®.

Table 5. Utilisation rates (%)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Default values	80	80	80	90	100	100	100	100	100	100	100	90
Housing values	100	100	100	100	100	100	100	100	100	100	100	100

4.2.3 Financials

Financial data is programmed into the linear programme so that it is capable of profit maximisation. General running costs that are variable to cow numbers and costs associated with feed supply are required for the profit maximisation process. Fixed costs such as rates, insurance, are not included as they do not affect the outcome of the LP. The financial data was sourced from Benton (2014) and Askin & Askin (2015). A rearing cost was included on the heifers to simulate the cost of bringing in replacements. The financial outputs from the LP are of limited importance, financial data is included rather to allow the optimisation process to occur.

4.3 LP Results

The LP produced an optimal situation with a total number of cows of 451 or 2.26cows/ha. The herd profile is shown in table 6. The LP purchased 600t.DM of pasture and maize silage. This was fed-out as shown in table 6. Feed demand was greater than feed supply from June to December. A figure of total feed utilised was calculated by dividing the total feed demand by total feed supply to determine how effectively the LP was working. The total feed utilised was 98.7% suggesting the LP was working effectively to utilise feed in the month it was grown. A maximum pasture cover of 2163kgDM/ha was reached in June, and a minimum pasture cover of 1782kgDM/ha in December. These pasture covers are expected to be within suitable levels for ryegrass and lucerne pasture management. The LP has limited ability in that it is unable to consider the effect pasture cover has on pasture quality and growth. It is therefore expected when modelled in Farmax® the use of supplements will differ to optimise pasture quality and production.

Table 6. LP outputs (kgDM/cow/day)

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Days	31	30	31	31	30	31	30	31	31	28	31	30
Cows	451	449	447	446	446	446	446	446	416	397	384	374
Ryegrass	5.4	2.2	2.2	5.6	9.0	10.1	7.2	4.5	2.2	3.6	3.8	5.2
Lucerne	2.2	5.3	0	1.8	7.2	9.0	9.0	8.1	6.3	5.8	4.1	2.1
Fodder Beet	4.7	2.4	0	0	0	0	0	0	0	0	3.3	4.7
Supplement	0	3.2	11.2	10.6	4.2	1.3	2.9	3.8	7.4	4.2	0	0
Silage made	0	0	0	0	0	0	0	0	0	0	0	-4.4
av. Pasture cover (kgDM/ha)	2112	2163	2008	1888	1873	1850	1821	1782	1787	1830	1905	1994

Chapter 5:
Validation of the Farm Model

5.1 Introduction

Validation of the farm model requires another process other than the LP to give confidence that the model would work in an actual farming scenario. Validating the model through on farm trials isn't plausible due to the time and cost required to perform. An alternative option to validation of the farm system is through another virtual process of farm modelling using the programme Farmax Dairy Pro®. Farmax Dairy Pro® was used to model the farm system, and make changes where required to ensure its feasibility.

5.2 Pasture cover feasibility

Livestock numbers, productivity levels, and feed supply figures from the base scenario linear program were put into the Farmax Dairy Pro® model. This was done to ensure outputs produced from the linear program calculated for optimal profits were feasible in terms of monthly pasture covers.

Farmax Dairy Pro® requires the user to input a range of details around the farm model, and from this is able to calculate feed demand and feed supply. The pasture cover output uses the feed supply and demand balance to determine monthly pasture cover levels. The actual pasture cover is compared to a minimum pasture cover that is required to meet production targets. When the feed supply data produced by the LP was run in Farmax Dairy Pro® the pasture cover output was considered unfeasible. It is expected this was due to the linear program being produced to optimise profitability rather than pasture covers. With the LP unable to consider the effect pasture covers had on pasture quality and minimum pasture covers required to meet performance. This is shown in figure 4 with the LP pasture cover prediction dropping below the minimum pasture cover required produced by Farmax Dairy Pro®.

To ensure the models feasibility, feed supply was adjusted until feasible pasture covers were met. This was done by keeping base feed supply data constant, such as area of forage and growth rates. Rather, adjusting the amount of each feed offered on a monthly basis and increasing the total amount of feed imported. A feasible pasture cover was met when feed offered was adjusted to that shown in table 7 and total feed imported was increased to 670t.DM. Pasture consisted of both ryegrass and lucerne pastures. The increase in imported feed by 70t.DM, is equivalent to 3% of total feed demand. This difference in feed balance between LP and Farmax models of 3% is likely to come from differing feed demand due to different live weight and milk production profiles in each program. The LP requires both of these to be estimated by the operator, whereas the Farmax Dairy Pro® model uses feed supply information to predict milk production and livestock weight.

Table 7. Feed reconciliation from Farmax Dairy Pro® (kgDM/cow/day)

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Pasture	3	7	6	9	14	15	15	13	12	10	5	1
Fodder Beet	6	1	0								6	7
Pasture Silage			3	1								
Pasture Silage (brought)	1	4	5	5	4	3	2	4	4	5	1	2
Maize Silage (brought)		3	4	4								
Total (Utilised)	9	14	17	18	18	18	17	17	16	14	10	8

Figure 4 shows the pasture cover of the adjusted model. The black line is calculated by Farmax Dairy Pro® as the minimum pasture cover required to meet livestock production and performance targets. Farmax uses the minimum pasture cover to determine if the model is feasible. The actual pasture cover produced by Farmax Dairy Pro® shown by the blue line remains above minimum pasture cover throughout the year, and so model is considered feasible. The pasture cover drops in late winter (July/ August) and again during the summer period (December-February). A reduction in pasture cover occurs when pasture consumption is greater than the pasture growth. The reduced pasture cover is expected over the winter period due to low soil temperatures limiting pasture growth and then over the summer period due to low soil moisture levels limiting pasture growth. The build-up of pasture covers prior to the start of calving (May), means pasture can be offered throughout the winter period even when pasture growth is minimal.

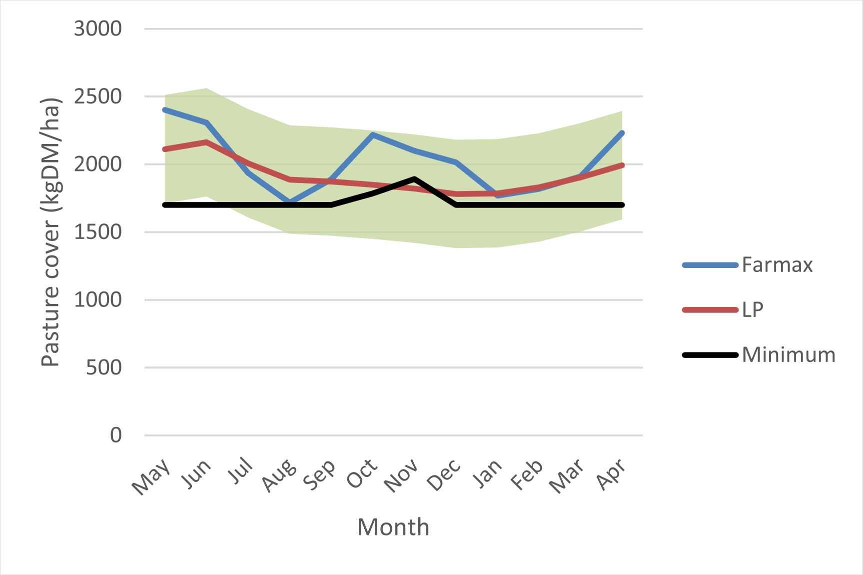


Figure 4. Pasture cover predictions

The gap between the actual pasture cover and minimum pasture cover is minimal in August and January. This suggests the stocking rate produced by the LP is at a maximum level and increasing the stocking rate further is likely to produce an unfeasible model.

The pasture cover predicted by the LP is similar to that predicted by Farmax Dairy Pro®, being within ±400kg DM/ha of the pasture covers calculated by Farmax. This is shown by the blue Farmax cover line being within the 400kg DM/ha range that follows the LP cover line in figure 6. The main differences occur over the spring period (Sept-Nov). In the LP model pasture covers don't recover from the winter and continue decreasing until December, when they begin to gradually increase. This occurs as the LP model has been set up to utilise pasture in the month it is grown by including a 15% loss in utilisation when it is carried over from one month to the next. Thus the LP model increases the feed supply of pasture when pasture growth increases in spring rather than allowing a pasture surplus to build pasture covers. The Farmax model follows a more realistic situation, where increased spring growth is used to build pasture covers following winter and prior to summer.

5.3 Financial outputs

As well as determining the feasibility of a model Farmax Dairy Pro® provides a range of useful outputs, including income and expense calculations. Farmax Dairy Pro® allows the user to set base income and expense data and uses information from the model such as milk production, cow numbers, feed inputs and nitrogen inputs to calculate total income and expenditure figures. The income and expense assumptions are discussed in 3.10 Financial Assumptions. The annual budget produced by Farmax Dairy Pro® is shown in appendix F.

5.4 Farmax Dairy Pro® key outputs

A physical summary of the dryland dairy system modelled with Farmax® is shown in table 8 below.

Table 8. Physical summary produced by Farmax Dairy Pro®

Category	**Description**	**Value**	**Units**
Farm	Effective Area	200	ha
	Stocking Rate	2.25	cows/ha
	Comparative Stocking Rate	77.1	kg Lwt/t.DM offered
	Potential Pasture Growth	8.8	t DM/ha
	Nitrogen Use	40	kg N/ha
	Feed Conversion Efficiency (offered)	11.2	kg DM offered/kg MS
Herd	Cow Numbers (1st May)	446	Cows
	Peak Cows Milked	446	Cows
	Days in Milk	282	Days
	Avg. BCS at calving	5.1	BCS
	Liveweight	947	kg/ha
Production	Milk Solids total	220,215	Kg
(to Factory)	Milk Solids per ha	1,101	kg/ha
	Milk Solids per cow (peak cows milked)	494	kg/cow
	Peak Milk Solids production	2.16	kg/cow/day
	Milk Solids as % of live weight	116.2	%
Feeding	Pasture Offered per cow *	3.2	t.DM/cow
	Supplements Offered per cow *	2.2	t.DM/cow
	Off-farm Grazing Offered per cow *	0.1	t.DM/cow
	Total Feed Offered per cow *	5.5	t.DM/cow
	Supplements and Grazing / Feed Offered *	41.1	%
	Bought Feed / Feed Offered *	27.2	%
(*) feed offered to females > 20 months old / peak cows milked			

Chapter6:
Financial Analysis

This chapter will address the research question *'Is dryland dairying able to achieve realistic returns on asset? And is dryland dairying a viable land use in Canterbury'.* The economic analysis undertaken in this chapter uses financial results produced from Farmax Dairy Pro® and key performance indicators to determine the profitability of the modelled dryland dairy system.

6.1 Statement of Assets

A statement of assets is shown in table 9 for the farm model. The value of assets has been based on assumptions described in 3.10.

Table 9. Statement of Assets

Dryland	200ha	$20,000/ha	$ 4,000,000
		Total land value	**$ 4,000,000**
Staff house		(150m2 at $2000/m2)	$ 300,000
Herringbone cow shed (40bale)		$160000/bale minus plant	$ 505,000
Fully enclosed housing structure		$3678/cow	$ 1,839,000
Implement storage & Calf shed 5 bay		$20,000	$ 20,000
		Total infrastructure value	**$ 2,664,000**
Tractor (105hp)			$ 95,000
Feed-out wagon			$ 40,040
Plant			$ 145,000
		Total plant and machinery value	**$ 280,040**
Dairy Cows	450	$1655	$ 744,750
Rising 1 year olds (born May 2015)	79	$1324	$ 104,596
Total livestock value			$ 849,346
Fonterra Shares	220215 shares	$5.40	$ 1,189,161
Total share value			$ 1,189,161
		Total Current Assets	**$ 8,982,547**

6.2 Annual Budget

A summary of the annual budget produced by Farmax Dairy Pro® is provided in this section and the annual budget is shown in appendix F. The average Canterbury dairy farm modelled by the Ministry of Primary Industries (MPI) is also included in the budget for comparison (Ministry of Primary Industries, 2012). The MPI model is based on the average of 1040 farms throughout Canterbury and North Otago, that have a mix of spray and border dyke irrigation, and do not own a run-off. The total revenue for the dryland dairy model is lower than the Canterbury average, this is from a lower milksolid production (1,101 vs 1405 kgMS/ha). The total revenue for the dryland dairy model is equivalent to \$7.60/kg MS, with milk sales of \$6.00/kg MS and a winter milk premium of \$1.05/kg MS across the total milk supply. The farm working expenses are \$835,786 or \$3.80/kg MS for the dryland dairy system. The dryland dairy model, has lower farm working expenses per kilogram of milksolid produced than the MPI model. The farm working expenses are also shown to be lower per cow and per ha in the annual budget. The lower farm working expenses are due to lower grazing, fertiliser and irrigation expenses, although the dryland dairy model has significantly high brought feed expenses of \$230,513, \$332/cow greater than the Canterbury average. The dryland dairy model has high depreciation expenses, largely due to the housing structure and associated machinery.

Key performance indicators (KPI) are calculated from the budget and compared to the MPI model. Table 10 describes the KPI's used and table 11 a summary of the annual budget using the KPI's.

Table 10. Explanation of key performance indicators

Dairy Gross Farm Revenue (GFR)	+ Milk & Net livestock sales + other Dairy income +/- Value of change in livestock numbers (non-cash)
Farm Working Expenses	Total dairy farm cash expenditure
FWE/kg MS	Cost of FWE per kilogram of milksolid sold
FWE/NCI	Farm working expenses as a proportion of net cash income
Depreciation	Estimate of lost value on depreciating assets
Total Operating Expenses	+ FWE +/- Feed inventory adjustment + Owned run-off adjustment + Labour adjustment + Depreciation
Dairy Operating Profit (DOP)	Dairy GFR – Total Operating Expenses
Cash Operating Surplus	Sum of all cash income and expenses for the year before debt servicing and tax
Return on Asset	Dairy Operating profit minus rent as a percentage of the opening assets

Table 11 shows the dryland dairy model has a dairy operating profit or economic farm surplus of $3,220/ha. This is a significant return per ha for unirrigated land. The DOP is less than the Canterbury average of $3,805 for the 2011/2012 season which had an average milk price of $6.57/kg MS. The lower DOP is due to lower income from lower production.

The return on asset which can be expected from the business has been calculated by the EFS or dairy operating profit divided by the total assets (excluding capital gain). Shown in table 11 the ROA for the 2016/2017 season is 7.2%, this is higher than the Canterbury average for the 2011/12 season. The higher ROA is due to a lower asset value rather than a higher dairy operating profit. The asset value of the dryland dairy farm is less due to a lower land value.

Table 11. Summary of the annual budget

	Dryland dairy	**Ministry Primary Industries (2012)**
Gross farm revenue	$1,674,418	$2,145,968
Farm Working Expenses (FWE)	$835,786	$1,221,484
FWE/kgMS	$3.80	$4.14
FWE/NCI	50.7%	57%
Depreciation	$194,571	$40,431
Total Operating Expenses	$1,030,357	$1,346,916
Dairy Operating Profit (DOP)	$644,060	$799,052
DOP/ha	$3,220	$3,805
Cash Operating Surplus	$838,632	
Return on Asset (ROA)	7.2%	6.4%

6.3 Investment Appraisal

An investment appraisal has been performed to determine the financial viability of the dryland dairy system, and enable it to be compared to an alternative land use of intensive sheep breeding and finishing. The investment analysis was done assuming the current farm system was a sheep breeding and finishing system typical for the Canterbury area, and was developed into the proposed dryland dairy system. The sheep breeding and finishing model is explained in section 3.10. The internal rate of return (IRR) and net present values (NPV) were calculated for both of the farm systems and the marginal return of the investment. To allow comparisons to be made the dryland dairy farm was considered to be a running farm at year 1 of the investment, rather than including the development phase.

The financial assumptions for the investment proposal are listed in section 3.10. The complete investment appraisals are presented in appendix H.

6.3.1 Sheep Breeding and Finishing Model

Table 12 shows the results of the annual cash flow analysis for the sheep breeding and finishing model. The real pre finance and tax IRR is 2.7% and the real post finance and tax IRR is 2.1%. The real rate of capital gain is 1.7%, so the return above capital gain from the farm is minimal.

Table 12. 15 year IRR and NPV for the sheep breeding and finishing model

	Pre finance and tax		**Post finance and tax**	
nominal IRR	4.7%		4.2%	
real IRR	2.7%		2.1%	
Discount rate	nominal	real	nominal	real
2%	1,808,835	393,778	1,422,607	63,932
4%	417,525	-647,115	86,691	-931,827
6%	-611,949	-1,418,148	-898,253	-1,666,368
8%	-1,378,824	-1,993,235	-1,628,989	-2,211,667
10%	-1,953,884	-2,425,111	-2,174,447	-2,618,999

6.3.2 Dryland Dairy model

Table 13 shows the results of the annual cash flow analysis for the development of the dryland dairy system on the sheep farm. The real pre finance and tax IRR is 8.1% and real post finance and tax IRR is 9.3%. This is a significantly higher return than the sheep model. With a discount rate of 6% which is expected to be a reasonable return from agriculture land, the real post finance and tax NPV is $1,401,173.

Table 13. 15 year IRR and NPV for the dryland dairy model

	Pre finance and tax		**Post finance and tax**	
nominal IRR	10.2%		11.5%	
real IRR	8.1%		9.3%	
Discount rate	nominal	real	nominal	real
2%	10,334,394	6,685,630	6,243,876	4,165,149
4%	6,748,065	3,895,423	4,200,483	2,596,396
6%	3,991,654	1,739,896	2,650,131	1,401,173
8%	1,852,252	57,628	1,463,038	481,769
10%	175,406	-1,268,702	545,681	-232,321

6.3.3 Comparison (Marginal return)

Marginal return analysis shows the performance of the proposed dryland dairy system against the 'current' sheep model. A positive marginal IRR indicates an increased return from the investment. The real marginal return IRR for the development of a dryland dairy system is calculated to be 13.4% pre finance and -0.6% post finance and tax. At a discount rate of 6% the post finance and tax NPV is $-2,015,006 for the 15 year period.

Table 14. 15 year IRR and NPV Marginal Return

	Pre finance and tax	**Post finance and tax**
Real IRR	13.4%	-0.6%
Discount rate		
2%	6,291,852	-981,330
4%	4,542,538	-1,554,324
6%	3,158,043	-2,015,006
8%	2,050,863	-2,389,111
10%	1,156,408	-2,695,869

Chapter 7:
Environmental analysis

This chapter will address the research question '*Can dryland dairying meet proposed environmental restrictions in Canterbury'*. Section 7.1 contains the assumptions made on the farm system to run Overseer® and section 7.2 contains the output data produced.

7.1 Farm system assumptions for Overseer

Modelling the proposed dryland dairy system to determine the environmental impact required assumptions to be made around the farm model. Input data for the Overseer® process was sourced from the Farmax Dairy Pro® model and modelling done by Glass (2014) was also used for reference. The farm model is based on a 50ha block at Ashley Dene, thus climatic and soil data was based on this site and sourced from Glass (2014). The Overseer model inputs and assumptions are explained in this section.

Block data was based on the 50ha block at Ashley Dene up scaled by four to replicate a 200ha scenario. There are two dominant soil types in this block, shown in table 15 below. These soils are shallow free draining soils typical of the Canterbury region. The fodder beet block rotates through the ryegrass and lucerne blocks.

Table 15. Block data

Blocks	Soil type	Soil texture	Drainage class	Effective area (ha)
Ryegrass	Lowcliffe	Silt loam	Imperfectly drained	120
Lucerne	Lismore	Silt loam	Well drained	80
Fodder Beet				(20)

Details around the housing structure and effluent management are listed in table 16. Liquid effluent is applied over 100ha on the ryegrass block and solid effluent is applied on both the lucerne and ryegrass blocks.

Table 16. Housing details and effluent management

Housing details	
Pad type	Covered wintering pad or animal shelter
Bunker management	No lining material
Bunker cleaning method	Scraping (no water), solids are separated
Concrete feeding apron	Scraping (no water), solids are separated
Liquid effluent	Spray regularly, low application rates (<12mm)
Solids management	spread on selected blocks, open to rain, 4 months storage
Dairy effluent system	
Management system	Holding pond (solids separated)
Solids management	spread on selected blocks, open to rain, 4 months storage
Pond solids	Spread on selected blocks, emptied every 2 years
Liquid effluent	Spray regularly, low application rates (<12mm)

For the majority of lactation cows spend 14 hours per day grazing lucerne and ryegrass, the remainder of their diet consists of pasture and maize silage fed in the housing facility. Over the winter period due to high nitrate leaching risk, and low pasture growth, cows will only spend 6 hours per day grazing, with the majority of their diet imported supplement fed indoors. Non-lactating cows will be indoors 24 hours, being fed pasture silage and lifted fodder beet. The time lactating and dry cows spend grazing per day is shown in table 17 below.

Table 17. Feed reconciliation and time spent grazing (Kg DM/hd/day)

	Dries			**Milkers**			
	Fodder beet (indoors)	Silage (indoors)	time spent grazing (h)	Silage (indoors)	Fodder beet (indoors)	Pasture (grazed)	time spent grazing (h)
May	7	2	0		4	12	14
June	7	2	0	8	2	6	6
July				10		6	6
August				10		8	6
September				4		13	14
October				3		15	14
November				2		15	14
December				4		13	14
January				5		10	14
February				6		9	14
March	7	2	0		4	12	14
April	7	2	0		4	12	14

Fertiliser applications other than nitrogen will be addressed on the basis of plant and soil testing. The model has assumed annual fertiliser applications of 15% potash super at 300kg.ha^{-1} on the lucerne block, and 250kg.ha^{-1} of superphosphate on the ryegrass block will maintain soil fertility. Nitrogen is applied on the pasture block in four applications at a rate of 20kg.N.ha^{-1} in August, October, February and April. The lucerne block doesn't require nitrogen applications.

7.2 Overseer results

Overseer produces a range of useful figures around the movement of nutrients. The main concern for this project is the 'nitrogen loss to water' figure shown in table 18 below.

Table 18. Nitrogen loss to water ouput from Overseer®

Block	**N loss to water (kg/ha/yr)**
Ryegrass	7
Lucerne	7
Fodder Beet	26
Total	11

The total nitrogen loss to water of 11kg.N/ha/yr is below the Environment Canterbury discharge limit of <15kgN.ha^{-1} by 2035. A nutrient budget for the farm is shown in table 19 below. Nitrogen fixation was the main source of nitrogen with the lucerne block predicted to fix 395 kg N/ha/yr.

Table 19. Nutrient budget for model produced by Overseer®

	N	**P**	**K**	**S**	**Ca**	**Mg**	**Na**
	(kg/ha/yr)						
Nutrients added							
Fertiliser, Lime & Other	52	23	13	25	44	0	0
Rain/ Clover N fixation	191	0	2	5	2	5	29
Irrigation	0	0	0	0	0	0	0
Supplements imported	59	6	50	5	10	4	4
Nutrients removed							
As products	73	12	18	4	16	2	5
Exported effluent	0	0	0	0	0	0	0
As supplements	0	0	0	0	0	0	0
To atmospheric	93	0	0	0	0	0	0
To water	11	0.3	7	27	30	1	2
Change in internal pools							
Plant material	-12	-1	-15	0	-2	-1	-1
Organic Pool	123	9	2	3	1	0	0
Inorganic material	0	11	-25	0	-1	-1	-1
Inorganic soil pool	14	-1	79	0	12	9	28

Chapter 8:
Discussion

8.1 Introduction

This chapter will discuss the modelled dryland dairy system from a financial an environmental basis, with the key factors that influenced the results. Also included is analysis and discussion on the impact of drought on the dryland model. Sensitivity analysis has also been done to determine the effect of changes to key variable such as milk price and production will have on the overall profitability of the model.

8.2 Environmental Results

Environmental analysis was done using Overseer® version 6.2.0 with the loss of nitrogen to water being the main environmental concern. Analysis with Overseer® showed the farm model was able to operate under the proposed N leaching restriction of <15kg.N/ha. The proposed model had a nitrogen loss to water figure of 11kg N/ha. This is similar to the value produced by Glass (2014) of 12kg.N/ha who modelled a similar dryland system for Ashley Dene. The nitrogen leaching from this model was lower than partial housing systems reviewed in the literature. It was also significantly lower than the irrigated Lincoln University dairy farm (LUDF) of 39kgN/ha/yr, which is on similar soils and uses best practice environmental mitigation systems and technology (Benton, 2014).

Nitrogen leaching from the lucerne block was predicted by Overseer® to be the same as the ryegrass block of 7kgN/ha. This goes against the literature, which suggested the deep taproot and absence of artificial nitrogen fertiliser would make the nitrogen losses from lucerne pasture less than that from the ryegrass pasture. The high nitrogen fixation from the lucerne pasture could be responsible for the similarity between the ryegrass and lucerne pastures.

8.2.1 Factors that Influenced Environmental Results

Dryland

The dryland system used had significant nitrogen leaching advantages. The low pasture and crop productivity due to the lack of irrigation meant low stocking rate and low fertiliser inputs. The stocking rate of 2.25cows/ha is significantly lower than typical Canterbury dairy farms. Urine deposits are the main source of nitrogen leaching from dairy farms, and so minimising cow numbers is likely to reduce the amount of urine deposits and so nitrogen leached. The perennial ryegrass pasture received 80kgN/ha/yr from artificial fertiliser inputs, this is much lower than typical irrigated dairy farms in Canterbury as the low response from moisture stressed pastures reduces the feasibility of fertiliser inputs. Reducing fertiliser inputs reduces the amount of nitrogen available to be leached in the soil. Nitrogen fixation from white clover in the ryegrass pastures was predicted by Overseer® to be 128kgN/ha/yr. This is a significant source of N, and was based on default clover levels provided by Overseer®. The limited productivity of the ryegrass pasture was likely to promote high clover yields and so high nitrogen fixation rates.

Housing facility

The housing facility is likely to have a significant influence on meeting the nitrogen leaching limit. The main environmental benefit of the housing facility is the ability to remove cows from pasture during high risk periods and capture effluent so it can be applied to pastures when soil conditions suit. Applying the effluent uniformly and at a concentration which plants can utilise means minimal nitrogen passes through the soil profile. As suggested in the literature review a restricted grazing system has the ability to reduce nitrogen leaching by approximately 40% on a traditional pasture based system. This study did not separate the effect of the partial housing system from other environmental mitigation strategies used, so the individual effect is un-quantified.

Supplement feed

The importation of supplements had a significant impact on the total nutrients added to the farm system. A total of 670t.DM of supplement feed was imported annually, which added 59kgN/ha to the farm system. This was greater than the average N fertiliser inputs of 52kgN/ha/yr. The increase in supplementary N would increase the amount of N excreted on farm as effluent.

Fodder beet crop

Fodder beet was used effectively as a feed supply for the non-lactating period. The ability to lift fodder beet meant it was suitable for the non-lactating period, as 100% of the diet could be fed indoors. Having cows indoors over the non-lactating period was likely to have significant influence in reducing the overall nitrogen leaching from the farm. The N loss to water from the fodder beet block was 26kgN/ha/yr which was significantly higher than the pastures, although low for a forage block. The nitrogen loss to water is likely to be largely from the mineralisation of soil organic matter. Overseer® predicted the soil organic pool to decrease by 258kgN/ha from the fodder beet crop, while artificial N inputs was only responsible for 105kgN/ha.

Overseer model

The use of the Overseer® programme to determine nitrogen leaching is relatively new, and the model is being constantly developed to improve the accuracy of its predictions. Future adjustments to the model are likely to change the predicted N losses from this model. Overseer was unable to model the use of diverse pastures, instead a standard perennial ryegrass and white clover pasture had to be assumed. The literature suggested diverse pastures could have a significant impact in reducing nitrogen leaching restrictions. Future development of the Overseer® programme is likely to increase its ability to model alternative forages, and reduce modelling uncertainty.

8.2.2 Other Environmental Considerations

Low N leaching from support block

Commonly dairy systems in the Canterbury region winter the herd off farm. Whereas the modelled farm system has the herd on farm all year round, with no support block requirement over the non-lactating period. Wintering systems in Canterbury are responsible for high nitrogen losses due to their nature of high soil water drainage and high yielding crops allowing a large number of cows in a small area. Although the removal of the wintering requirement isn't relevant to the Overseer® analysis undertaken in this report, it does result in a large reduction in the indirect environmental effect of the dairy enterprise.

Nitrogen loss to atmosphere

Although nitrogen loss to water was the main environmental concern for this study, nitrogen loss to the atmosphere is also an important environmental impact from dairy systems. Nitrous oxide (N_2O) losses from agriculture are known to be a significant contributor to greenhouse gas emissions, and global warming. N_2O emissions were predicted to be 6.3kgN/ha/yr by Overseer®.

Phosphorus loss to water

Phosphorus contamination of fresh water is also an important environmental impact from agriculture systems. Phosphorus rather than nitrogen often limits algal growth, and so phosphorus contamination can have a significant impact on fresh water quality. The major source of phosphorus contamination is surface run-off of, fertiliser, eroded soil, sewage and animal wastes. The modelled system had a total phosphorus loss to water figure of 0.3 kg P/ha/yr.

8.3 Financial findings

The modelled dairy system farms under the N leaching restriction of 15kgN/ha without the use of irrigation and is expected to provide a return on asset of 7.2%. The development of the dryland system requires significant capital investment with the development of a fully enclosed housing structure. The housing structure provides the ability to remove cows from pastures, which has significant environmental benefits, but also provides financial incentives with cows able to be wintered on-farm, and calve in the autumn. Although the housing facility requires significant financial investment ($3,678/cow) the low land price of un-irrigated land in Canterbury means the total assets of the dryland dairy model is significantly lower than the typical irrigated dairy property in Canterbury. The relatively low asset value of the dairy farm means the business is able to provide a substantial return on asset with a relatively low intensity system.

The proposed farm system has a low stocking rate (2.25cows/ha), but high production per cow of 489kg MS. The low stocking rate allows environmental constraints to be met but as well reduces variable expenses (animal health, breeding and replacement rearing) and to some extent the fixed costs. The number of cows influences the fixed costs as the cost of the cowshed and housing facility is proportional to the number of cows it is built to handle.

The annual revenue for the farm is competitive against other dairy systems, with a $6.00/kgMS price resulting in a total revenue of $8,372/ha. The premium received by contract winter milk supply is significant and increases the average total milk price by $1.05/kgMS. This somewhat offsets the relatively low /ha production of the farm model of 1,101 kgMS/ha. The per ha production of 1,101/kgMS is lower than the Canterbury average of 1405 kg MS/ha (Ministry of Primary Industries, 2012).

Total farm working expenses for the proposed system are lower than the average Canterbury dairy farm. The modelled dryland dairy system requires a large amount of feed to be imported. With this comes a cost of sourcing the feed as well as increased machinery, labour and deprecation expenses. The proposed system could be considered system 5 of the 1-5 DairyNZ production systems, with imported feed used all year, throughout lactation and for dry cows. The high dependency on imported supplements is a large cost to the farm model and it would be expected to make the model a high cost system. However the farm model has cost advantages over the typical Canterbury dairy farm with no irrigation expenses, or winter cow grazing expenses and reduced fertiliser expenses. Wintering costs are a significant expense to the farm system, wintering costs the Lincoln University Dairy Farm $22/week for an average of 9.8weeks (Benton, 2014) which is equivalent to $97,020 for 450 cows. This is a significant cost reduction, however is somewhat transferred into greater imported feed costs. The fodder beet used to feed cows over winter also means 20ha of dairy platform is ineffective for the majority of the year. No irrigation expenses will have increasing benefit to the dryland dairy model as water costs are becomingly increasingly expensive in the Canterbury region. Overdrawn ground water has meant irrigation water is increasingly being sourced from ‘scheme’ water. These ‘schemes’ store surplus water during winter and spring from rivers and use it to irrigate over the drier months. The nature of this water means it is significantly more expensive to source. Applying water also requires significant expenditure on infrastructure, and so this is also a significant cost saving to the dryland dairy system. The dryland dairy system has reduced fertiliser expenses from the use of a housing facility, lucerne pastures and low productivity ryegrass pastures. The housing facility reduces the requirement of imported fertiliser as it reduces the loss of nutrients from the farm system through run-off and leaching. The housing facility also moves the farm system towards greater imported supplements which brings a significant amount of nutrients into the farm system. Lucerne pastures do not require any nitrogen applications, due to their nitrogen fixation capability; this has a significant impact on reducing the overall fertiliser expense. As well the ryegrass pastures receive annual nitrogen applications of 80kgN/ha, which is significantly lower than most dairy farms.

The dairy operating profit or economic farm surplus for the dryland dairy model is predicted to be $3,220. This is calculated with a $6/kgMS base milk price and a contract winter milk premium of $3/kgMS. Farm working expenses are equivalent to $3.80/kgMS and depreciation $0.88/kgMS. The average Canterbury farm had a dairy operating profit of $3,805/ha for the 2011/12 season, when the average milk price paid that season was $6.57/kgMS (Ministry of Primary Industries, 2012). This shows the farm model is competitive against the average Canterbury dairy farm which contains a mixture of spray and border dyke irrigation.

Investment analysis performed found that the real post finance and tax IRR for the sheep breeding and finishing model is 2.1% and for the dryland dairy model 9.3%. This suggesting the dryland dairy model is capable of providing significantly higher returns compared to the average sheep breeding and finishing property. The dryland dairy model is based on a high debt: asset ratio of 0.57, compared to the sheep model of only 0.08. The high level of leveraging allows the dryland dairy model to provide and increased return, however increases the businesses exposure to risk.

The marginal IRR for the investment was -0.6% post finance and tax. The negative marginal IRR shows that the dryland dairy model is unable to pay off the investment over the 15 year period. The capital investment for the proposal is largely made up of the cowshed and housing facility. These assets are likely to be functional well pass the 15 year investment proposal. Analysing the proposal for a longer period such as 20 years is likely to result in a positive marginal return. The dryland dairy model provides a significantly higher return than the sheep breeding and finishing farm, however the large capital requirement means the investment to develop a dryland dairy property isn’t profitable over a 15 year project life.

Table 20. Summary of investment appraisal

	Sheep	**Dryland dairy**	**marginal analysis**
Real pre finance and tax IRR	2.7%	8.1%	13.4%
Real post finance and tax IRR	2.1%	9.3%	-0.6%

8.4 The effect of drought

A major implication of dryland farming is the dependence on rainfall for DM production. Annual rainfall can vary significantly between seasons and thus annual DM production is unreliable. The severity and frequency of droughts will determine whether the system will remain viable long-term. Sensitivity analysis is used to determine the financial effect on the farm business of 'drought' situations. As discussed in chapter 2.2 the effect of drought is difficult to model due to the unpredictable and variable nature. It is suggested that drought can reduce annual pasture production by 40% (Rickard & Fitzgerald, 1969) to 60% (Radcliffe & Baars, 1987) on Lismore soils in Canterbury.

Analysis of the effect droughts will have on the farm system has been modelled by modelling two drought scenarios, a minor and a major drought. A minor drought scenario has been based on a decrease in ryegrass pasture production by 25% in the September to May period. This is likely to simulate a drought which can be expected once in every four years (Rickard & Fitzgerald, 1969). The same reduction in DM production has been assumed for the fodder beet crop. The effect of the drought on the lucerne pasture production is expected to be less due to the increased drought tolerance of lucerne, and so a reduction in DM production of 15% has been assumed for the lucerne pasture. A major drought scenario has been modelled as a drought that reduces annual ryegrass DM production by 50%, during the September to May period. This drought scenario is likely to replicate a 1 in 40 year drought (Rickard & Fitzgerald, 1969). Fodder beet DM production is also expected to be reduced by 50% and lucerne production by 40%. Both of the scenarios have been modelled using Farmax Dairy Pro® so that the effect of reduced cow numbers and early dry-off have can be realised, and the additional requirement for purchased supplements can be determined. The reduction in pasture growth with the different drought scenarios is illustrated in figure 5.

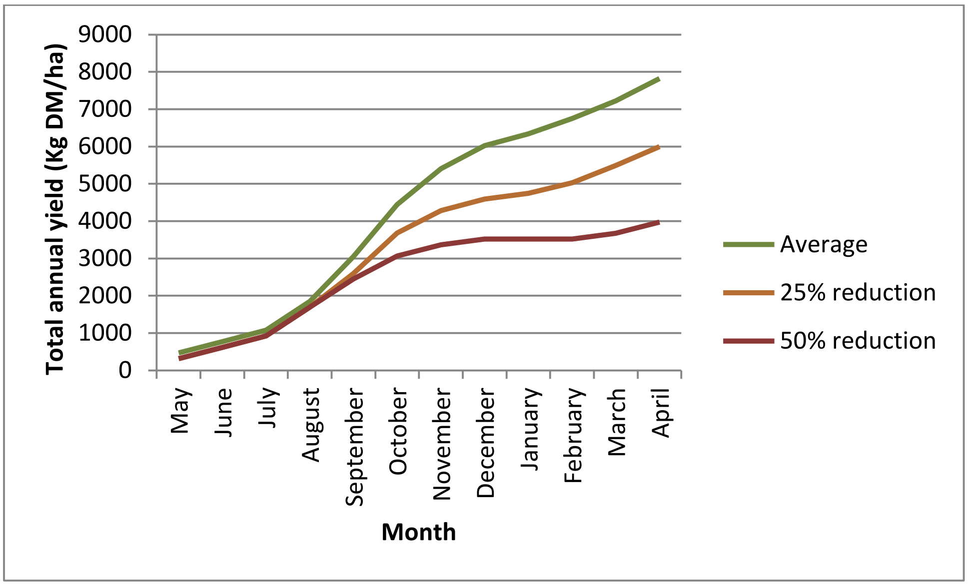


Figure 5. Ryegrass production in different drought scenarios

The feed supply from the base model was adjusted to the new drought scenarios and adjustments were made to the once a day (OAD) date, dry-off date, culling date and imported supplements until 'feasible' pasture covers were met. In the minor drought scenario half of the herd was placed on once-a-day on the 1st January and the remaining half on the 15th January. Half were then dried off on the 31st January and remainder 15th February. All the cull cows were sent to processing between December and January. In the major drought model half of the herd was placed on once-a-day milking on the 15th December, and the other half on 31st December. One half was then dried off on 7th January and the remainder 15th January. All the cull cows were sent to processing in December. Supplement prices were increased in the drought scenarios to reflect the actual market situation during periods of drought. Price assumptions are shown in table 21 below.

Table 21. Supplement prices

	Base model	**Minor drought scenario**	**Major drought scenario**
Maize silage ($/t delivered)	360	380	420
Pasture silage ($/t delivered)	340	360	400

Table 22 shows both physical and financial key performance indicators for the two drought scenarios and the base model.

Table 22. Key performance and financial results of different drought scenarios

	Base model	**Minor drought scenario**	**Major drought scenario**
Cow numbers 1st May	450	450	450
Imported supplements (kgDM/cow)	1,489	1,740	2,103
Ryegrass & lucerne pasture supply (KgDM/cow)	3,551	2,846	1,964
Fodder Beet supply (KgDM/cow)	533	400	267
Supplement imported / total feed suuply	27%	35%	49%
Kg milksolids/cow at peak	2.16	2.19	2.10
Kg milksolids/ cow	489	418	372
Days in milk per cow	282	250	225
Total kg Milksolids	220,215	186,399	165,689
Total Revenue	$1,674,418	$1,489,072	$1,329,267
Imported supplements	$230,493	$280,888	$380,926
Farm Working Expenses	$835,786	$886,161	$986,199
Dairy operating profit or EFS	$644,060	$408,340	$148,497
Return on Asset	7.2%	4.5%	1.7%

The modelled drought scenarios use imported supplements to maintain capital stock so there is no flow on effect from the drought into the following season. This is reflected in the increase in imported supplements from 1,489kgDM/cow to 1,740kgDM/cow in the minor drought scenario and 2,103kgDM/cow in the major drought scenario.

Even with high levels of imported supplements, the low pasture and crop yields mean milk production cannot be sustained at base model levels. The length of lactation is a key driver of annual milk production and in order to reduce feed demand, the length of lactation has been reduced. The reduction in lactation length is reflected in the milk production. With the lactation length decreasing by 20% and the total milk production decreasing by 25% in the major drought scenario.

The May calving date is advantageous to the farm system in drought years as it allows cows to be dried-off early in summer, while maintaining a reasonable lactation length. Drying cows off early is an important drought strategy as it reduces feed demand to maintenance requirements so pasture and supplements can be conserved.

As shown in table 22 the dairy operating profit is reduced significantly in each of the drought scenarios. The dairy operating profit remains positive in the major drought scenario, which could be expected once in every 40 years. The positive dairy operating profit and low return on asset suggest the business is resilient to these drought scenarios if it has minimal debt servicing requirements. If global warming predictions come to fruition, these drought scenarios will become more frequent reducing the viability of the business. Further advances in dryland management strategies are likely to be required for not only this model but also other dryland farm systems with the development of global warming.

8.5 Sensitivity analysis

The analysis in this study predicts that the dryland dairy model will be a viable land use option for non-irrigated properties in the Canterbury region with a ROA of 7.2% and within nitrogen leaching restrictions of <15kgN/ha for the Selwyn- Waihora catchment. A range of assumptions have been made to predict the financial outcome of the model. A number of scenarios have been analysed where these key assumptions have been altered to determine their influence on the financial viability of the model. Changes include a varied: milk price, milk production, supplement cost and farm working expenses. An all gone wrong scenario has also been performed. Analysis will be performed on the dairy operating profit (DOP), the internal rate of return (IRR) and marginal IRR between the dryland dairy model and sheep breeding and finishing model.

8.5.1 Milk price

In recent years, the farm gate milk price paid by Fonterra and other dairy processors in New Zealand has varied significantly between seasons. This variation is shown in table 23 below.

Table 23. Farm gate milk price paid by Fonterra for past 5 seasons

	Milk price ($/kgMS)
2014/2015	$4.40
2013/2014	$8.40
2012/2013	$5.80
2011/2012	$6.05
2010/2011	$7.60

The large variation from year to year makes budgeting difficult, with milk price having a large influence on the profitability of a business. A sensitivity analysis has been performed to determine the effect on the business of a varied long term milk price. The financial results with different milk prices is shown in table 24. The total revenue, dairy operating profit, pre finance and tax IRR, post finance and tax IRR and pre finance and tax marginal return IRR are shown. Even at a long term milk price of $4.50/kgMS and a contract winter milk premium of $1.50/kgMS, the real post finance and tax IRR is positive at 2.2%. The marginal return post finance and tax IRR is 4.4% at a $7/kgMS base milk price, and $3/kgMS winter milk premium.

Table 24. Financial results with varied milk price ($/kgMS)

Base price	Premium	Total revenue	DOP	Pre IRR	Post IRR	Marginal IRR
7.00	3.00	1,772,148	741,791	10.5%	12.9%	4.4%
6.00	**3.00**	**1,674,417**	**644,060**	**8.1%**	**9.3%**	**-0.6%**
6.00	2.00	1,475,048	444,691	7.2%	8.1%	-2.6%
5.50	3.00	1,441,830	411,473	6.8%	7.5%	-3.6%
5.00	3.00	1,331,724	301,367	5.6%	5.8%	-7.0%
5.00	2.00	1,254,836	224,479	4.7%	4.6%	-9.8%
4.50	1.50	1,106,286	75,929	3.1%	2.2%	-17.1%

8.5.2 Supplementary feed costs

With a large proportion of the total feed supply being imported supplements, the price of imported supplements can have a significant effect to the profitability of the farm model. Table 25 shows the effect of changes in the supplementary feed price. The IRR's calculated are real and the marginal IRR is post finance and tax. The upper most change analysed to the feed price of $+0.20/kgDM reduced the post finance and tax IRR for the model by 2.2% to 7.1%. This change in feed price represents a pasture silage price of $540/t.DM and maize silage price of $560/t.DM. This analysis shows the farm model will remain profitable even if supplementary feed prices increase significantly above the modelled price.

Table 25. Effect of changing supplementary feed price

Feed price ($/kgDM)	DOP	Pre IRR	Post IRR	Marginal IRR
-0.10	711,060	8.9%	10.4%	1.1%
-0.05	677,560	8.5%	9.8%	0.2%
0	644,060	8.1%	9.3%	-0.6%
+0.05	610,560	7.7%	8.7%	-1.5%
+0.10	577,060	7.3%	8.2%	-2.4%
+0.20	510,060	6.5%	7.1%	-4.4%

8.5.3 Milk Production

With the proposed model the milk production has been calculated by the Farmax Dairy Pro® modelling process. This process uses a range of assumptions to estimate the milk production from the farm. The actual production from the farm model could be different to that calculated by Farmax® and so sensitivity analysis has been performed to consider the effect on different financial measures. Table 26 shows the financial results of the milk production increasing and decreasing by 5%-20%. The IRR's calculated are real and the marginal IRR is post finance and tax. A decrease in milk production to 391kgMS/cow has a post finance and tax IRR of 4.4%, suggesting even at this level of milk production the dryland dairy model would provide a greater return than the sheep breeding and finishing model.

Table 26. Effect of changing milk production on financial results

	Total milk yield (kgMS)	kgMS/cow	DOP	Pre IRR	Post IRR	Marginal IRR
-20%	176,170	391	333,673	4.6%	4.4%	-10.3%
-15%	187,180	416	411,270	5.5%	5.6%	-7.4%
-10%	198,191	440	488,867	6.3%	6.8%	-4.9%
-5%	209,201	465	566,464	7.2%	8.0%	-2.7%
0%	220,212	489	644,061	8.1%	9.3%	-0.6%
5%	231,223	514	721,657	8.9%	10.5%	1.2%
10%	242,233	538	799,254	9.8%	11.8%	3.0%
15%	253,244	563	876,851	10.7%	13.1%	4.7%
20%	264,254	587	954,448	11.5%	14.4%	6.2%

8.5.4 Total farm working expenses

The total farm working expenses have been estimated from values produced by Benton (2014) and calculated on key inputs. Table 27 shows what effect increased and decreased farm working expenses would have on the model. Farm working expenses are the main expenses to the business and so variation has a large effect on the return from the investment.

Table 27. Effect of changing total farm working expenses on financial results

	FWE	DOP	Pre IRR	Post IRR	Marginal IRR
-10%	752,207	727,640	9.0%	10.7%	1.5%
0	835,786	644,061	8.1%	9.3%	-0.6%
+10%	919,365	560,482	7.1%	7.9%	-2.9%
+20%	1,002,943	476,904	6.1%	6.5%	-5.5%
+30%	1,086,522	393,325	5.2%	5.2%	-8.5%
+50%	1,253,679	226,168	3.2%	2.5%	-16.7%

8.4.5 All gone wrong scenario

A scenario considered as ‘all gone wrong’ has been produced where factors most influential to the proposed system have been adjusted to the worst case scenario. The key factors changed are the milk price, milk production, farm working expenses and the interest rate. The DOP, pre finance and tax IRR, post finance and tax IRR and marginal return pre finance and tax IRR for the investment are calculated. Shown in table 28 the all gone wrong scenario has a negative dairy operating profit of $-289,408. The real post finance and tax IRR for the 15 year investment is -8.9% and the real marginal pre finance and tax IRR is -9.2%. This analysis shows the proposed model will not be feasible financially if the described all gone wrong assumptions became true.

Table 28. All gone wrong scenario analysis

	Base	All gone wrong
Milk price (base)	$ 6.00	$ 4.50
Milk price (premium)	$ 3.00	$ 1.50
Milk production	220,215	176,172
Farm working expenses	$ 835,786	$ 1,002,943
Interest rate	6.0%	8.0%
DOP	$ 644,060	$ -289,408
Pre finance and tax IRR	8.1%	-2.6%
Post finance and tax IRR	9.3%	-8.9%
Marginal Pre finance and tax IRR	13.4%	-9.2%

8.5 Other opportunities/ challenges

Late calving/ Empty cows

The autumn calving system allows for the option of utilising late calving or empty cows from traditional winter/ spring calving systems. Empty cows present a large cost to typical pasture based farm systems in New Zealand. With 10-15% of cows culled annually from a typical herd due to their inability to get in calf within a suitable timeframe. In an autumn calving system, these cows are able to be milked through, to get in-calf for an autumn calving. In the situation at Ashley Dene these late calving/ empty cows could be purchased as an alternative to rearing replacements or could be purchased to be milked through the winter and sold as in calf cows the following autumn. There is also an opportunity for large corporate farming businesses which are becoming common in New Zealand to use this farm model, and utilise empty/ late calving cows from within their own business.

Intensify

The proposed system has peak cow numbers of 450 (1st May). The housing structure design has a potential capacity of 500 cows, which allows room for future expansion. Profitability could be increased by an increase in cow numbers if there is a change in the model assumptions such as a reduction in supplement costs, increase in milk price or increased productivity of lucerne, ryegrass or fodder beet forages. Intensifying the farm system is however likely to increase the environmental impact and hence any intensification will need to be approached with caution.

Cut and Carry

The proposed system uses cows to graze lucerne and ryegrass pastures in order to minimise production costs. Future developments in nitrogen leaching lose restrictions or changes to the Overseer® programme could mean the farm system would have to reduce nitrogen leaching loses further. A fully indoor system, with pastures harvested and fed indoors would allow nitrogen losses to be reduced further. Lucerne pastures especially could benefit from a cut and carry system due to their particular management requirements. Using a cut and carry system the ryegrass pasture could be replaced with lucerne to optimise annual dry matter production.

Split calving herd

With the housing facility, there is the opportunity to milk all year round. This could be done through a split herd calving, with one herd calving in the autumn and the other in the spring. Advantages of a split herd calving could be more consistent feed demand, with less seasonal variation. The current system has a large demand over the winter period when pasture growth is minimal, split calving would reduce the demand over this period. The disadvantage of a spring calving herd however remains as summer drought would decrease the lactation length considerably if the spring calving herd had to be dried-off and there would be a loss of winter milk premiums.

N leaching credits

The analysed model has a predicted nitrogen loss to water value of 11kgN/ha. This is up to 4kgN/ha below the required <15kgN/ha required in the Selwyn-Waihora district by 2035. From this the dryland dairy system could be used in combination with a more intensive higher N leaching agriculture system as a way of meeting the overall nitrogen leaching target.

Back to back droughts

The effect of drought has been considered on an annual basis. Droughts however can occur two years in a row and have even more severe consequences. With global warming the chance of having back to back droughts will increase. With back to back droughts, pasture cover and animal condition will not be fully recovered prior to the following season and so the following drought will have even greater consequences. Pasture persistence is also likely to be negatively affected and so pasture production will be harmed further. The financial effect of back to back droughts has not been modelled, but is likely to result in increased feed expenses to cover the feed deficit, reduced production and increased regrassing costs.

Winter milk premium

If the dryland dairy model proves popular, the contract winter milk premium is likely to be eroded. The winter milk premium is a key driver to the models profitability, and so will result in reduced profitability of the model.

Chapter 9:
Conclusion

This chapter will provide answers to the research questions; discuss the risks and benefits involved with adapting the farm model, look at the limitations of the research and areas for future research.

From the literature the need to develop farm systems that meet impending nitrogen leaching restrictions was identified. It was considered that the large costs involved with sourcing and applying irrigation water meant the profitability of typical irrigated farm systems may become questionable when productivity is constrained by environmental regulation. This study addressed this issue by considering a dryland dairy system that meets future nitrogen leaching restrictions.

9.1 Research Questions

- **Can dryland dairying meet proposed environmental restrictions in Canterbury?**

The proposed dryland dairy system had a nitrogen loss to water figure of 11 kg.N/ha when modelled with Overseer® 6.2.0. This is below the Variation 1 of the proposed Canterbury Land and Water Regional Plan for the Selwyn-Waihora catchment area of <15kgN.ha^{-1} by 2035 (Variation 1, 2014). Therefore with current Overseer® modelling the dryland dairy system is able to meet the proposed environmental restrictions for the Selwyn-Waihora catchment.

- **Is dryland dairying in Canterbury able to achieve realistic returns on asset?**

It was concluded in this study that the dryland dairy model will provided a return on asset of 7.2%. This is considered a good return on asset from an agricultural investment. Key assumptions included a base milk price of $6/kgMS, a contract winter milk premium of $3/kgMS, and a total farm working expense of $3.80/kgMS. The ROA from the average irrigated Canterbury dairy farm was 6.4% in the 2011/12 season when the average base milk price was $6.57. Therefore the dryland dairy model is able to provide a competitive return on asset.

- **Is dryland dairying a viable land use in Canterbury?**

The environmental and financial results concludes that a dryland dairy system is a viable means of meeting nitrogen leaching restrictions on a non-irrigated property in Canterbury. The return on asset from the dryland dairy farm is suggested to be higher than the average irrigated Canterbury dairy farm, due to the lower land value the dryland dairy model operates on. With this the dryland dairy model would be suited to land where sourcing irrigation isn't possible. The dryland dairy model had been compared to traditional farm systems that do not meet proposed nitrogen leaching restrictions. Meeting the proposed nitrogen restrictions is likely to significantly reduce the profitability of these traditional farm systems and give the dryland dairy model a further advantage.

A 15 year investment analysis of a Canterbury sheep and beef property converting to the proposed dryland dairy model showed the investment provided a greater post finance and tax IRR than the sheep breeding and finishing; increasing from 2.1% to 9.3% when the property was converted to a dryland dairy system. This investment analysis suggesting much greater returns could be achieved form the land if converted to the dryland dairy model. However converting to the dryland dairy model requires a large amount of leveraging, with the debt to asset ratio increased from 0.08 to 0.57. With the increased debt level comes greater exposure to risk. The main sources of risk to the proposed system include drought, variance in market prices, increase in interest rates and not meeting production targets.

The post finance and tax marginal return of the investment was -0.6%. This negative marginal return is due to the high capital investment required to develop the model, and a marginal return which isn't sufficient to pay the investment off in the 15year period. The working life of the proposed model is likely to be longer than 15years and a longer investment period is likely to result in a positive marginal IRR.

Table 29. Investment analysis key outcomes

	Sheep	**Dryland dairy**	**marginal analysis**
Real pre finance and tax IRR	2.7%	8.1%	13.4%
Real post finance and tax IRR	2.1%	9.3%	-0.6%

9.2 Limitations to Research

9.2.1 Research Approach

The research has been based on a quantitative research method of theoretical modelling, opposed to case study type research, or field trials. This involved making a range of assumptions for input figures. Assumptions were based on reliable sources of literature and industry experts to ensure their validity. In some situations, such as the use of lucerne in dairying, previous literature was limited and so assumptions were likely to carry a larger margin of error. The computer software Farmax Dairy Pro® and Overseer® used for the modelling process are another source of error related to this modelling. This is discussed below.

9.2.2 Overseer®

The use of Overseer® to model nitrogen losses is relatively recent and is subject to continued development to improve its accuracy. It is suggested sources of modelling uncertainty include; context and framing, inputs, model structure, parameters and model implementation. Ledgard & Waller (2001) has been the only published report that has measured the models accuracy in predicting nitrogen loss to water, and suggested the model to have a margin of error of +/- 30%. Latest versions of Overseer® are likely to have reduced modelling uncertainty. The N loss to water prediction for the farm model will also be suspect to continual change as the Overseer® model is developed in the future.

Another limitation related to using Overseer® was the limited ability of the program to model alternative forages. Recent research on diverse pastures suggest they are capable to make significant reductions to nitrogen leaching compared to standard perennial ryegrass/ white clover pasture mixes. The Overseer® model does not include a ‘diverse pastures’ option and so the pastures were inputted as standard perennial ryegrass/ white clover pastures.

9.2.3 Farmax Dairy Pro®

The farm modelling software Farmax Dairy Pro® is likely to have a greater modelling accuracy than Overseer® with Bryant et al. (2010) suggesting the mean prediction error for predicting pasture covers was 7%. Farmax uses a network of calculations to determine outputs, with each equation being based on assumptions and so are a potential source of error. A linear programme model was built, and Farmax® concluded with similar key figures suggesting greater validity of the model. The modelling tools Overseer® and Farmax Dairy Pro® were used rather than direct field measurements due to budget and time constraints.

Like Overseer® Farmax Dairy Pro® had limited ability to model lucerne pastures. Lucerne pastures were inputted to the model as a typical ryegrass pasture, and growth rates adjusted to satisfy lucerne's unique grazing management requirements. This is likely to have reduced the accuracy of the modelling process.

A further limitation of the use of Farmax Dairy Pro® was the models inability to consider a partial housing system. Feed demand is likely to be less in a partial housing system compared to the typical outdoor grazing system as amongst other things cows spend less energy regulating body temperature. The feed demand calculations are unable to be adjusted in Farmax Dairy Pro® and so was likely to be too high in the modelling process.

9.3 Future Research Opportunities

As stated in section 9.2.1 a major limitation to this study is that it is based on theoretical modelling. Therefore this is an opportunity for future research using farmlet trials to reinforce the results from this study with actual farm data. Farmlet trials would give greater validity to the farm model and so would be suggested prior to the development of a dryland dairy system at Lincoln University's Ashley Dene property.

Reviewing the literature it has become apparent that there is limited research around the use of lucerne as a pasture on dairy farms. Lucerne lost support in the 1980's due to inappropriate management practices and various disease problems. However, the development of new cultivars and better management practices has led to the revitalisation of lucerne use, with numerous success stories in the sheep industry. Research using long term dairy trials on lucerne pastures would allow the productivity and persistence of a dairy grazed lucerne pasture to be realised. Limited research is also available on nitrogen leaching under grazed lucerne pasture.

With lucerne’s deep tap root and nitrogen fixation capability it is likely significant environmental benefits could be realised from the use of lucerne pasture.

With the use of a partial housing/ restricted grazing system arises the opportunity to minimise urine deposition on pasture and maximise urine deposition on the concrete structure. Thus allowing the urine to be applied to pasture with even application and at a rate the pasture can utilise. This provides the opportunity for research into technology or management systems that maximise urine deposition while cows are on the concrete structure, minimising deposition while these cows are grazing pasture.

References

Ashley Dene Business Case (2014) *Lincoln University Capital Expenditure Proposal, Evaluation and Business Case Form*

Askin, D., & Askin, V. (2014). *Financial budget manual*. Canterbury: Lincoln University.

Baskaran, R., Cullen, R., & Colombo, S. (2009). Estimating values of environmental impacts of dairy farming in New Zealand. *New Zealand Journal of Agricultural Research, 52*(4), 377-389.

Benton (2014) A theoretical study of the economic and environmental impacts of incorporating housing structures into a Canterbury dairy farm (Dissertation) Retrieved from. Lincoln University research archive.

Brown (2014) An investigation of the incorporation of a standoff facility with the grazing of fodder beet in a Canterbury dairy wintering system (Dissertation) Retrieved from. Lincoln University research archive.

Brown, H. E., Moot, D. J., Lucas, R. J. and Smith, M. C. (2006) Sub clover, cocksfoot and lucerne combine to improve dryland stock production. *Proceedings of the New Zealand Grassland Association*, 68, 109-115.

Brown, H. E., Moot, D. J. and Pollock, K. M. (2005) Herbage production, persistence, nutritive characteristics and water use of perennial forages grown over 6 years on a Wakanui silt loam. *New Zealand Journal of Agricultural Research*, 48, 423-439.

Brown, H. E., Moot, D. J. and Pollock, K. M. (2003) Long term growth rates and water extraction patterns of dryland chicory, lucerne and red clover. *In*: D. J. Moot, (ed). Legumes for Dryland Pastures: New Zealand Grassland Association. Grassland Research and Practice Series No. 11, 91-100

Bryant A.M. (1978) Milk yield and composition from cows grazing lucerne*. Proceedings of the New Zealand Society of Animal Production* 38:185–190.

Bryant, J., Ogle, G., Marshall, P., Glassey, C., Lancaster, J., García, S., & Holmes, C. (2010). Description and evaluation of the Farmax Dairy Pro decision support model. New Zealand Journal of Agricultural Research, 53(1), 13-28.

Cabrita, A.R.J.; Dewhurst, R.J.; Abreu, J.M.F.; Fonseca, A.J.M. (2006) Evaluation of the effects of synchronising the availability of N and energy on rumen function and production responses of dairy cows - a review. *Animal Research* 55: 1-24.

Campion, R. (2011). Utilising Lucerne's Potential for Dairy Farming. Proceedings of the 18th International Farm Management Association Congress.

Castillo, A. R., Kebreab, E., Beever, D. E. and France, J. (2000). A review of efficiency of nitrogen utilisation in lactating dairy cows and its relationship with environmental pollution. Journal of Animal and Feed Sciences, 9: 1-32.

Christensen, C., Hanly, J., Hedley, M., & Horne, D. (2010). *Reducing nitrate leaching losses by using duration-controlled grazing of dairy cows.* Paper presented at the 19th World Congress of Soil Science, Soil Solutions for a Changing World, Sydney, Australia.

Dairy Statistics (2014) Retrieved May 5, 2015, from http:/www.dairynz.co.nz/media/1327583/nz-dairy-statistics-2013-2014-web.pdf

Daughney, C., & Randall, M. (2009). National Groundwater Quality Indicators Update: States and Trends 1995-2008. Retrieved May 12, 2015.

De Klein, C. A. M., Paton, J., & Ledgard, S. (2000). An evaluation of a strategic de-stocking regime for dairying to improve nitrogen efficiency and reduce nitrate leaching from dairy farms in nitrate sensitive areas. *Proceedings of the New Zealand Grassland Association*, 62, 105-110.

De Klein, C.A.M. de, Monaghan, R.M., Ledgard, S.F. & Shepherd, M. (2010). A system‟s perspective on the effectiveness of measures to mitigate the environmental impacts of nitrogen losses from pastoral dairy farming. Proceedings of the 4th Australasian Dairy Science Symposium, Lincoln, New Zealand, pp. 14-28.

De Klein, C., & Ledgard, S. (2001). An analysis of environmental and economic implications of nil and restricted grazing systems Research ed to reduce nitrate leaching from New Zealand dairy farms. I. Nitrogen losses. *New Zealand Journal of Agricultural Research,* 201-215.

Dent, J.B., Harrison, S.R. & Woodford, K.B. (1986). *Farm Planning with Linear Programming: Concept and Practice.* Sydney, Australia: Butterworths Pty Ltd.

De Wolde, A. (2006). An alternative wintering system for Southland. (Master of Professional Studies), Lincoln University.

Di, H. J., & Cameron, K. C. (2002). Nitrate leaching in temperate agroecosystems: sources, factors and mitigating strategies. *Nutrient Cycling in Agroecosystems*, 64(3), 237-256.

FAO 2014- Building a common vision for sustainable food and agriculture. (2014). Retrieved April 28, 2015, from http://www.fao.org/3/919235b7-4553-4a4a-bf38-a76797dc5b23/i3940e.pdf

Farm Prices Steady but Sales Volumes Falling. (2015). Retrieved September 19, 2015, from https://www.reinz.co.nz/shadomx/apps/fms/fmsdownload.cfm?file_uuid=25664BED-4ADF-411F-A9ED-C74FF31A463C&siteName=reinz

Fonterra (2015) Retrieved October 10, 2015

Gerrish, J. (2001) Species stability in diverse pasture mixtures. *Forage Systems* Update Vol. 10, No. 2. University of Missouri

Gibbs (2014) Fodder Beet in the New Zealand Dairy Industry. Side conference. Retrieved from: http://side.org.nz/wp-content/uploads/2014/05/4.3-Fodder-Beet-GIBBS.pdf

Glass, C. (2014). Ashley Dene dry dairy FDE Muck. XML File.

Greenwood, P.B. (1979). Lucerne growing in Otago. Farm Production and Practice Aglink, 233. *Ministry of Agriculture and Fisheries*: Wellington.

Hayman, J. M. (1985) The effect of irrigation interval and soil type on pasture and lucerne production. *Proceedings of the New Zealand Grassland Association*, 46, 15-23.

Hoglund JH, White JGH (1985) Cultivatable summer dry east coast: environmental and agronomic constraints in dryland pasture and choice of species. In: Burgess R, Brock H ed. Using herbage cultivars*. New Zealand Grassland Association*, Research Practice Series 3: 39-44.

Journeaux, P. (2013). Economic Analysis on the Value of Winter Housing for Dairy Farming in Tararua District. Paper presented at the *New Zealand Agricultural & Resource Economics Society (inc) Conference*, Lincoln University.

Kearney, J. K., Moot, D. J. and Pollock, K. M. (2010) On-farm comparison of pasture production in relation to rainfall in Central Otago. *Proceedings of the New Zealand Grassland Association*, 72, 121-126.

Ledgard, S. F., & Waller J. E. (2001). Precision of estimates of nitrate leaching in OVERSEER. Client report to FertResearch.

Matthew, C., Nelson, N., Ferguson, D., & Xie, Y. (2011). Fodder beet revisited. *Agronomy New Zealand*, 41, 39-48.

McLaren, R., & Cameron, K. (1996). Soil Science: *Sustainable production and environmental protection.* Victoria, Australia: Oxford University Press.

Mills A, Moot D.J, (2010) Annual dry matter, metabolisable energy and nitrogen yields of six dryland pastures six and seven years after establishment. *Proceedings of the New Zealand Grasslands Association* 72: 177–184.

Ministry for the Environment (2014). National Policy Statement for Freshwater Management 2014. Retrieved April 25, 2015, from http://www.mfe.govt.nz/publications/fresh-water/national-policy-statement-freshwater-management-2014

Ministry for Primary Industries (2012). Retrieved April 20, 2015, from https://www.mpi.govt.nz/document-vault/4189

Monaghan, R. M. (2012). The impacts of animal wintering on water and soil quality: AgResearch.

Monaghan, R. M., De Klein, C. A. M., Smeaton, D., Stevens, D. R., Hyslop, M. G., & Drewry, J. J. (2004). The environmental and economic performance of dairy systems within the four Best Practice Dairy Catchments: FertResearch.

Monaghan, R.M.; Hedley, M.J.; Di, H.J.; McDowell, R.W.; Cameron, K.C.; Ledgard, S.F. 2007: Nutrient management in New Zealand pastures – recent developments and future issues. *New Zealand journal of agricultural research*, 50: 181-201.

Moot, D. (2015) personal communication, *Lucerne weed management*, Professor in Plant Science at Lincoln University

Moot, D.J., Brown, H.E., Teixeira, E.I., Pollock, K.M. (2003) Crop growth and development affect seasonal priorities for lucerne management. *Legumes for dryland pastures.* Grassland Research and Practice Series, Vol. 11, pp. 201 - 208.

Moot, D. Review of Lucerne in New Zealand. 2009. New Zealand Farm Environment Trust and Ministry of Agriculture and Fisheries

Nichol, W.; Westwood, C.; Dumbleton, A.; Amyes, J. 2003. Brassica wintering for dairy cows: overcoming the challenges. pp. 154-172. *In*: Proceedings of the South Island Dairy Event (SIDE), Canterbury, New Zealand, 2003. South Island Dairy Event, Canterbury, New Zealand.

NZX. (2015). Fonterra Shareholders Fund (FSF). Retrieved 1st October, 2015, from https://www.nzx.com/markets/NZSX/securities/FSF

Pangborn, M., & Woodford, K. (2011). Canterbury Dairying- A Study in Land Use Change and Increasing Production. 18th International Farm Management Congress, Congress Proceedings, 81-87.

Radcliffe, lE. and Baars, lA (1987). The productivity of temperate grasslands. In RW. Snaydon (Ed.), *Ecosystems of the world: 17b managed grasslands* (pp. 7- 17). Elsevier Science Publishers: Amsterdam, Netherlands.

Ravensdown Fertiliser. (2015). Retrieved October 8, 2015, from http://www.ravensdown.co.nz/products/fertiliser

Rickard, D., & Fitzgerald, P. (1969). The estimation and occurrence of agriculture drought. Department of Agriculture, 8(1), 11-16.

Smit C. (2015) personal communication, *Pasture and maize silage costings,* Canterbury Dairy Farmer

Smith, G., Bryant, R.H., and Edwards, G.R. (2013) Brief Communication: Milksolids production of dairy cows grazing lucerne and perennial ryegrass in spring. *Proceedings of the New Zealand Society of Animal Production*. 73: 93-95.

S-MAP (2015). Retrieved October 19, 2015, from http://smap.landcareresearch.co.nz/smap#layerIds=82,84,106,76,125,77,83,113,109,107,78,116,115,112,99_¢er=5166939.0116543,1546804.8852763&z=9

Taylor (1967) *A management study of light land farming in Canterbury, New Zealand*, (Thesis), Lincoln College

Variation 1 – Proposed Canterbury Land and Water Regional Plan. (2014). Retrieved April, 27, 2015, from http://ecan.govt.nz/publications/Plans/lwrp-info-sheet-0214.pdf

White, lG.H. (1999). The farmlands of New Zealand. In J.G.H. White & J. Hodgson (Eds.), *New Zealand pasture and crop science* (pp. 1-10). Oxford University Press: Auckland, New Zealand.

Whole Farm Analysis: South Island Finishing Breeding. (2015). Retrieved October 7, 2015, from http://www.beeflambnz.com/information/on-farm-data-and-industry-production/sheep-beef-farm-survey/nsi/

Wilton B. (2015) personal communication, *Solid spreading costings,* Wilton Contracting

Woodward, S.L.; Waghorn, G.C.; Bryant, M.A.; Benton, A. 2012. Can diverse pasture mixtures reduce nitrogen losses? pp. 463-464. In: Proceedings of the 5th Australasian Dairy Science Symposium.

Woodward, S., Waugh, C., Roach, C., Fynn, D., and Phillips, J. (2013) Are diverse species mixtures better pastures for dairy farming? *Proceedings of the New Zealand Grassland Association,* 79-84

Personal Communication

Moot, D. (2015) personal communication, *Lucerne weed management*, Professor in Plant Science at Lincoln University

Smit C. (2015) personal communication, *Pasture and maize silage costings,* Canterbury Dairy Farmer

Wilton B. (2015) personal communication, *Solid spreading costings,* Wilton Contracting

Appendix A: LP Model

				Bulls	R2/3yr	3/4yr	4/5yr	5/6yr	6/7yr	7/8yr	8/9yr	9/10yr	Calf sales	Cull bulls	Cull R2yr	Cull MA	Milksolids
land	200	<=	200														
Silage pit	0	<=	0														
June	0	<=	-0	0	4685	4685	4685	4685	4685	4685	4685	4685					
July	0	<=	-0	1984	5662	5662	5662	5662	5662	5662	5662	5662					
August	0	<=	0	2175	6058	6058	6058	6058	6058	6058	6058	6058					
September	0	<=	0	2105	6713	6713	6713	6713	6713	6713	6713	6713					
October	0	<=	0	2,170	6945	6945	6945	6945	6945	6945	6945	6945					
November	0	<=	0	0	6379	6379	6379	6379	6379	6379	6379	6379					
December	0	<=	0	0	5737	5737	5737	5737	5737	5737	5737	5737					
January	0	<=	0	0	5104	5104	5104	5104	5104	5104	5104	5104					
February	0	<=	0	0	3687	3687	3687	3687	3687	3687	3687	3687					
March	0	<=	0	0	2744	2744	2744	2744	2744	2744	2744	2744					
April	0	<=	0	0	1839	1839	1839	1839	1839	1839	1839	1839					
May	0	<=	-0	0	2589	2589	2589	2589	2589	2589	2589	2589					
Bulls tie	0	<=	-0	-1.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02					
R2/MA tie	0	<=	0		-0.88	1											
Yr3/4 tie	0	<=	-0			-0.89	1.00										
Yr4/5 Tie	0	<=	0				-0.89	1.00									
Yr5/6 tie	0	<=	0					-0.87	1.00								
Yr6/7 tie	0	<=	0						-0.83	1.00							
Yr 7/8 tie	0	<=	-0							-0.78	1.00						
Yr 8/9 tie	0	<=	0								-0.73	1.00					
Yr 9/10 tie	0	<=	0														
calves sales tie	0	<=	-0		-0.90	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	1				
Culls R2yr tie	0	<=	0		-0.10										1		
culls MA tie	0	<=	0			-0.09	-0.09	-0.13	-0.17	-0.22	-0.27	-1				1	
milksolids tie	0	<=	-0		-514	-514	-514	-514	-514	-514	-514	-514					1
Switch	0		0														
Cash surplus/deficit			741,122	-1,300.00	-1,766	-843	-843	-843	-843	-843	-843	-843	20	687.50	607.50	562.50	6.00
Activity levels				9	87	77	69	61	53	44	34	25	369	9	9	74	231,785

Purchase silage	Silage made Oct	Silage made Nov	Silage made Dec	Silage made Jan	Silage made Feb	Silage made Mar	Silage made Apr	Silage made May	Silage fed Jun	Silage fed July	silage fed Aug	Silage fed Sept	Silage fed Oct	Silage fed Nov	Silage fed Dec	Silage fed Jan	Silage fed Feb	Silage fed Mar	Silage fed apr
-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1
									-1										
										-1									
											-1								
												-1							
	1												-1						
		1												-1					
			1												-1				
				1												-1			
					1												-1		
						1												-1	
							1												-1
								1											
-0.031	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003
6,600,000	0	0	0	0	0	0	550,000	0	460,988	1,683,338	1,585,326	605,489	200,226	414,155	573,453	1,100,263	526,762	0	0

Silage fed May	June	July	August	September	October	November	December	January	February	March	April	May	Feed input Lucerne	June	July	August	September	October	November
													1						
1																			
	-0.85	1											-9900	-0.85	1				
		-0.85	1										0		-0.85	1			
			-0.85	1									-3534			-0.85	1		
				-0.85	1								-13560				-0.85	1	
					-0.85	1							-17360					-0.85	1
						-0.85	1						-17100						-0.85
							-0.85	1					-16182						
								-0.85	1				-11067						
									-0.85	1			-8736						
										-0.85	1		-6448						
											-0.85	1	-3240						
-1	1											-0.85	-3410	1					
-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003		-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
0	0	0	0	0	0	0	0	0	0	0	0	0	80	884,610	643,406	0	0	0	0

December	January	February	March	April	May	Feed ryegrass	june	july	august	september	october	november	december	january	february	march	april	may	Feed Fodder Beet
						1													1
						-3300	-1.00	1											-21060
						-3410		-1.00	1										0
						-8835			-1.00	1									0
						-13560				-1.00	1								0
						-15624					-1.00	1							0
1						-10944						-1.00	1						0
-0.85	1					-7192							-1.00	1					0
	-0.85	1				-3162								-1.00	1				0
		-0.85	1			-4368									-1.00	1			0
			-0.85	1		-4836										-1.00	1		-25740
				-0.85	1	-6480											-1.00	1	-35100
					-0.85	-6820	1											-1	-35100
-0.002	-0.002	-0.002	-0.002	-0.002	-0.002		-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015	-0.015
0	0	0	0	276,754	465,025	100	0	0	0	0	0	0	0	0	0	0	0	0	20

Appendix B: LP feed demand profile

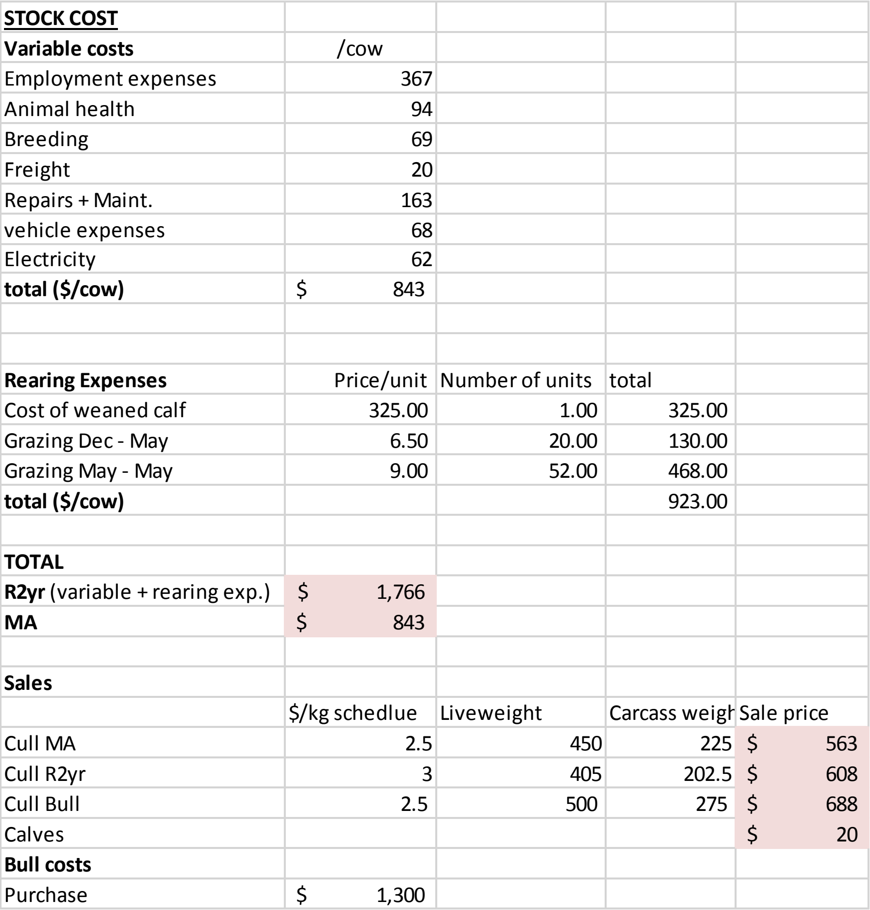
MA Cows		June	July	August	September	October	Novembe	December	January	February	March	April	May
Days		30	31	31	30	31	30	31	31	28	31	30	31
Average Weight		440	420	400	405	410	420	420	425	425	430	440	450
Maintenance (0.56 MJ ME/kg^0.75)	0.56	53.8	52.0	50.1	50.6	51.0	52.0	52.0	52.4	52.4	52.9	53.8	54.7
LWG : at MJ ME/kg LWG:	38	0	0	0	6	6	13	0	6	0	6	13	0
Kg Change/ Day		-0.3	-0.6	-0.6	0.2	0.2	0.3	0.0	0.2	0.0	0.2	0.3	0.0
MJ ME/kg LW Loss	28	-9.3	-18.1	-18.1	0	0	0	0	0	0	0	0	0
Walking on Flat		6	6	6	6	6	6	6	6	6	0	0	6
Milk Production requirements													
Milksolids (kgMS/day)		1.40	1.90	2.10	2.15	2.15	1.90	1.70	1.50	1.20	0.60	0.10	0.30
MJME/KgMS		76.0	76.0	76.0	76.0	76.0	76.0	76.0	76.0	76.0	75.0	75.0	76.0
Milk Production (MJME/day)		106.4	144.4	159.6	163.4	163.4	144.4	129.2	114.0	91.2	45.0	7.5	22.8
Pregnacy and Calf										6	11	19	34
TOTAL ME:		157	184	198	226	227	215	187	179	150	104	74	84
Proportion of peak cows		1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.92	0.88	0.85	0.83	1.00
Monthly Requirements.		4685	5662	6058	6713	6945	6379	5737	5104	3687	2744	1839	2589
KgDM/cow/day		14.3	16.8	18.0	20.6	20.6	19.5	17.0	16.2	13.6	9.5	6.7	7.6

Bulls		June	July	August	September	October	Novembe	December	January	February	March	April	May
Days		30	31	31	30	31	30	31	31	28	31	30	31
Average weight			500	500	500	500							
Maintenance			58	58	58	58							
Walking on flat			6	12	12	12							
Total ME			64	70	70	70							
monthly requirements			1984	2175	2105	2170							
KgDM/cow/day			5.8	6.4	6.4	6.4							

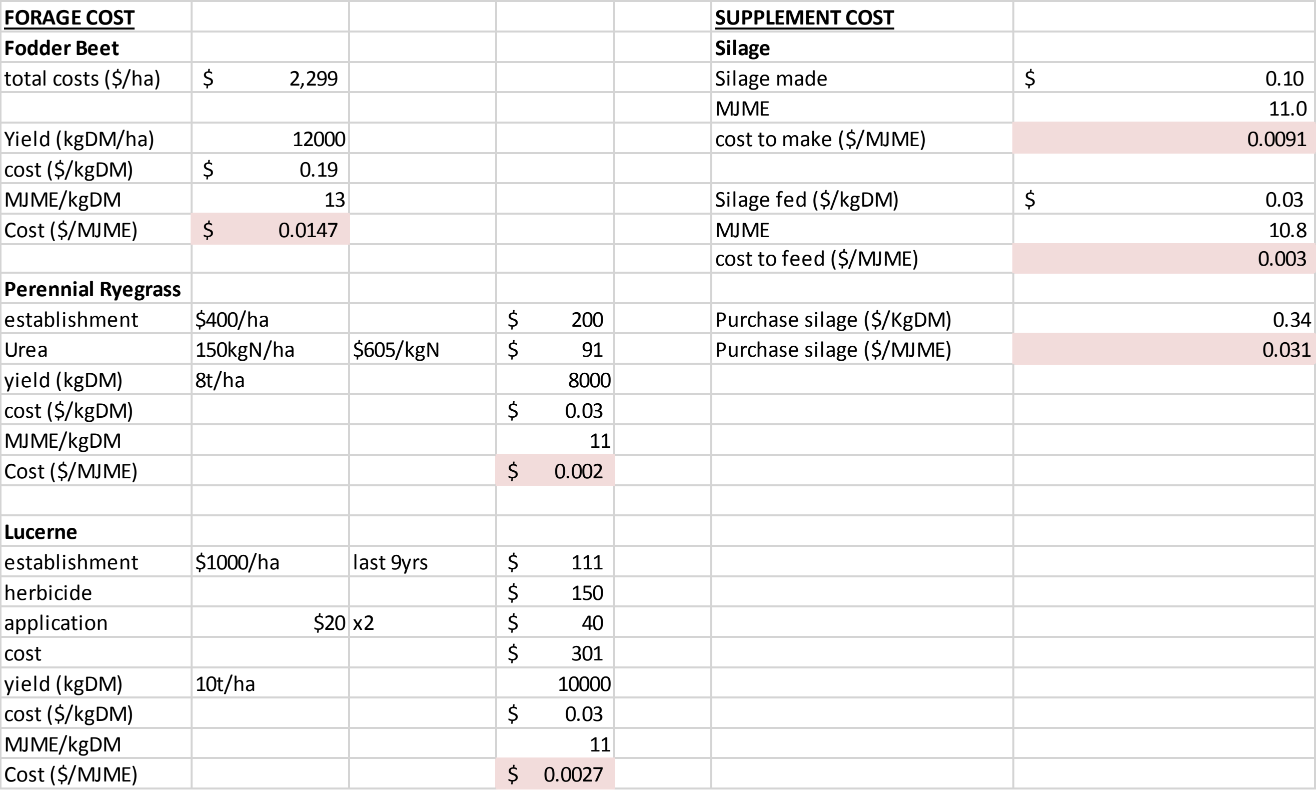
Appendix C: LP feed supply profile

	June	July	August	Septembe	October	Novembe	Decembe	January	February	March	April	May
days	30	31	31	30	31	30	31	31	28	31	30	31
Ryegrass												
Pasture growth (kgDM/ha)	10	10	25	40	45	32	20	10	15	15	20	20
MJME/kgDM	11	11	11.4	11.3	11.2	11.4	11.6	10.2	10.4	10.4	10.8	11
utilisation	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Intake (MJME/ha/month)	3300	3410	8835	13560	15624	10944	7192	3162	4368	4836	6480	6820
Lucerne												
Lucerne growth (kgDM/ha)	30	0	10	40	50	50	45	35	30	20	10	10
MJME/kgDM	11	11	11.4	11.3	11.2	11.4	11.6	10.2	10.4	10.4	10.8	11
utilisation	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Intake (MJME/ha/month)	9900	0	3534	13560	17360	17100	16182	11067	8736	6448	3240	3410
Fodder Beet												
Fodder beet growth												
Feed avaliable (kgDM/ha)	2160									2640	3600	3600
MJME/kgDM	13	13	13	13	13	13	13	13	13	13	13	13
utilisation	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%
Intake (MJME/ha/month)	21060	0	0	0	0	0	0	0	0	25740	35100	35100

Appendix D: LP financial assumptions

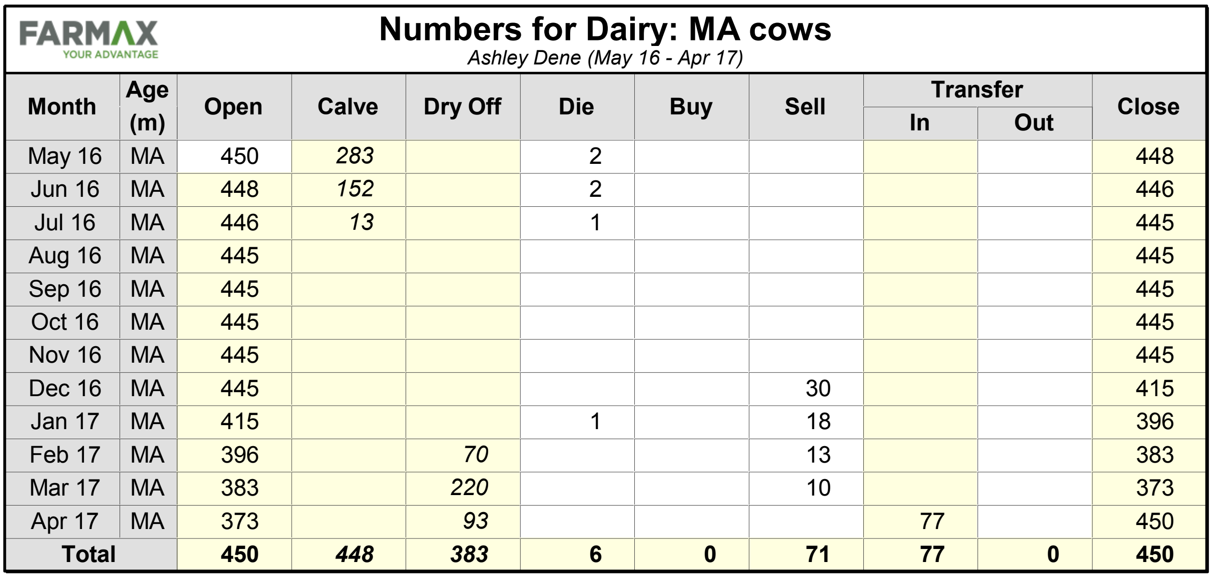


STOCK COST				
Variable costs	/cow			
Employment expenses	367			
Animal health	94			
Breeding	69			
Freight	20			
Repairs + Maint.	163			
vehicle expenses	68			
Electricity	62			
total ($/cow)	$ 843			
Rearing Expenses	Price/unit	Number of units	total	
Cost of weaned calf	325.00	1.00	325.00	
Grazing Dec - May	6.50	20.00	130.00	
Grazing May - May	9.00	52.00	468.00	
total ($/cow)			923.00	
TOTAL				
R2yr (variable + rearing exp.)	$ 1,766			
MA	$ 843			
Sales				
	$/kg schedlue	Liveweight	Carcass weigh	Sale price
Cull MA	2.5	450	225	$ 563
Cull R2yr	3	405	202.5	$ 608
Cull Bull	2.5	500	275	$ 688
Calves				$ 20
Bull costs				
Purchase	$ 1,300			



FORAGE COST					**SUPPLEMENT COST**	
Fodder Beet					**Silage**	
total costs ($/ha)	$ 2,299				Silage made	$ 0.10
					MJME	11.0
Yield (kgDM/ha)	12000				cost to make ($/MJME)	0.0091
cost ($/kgDM)	$ 0.19					
MJME/kgDM	13				Silage fed ($/kgDM)	$ 0.03
Cost ($/MJME)	$ 0.0147				MJME	10.8
					cost to feed ($/MJME)	0.003
Perennial Ryegrass						
establishment	$400/ha		$ 200		Purchase silage ($/KgDM)	0.34
Urea	150kgN/ha	$605/kgN	$ 91		Purchase silage ($/MJME)	0.031
yield (kgDM)	8t/ha		8000			
cost ($/kgDM)			$ 0.03			
MJME/kgDM			11			
Cost ($/MJME)			$ 0.002			
Lucerne						
establishment	$1000/ha	last 9yrs	$ 111			
herbicide			$ 150			
application	$20	x2	$ 40			
cost			$ 301			
yield (kgDM)	10t/ha		10000			
cost ($/kgDM)			$ 0.03			
MJME/kgDM			11			
Cost ($/MJME)			$ 0.0027			

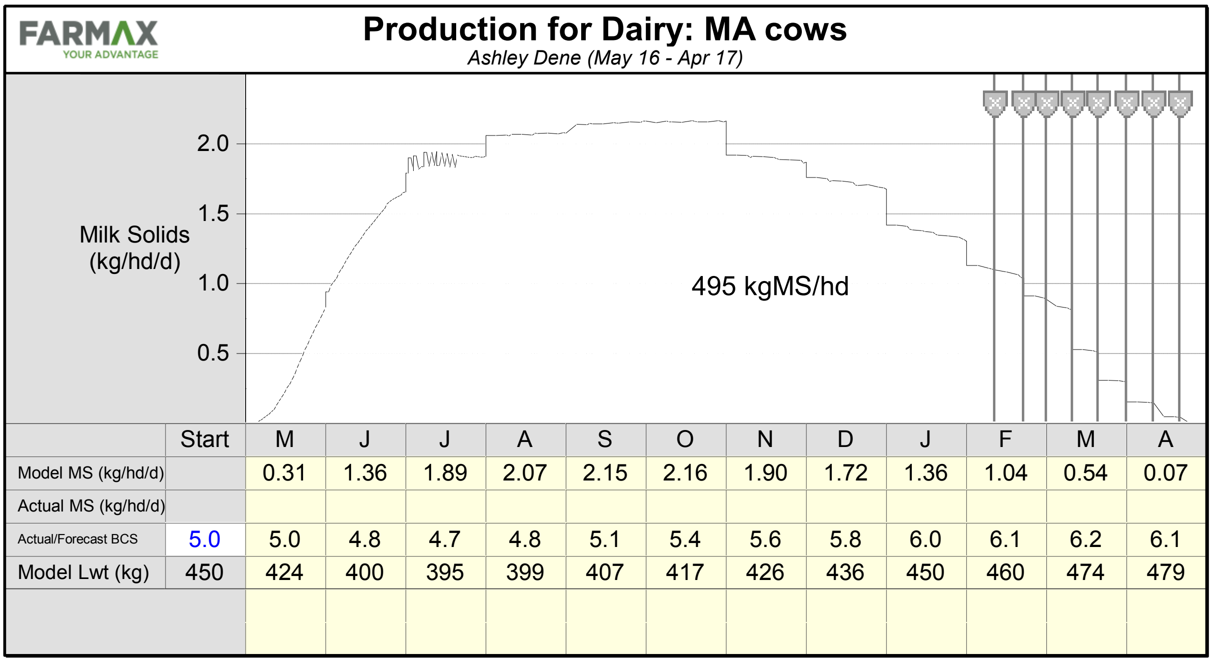
Appendix E: Farmax Outputs



Numbers for Dairy: MA cows

Ashley Dene (May 16 - Apr 17)

Month	Age (m)	Open	Calve	Dry Off	Die	Buy	Sell	Transfer In	Transfer Out	Close
May 16	MA	450	*283*		2					448
Jun 16	MA	448	*152*		2					446
Jul 16	MA	446	*13*		1					445
Aug 16	MA	445								445
Sep 16	MA	445								445
Oct 16	MA	445								445
Nov 16	MA	445								445
Dec 16	MA	445					30			415
Jan 17	MA	415			1		18			396
Feb 17	MA	396		*70*			13			383
Mar 17	MA	383		*220*			10			373
Apr 17	MA	373		*93*				77		450
Total		**450**	***448***	***383***	**6**	**0**	**71**	**77**	**0**	**450**



Production for Dairy: MA cows

Ashley Dene (May 16 - Apr 17)

	Start	M	J	J	A	S	O	N	D	J	F	M	A
Model MS (kg/hd/d)		0.31	1.36	1.89	2.07	2.15	2.16	1.90	1.72	1.36	1.04	0.54	0.07
Actual MS (kg/hd/d)													
Actual/Forecast BCS	5.0	5.0	4.8	4.7	4.8	5.1	5.4	5.6	5.8	6.0	6.1	6.2	6.1
Model Lwt (kg)	450	424	400	395	399	407	417	426	436	450	460	474	479

Appendix F: Annual Budget

	Dryland dairy model				MPI Canterbury Average			
	1st May 2016- 30th April 2017				*1st July 2011- 30th June 2012*			
	total	**/ha**	**/cow**	**/kgMS**	**total**	**/ha**	**/cow**	**/kgMS**
Area	200				210			
Cows (peak)	450	2.25			733	3.49		
Total milksolid production	220,212	1,101	489		295,065	1,405	403	
Revenue								
Milk sales	1,551,937	7,760	3,449	7.05	1,939,537	9,236	2,646	6.57
Milk (dividend)	66,064	330	147	0.30	90,368	430	123	0.31
Net livestock sales	29,004	145	64	0.13	107,818	513	147	0.37
Change in livestock value	27,413	137	61	0.12		0	0	0.00
other farm income	0	0	0	0	8,245	39	11	0.03
Total Revenue	**1,674,418**	8,372	3,721	7.60	**2,145,968**	10,219	2,928	7.27
Expenses								
Labour expenses	170,830	854	380	0.78	250,183	1,191	341	0.85
animal health	42,152	211	94	0.19	66,123	315	90	0.22
breeding	35,754	179	79	0.16	32,706	156	45	0.11
Farm dairy	5,234	26	12	0.02	14,220	68	19	0.05
Electricity	18,726	94	42	0.09	49,059	234	67	0.17
Contractor charges	25,833	129	57	0.12		0	0	0
Cash crop	0	0	0	0		0	0	0
Feed crop	46,000	230	102	0.21	25,000	119	34	0.08
Brought feed	230,513	1,153	512	1.05	132,000	629	180	0.45
Calf feed	1,179	6	3	0.01		0	0	0.00
Grazing	49,082	245	109	0.22	235,590	1,122	321	0.80
Fertiliser	58,902	295	131	0.27	149,310	711	204	0.51
Irrigation	0	0	0	0	17,775	85	24	0.06
Regrassing	12,000	60	27	0.05	14,220	68	19	0.05
Weed & Pest	5,888	29	13	0.03	6,399	30	9	0.02
Vehicles & Fuel	59,481	297	132	0.27	45,504	217	62	0.15
R&M	42,761	214	95	0.19	109,494	521	149	0.37
Freight	1,995	10	4	0.01	10,665	51	15	0.04
Administration	14,904	75	33	0.07	17,064	81	23	0.06
Rates & Insurance	14,552	73	32	0.07	35,550	169	48	0.12
other expenditure	0	0	0	0	10,622	51	14	0.04
Total Farm Working Expenses	**835,786**	4,179	1,857	3.80	**1,221,484**	5,817	1,666	4.14
Depreciation	194,571	973	432	0.88	40,431	193	55	0.14
Total Operating expenses	**1,030,357**	5,152	2,290	4.68	**1,261,915**	6,009	1,722	4.28
Dairy Operating Profit	**644,060**	3,220	1,431	2.92	**884,053**	4,210	1,206	3.00

Appendix G: Statement of Assets

Dryland	200ha	$20,000/ha	$	4,000,000
		Total land value	**$**	**4,000,000**
Staff house		(150m2 at $2000/m2)	$	300,000
Herringbone cow shed (40bale)		$160000/bale minus plant	$	505,000
Fully enclosed housing structure		$3678/cow	$	1,839,000
Implement storage & Calf shed 5 bay		$20,000	$	20,000
		Total infastructure value	**$**	**2,664,000**
Tractor (105hp)			$	95,000
Feed-out wagon			$	40,040
Plant			$	145,000
		Total plant and machinery value	**$**	**280,040**
Dairy Cows	450	$1655	$	744,750
Rising 1 year olds (born May 2015)	79	$1324	$	104,596
		Total livestock value	**$**	**849,346**
Fonterra Shares	220215	$5.40	$	1,189,161
		Total share value	**$**	**1,189,161**
Total Current Assets			$	8,982,547

Appendix H: Investment analysis assumptions

Depreciation Schedules

Item		**Buildings**	
Opening		2,344,000	
DV rate		6.0%	
Years	opening	Dep.	Closing
1	2,344,000	-140,640	2,203,360
2	2,203,360	-132,202	2,071,158
3	2,071,158	-124,270	1,946,889
4	1,946,889	-116,813	1,830,076
5	1,830,076	-109,805	1,720,271
6	1,720,271	-103,216	1,617,055
7	1,617,055	-97,023	1,520,031
8	1,520,031	-91,202	1,428,830
9	1,428,830	-85,730	1,343,100
10	1,343,100	-80,586	1,262,514
11	1,262,514	-75,751	1,186,763
12	1,186,763	-71,206	1,115,557
13	1,115,557	-66,933	1,048,624
14	1,048,624	-62,917	985,706
15	985,706	-59,142	926,564

Item		**Plant**	
Opening		145,000	
DV rate		16%	
Years	opening	Dep.	Closing
1	145,000	-23,200	121,800
2	121,800	-19,488	102,312
3	102,312	-16,370	85,942
4	85,942	-13,751	72,191
5	72,191	-11,551	60,641
6	60,641	-9,703	50,938
7	50,938	-8,150	42,788
8	42,788	-6,846	35,942
9	35,942	-5,751	30,191
10	30,191	-4,831	25,361
11	25,361	-4,058	21,303
12	21,303	-3,408	17,894
13	17,894	-2,863	15,031
14	15,031	-2,405	12,626
15	12,626	-2,020	10,606

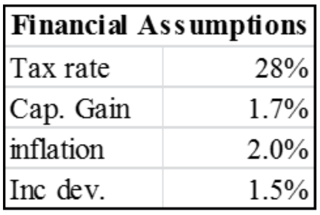
Item		**Vehicles**	
Opening		135,040	
DV rate		13.0%	
Years	opening	Dep.	Closing
1	135,040	-17,555	117,485
2	117,485	-15,273	102,212
3	102,212	-13,288	88,924
4	88,924	-11,560	77,364
5	77,364	-10,057	67,307
6	67,307	-8,750	58,557
7	58,557	-7,612	50,944
8	50,944	-6,623	44,322
9	44,322	-5,762	38,560
10	38,560	-5,013	33,547
11	33,547	-4,361	29,186
12	29,186	-3,794	25,392
13	25,392	-3,301	22,091
14	22,091	-2,872	19,219
15	19,219	-2,498	16,721

Item		**Development expenses**	
Opening		100,000	
DV rate		20%	
Years	opening	Dep.	Closing
1	100000	-20,000	80,000
2	80,000	-16,000	64,000
3	64,000	-12,800	51,200
4	51,200	-10,240	40,960
5	40,960	-8,192	32,768
6	32,768	-6,554	26,214
7	26,214	-5,243	20,972
8	20,972	-4,194	16,777
9	16,777	-3,355	13,422
10	13,422	-2,684	10,737
11	10,737	-2,147	8,590
12	8,590	-1,718	6,872
13	6,872	-1,374	5,498
14	5,498	-1,100	4,398
15	4,398	-880	3,518

Loan Schedule

	Amortised loan				
	Loan Amount	5,082,547			
	Term	25			
	Interest	6.00%			
	PMT	-397,591			
Year	Opening	Principle	Interest	Closing	Check
1	5,082,547	-92,638	-304,953	4,989,909	-397,591
2	4,989,909	-98,196	-299,395	4,891,712	-397,591
3	4,891,712	-104,088	-293,503	4,787,624	-397,591
4	4,787,624	-110,334	-287,257	4,677,291	-397,591
5	4,677,291	-116,954	-280,637	4,560,337	-397,591
6	4,560,337	-123,971	-273,620	4,436,366	-397,591
7	4,436,366	-131,409	-266,182	4,304,957	-397,591
8	4,304,957	-139,294	-258,297	4,165,664	-397,591
9	4,165,664	-147,651	-249,940	4,018,013	-397,591
10	4,018,013	-156,510	-241,081	3,861,503	-397,591
11	3,861,503	-165,901	-231,690	3,695,602	-397,591
12	3,695,602	-175,855	-221,736	3,519,747	-397,591
13	3,519,747	-186,406	-211,185	3,333,341	-397,591
14	3,333,341	-197,591	-200,000	3,135,750	-397,591
15	3,135,750	-209,446	-188,145	2,926,304	-397,591
16	2,926,304	-222,013	-175,578	2,704,291	-397,591
17	2,704,291	-235,333	-162,257	2,468,958	-397,591
18	2,468,958	-249,453	-148,137	2,219,504	-397,591
19	2,219,504	-264,421	-133,170	1,955,084	-397,591
20	1,955,084	-280,286	-117,305	1,674,798	-397,591
21	1,674,798	-297,103	-100,488	1,377,695	-397,591
22	1,377,695	-314,929	-82,662	1,062,765	-397,591
23	1,062,765	-333,825	-63,766	728,940	-397,591
24	728,940	-353,855	-43,736	375,086	-397,591
25	375,086	-375,086	-22,505	0	-397,591

Financial Assumptions



Financial Assumptions	
Tax rate	28%
Cap. Gain	1.7%
inflation	2.0%
Inc dev.	1.5%

Appendix I: Investment Appraisal

Sheep Breeding and Finishing Enterprise

Sheep Breeding and Finishing Enterprise	year 1-15										
Annual income	197,664										
Annual expense	-146,438										
Year	0	1	1	2	2	3	3	4	4	5	5
		cash	tax	cash	tax	cash	tax	cash	tax	cash	tax
Land	-4,000,000										
Plant & Machinery	-62,744										
Livestock	-296,802										
Loan	355,330										
Deprecation			-13,176		-10,409		-8,223		-6,496		-5,132
Interest		-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320
Principal		0		0		0		0		0	
Income		200,629	200,629	203,638	203,638	206,693	206,693	209,793	209,793	212,940	212,940
Expense		-149,367	-149,367	-152,354	-152,354	-155,401	-155,401	-158,509	-158,509	-161,679	-161,679
Losses carried forward					0		0		0		0
Taxable income			16,766		19,555		21,749		23,468		24,809
Tax amount		-4,695		-5,475		-6,090		-6,571		-6,946	
Nominal pre finance and tax cash flow	-4,004,216	51,262		51,284		51,292		51,284		51,261	
Real pre finance and tax cash flow	-4,004,216	50,257		49,293		48,333		47,379		46,429	
Nominal post finance and tax cash flow	-4,004,216	25,248		24,489		23,882		23,393		22,995	
Real post finance and tax cash flow	-4,004,216	24,753		23,538		22,505		21,612		20,827	

	Pre Finance and Tax			Post Finance and Tax		
Nominal IRR	4.7%			4.2%		
Real IRR	2.7%			2.1%		
	Discount rate	Nominal	Real	Discount Rate	Nominal	Real
NPV	2%	1,808,835	393,778	2%	1,422,607	63,932
	4%	417,525	647,115	4%	86,691	931,827
	6%	611,949	1,418,148	6%	898,253	1,666,368
	8%	1,378,824	1,993,235	8%	1,628,989	2,211,667
	10%	1,953,884	2,425,111	10%	2,174,447	2,618,999

6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15
cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax
																		6,898,288	
																		0	
																		399,456	102,654
																		-355,330	
	-4,054		-3,203		-2,530		-1,999		-1,579		-1,248		-986		-779		-615		-486
-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320	-21,320
0		0		0		0		0		0		0		0		0		0	
216,134	216,134	219,376	219,376	222,667	222,667	226,007	226,007	229,397	229,397	232,838	232,838	236,331	236,331	239,876	239,876	243,474	243,474	247,126	247,126
-164,913	-164,913	-168,211	-168,211	-171,575	-171,575	-175,007	-175,007	-178,507	-178,507	-182,077	-182,077	-185,719	-185,719	-189,433	-189,433	-193,222	-193,222	-197,086	-197,086
	0		0		0		0		0		0		0		0		0		0
	25,847		26,642		27,241		27,681		27,991		28,193		28,307		28,344		28,317		130,888
-7,237		-7,460		-7,628		-7,751		-7,837		-7,894		-7,926		-7,936		-7,929		-36,649	
51,221		51,165		51,092		51,000		50,890		50,761		50,612		50,442		50,252		6,992,454	
45,483		44,542		43,606		42,675		41,748		40,825		39,907		38,994		38,085		5,195,497	
22,664		22,385		22,144		21,930		21,733		21,547		21,366		21,186		21,003		6,934,486	
20,125		19,488		18,900		18,350		17,828		17,329		16,847		16,378		15,918		5,152,425	

Dryland Dairy Model

Dryland Dairy Enterprise	year 1-15										
Annual income	1,674,418										
Annual expense	-835,786										
Year	0	1	1	2	2	3	3	4	4	5	5
		cash	tax	cash	tax	cash	tax	cash	tax	cash	tax
Land	-4,000,000										
Buildings	-2,664,000										
Plant & Machinery	-342,784										
Livestock	-849,346										
Shares	-1,189,161										
Development	-100,000										
Existing Loan	58,528										
Loan	5,082,547										
Deprecation			-214,571		-193,372		-174,950		-158,861		-144,737
Interest		-301,441	-301,441	-295,883	-295,883	-289,991	-289,991	-283,746	-283,746	-277,126	-277,126
Principal		-92,638		-98,196		-104,088		-110,334		-116,954	
Income		1,699,534	1,699,534	1,725,027	1,725,027	1,750,902	1,750,902	1,777,166	1,777,166	1,803,823	1,803,823
Expense		-852,501	-852,501	-869,551	-869,551	-886,943	-886,943	-904,681	-904,681	-922,775	-922,775
Losses carried forward					0		0		0		0
Taxable income			331,020		366,221		399,018		429,878		459,186
Tax amount		-92,686		-102,542		-111,725		-120,366		-128,572	
Nominal pre finance and tax cash flow	-9,145,291	847,032		855,475		863,960		872,484		881,048	
Real pre finance and tax cash flow	-9,145,291	830,424		822,256		814,129		806,041		797,993	
Nominal post finance and tax cash flow	-4,004,216	360,268		358,854		358,155		358,039		358,397	
Real post finance and tax cash flow	-4,004,216	353,203		344,920		337,498		330,773		324,611	

	Pre Finance and Tax			Post Finance and Tax		
Nominal IRR		10.2%			11.5%	
Real IRR		8.1%			9.3%	
	Discount rate	Nominal	Real	Discount Rate	Nominal	Real
NPV	2%	10,334,394	6,685,630	2%	6,243,876	4,165,149
	4%	6,748,065	3,895,423	4%	4,200,483	2,596,396
	6%	3,991,654	1,739,896	6%	2,650,131	1,401,173
	8%	1,852,252	57,628	8%	1,463,038	481,769
	10%	175,406	1,268,702	10%	545,681	232,321

6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15
cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax
																		6,898,288	
																		926,564	
																		10,606	
																		1,143,108	293,762
																		1,600,454	
																		3,518	
																		-58,528	
																		-2,926,304	
	-132,277		-121,232		-111,395		-102,597		-94,693		-87,565		-81,112		-75,250		-69,909		-65,027
-270,109	-270,109	-262,670	-262,670	-254,786	-254,786	-246,428	-246,428	-237,569	-237,569	-228,178	-228,178	-218,224	-218,224	-207,673	-207,673	-196,489	-196,489	-184,633	-184,633
-123,971		-131,409		-139,294		-147,651		-156,510		-165,901		-175,855		-186,406		-197,591		-209,446	
1,830,881	1,830,881	1,858,344	1,858,344	1,886,219	1,886,219	1,914,512	1,914,512	1,943,230	1,943,230	1,972,378	1,972,378	2,001,964	2,001,964	2,031,994	2,031,994	2,062,473	2,062,473	2,093,411	2,093,411
-941,230	-941,230	-960,055	-960,055	-979,256	-979,256	-998,841	-998,841	-1,018,818	-1,018,818	-1,039,195	-1,039,195	-1,059,978	-1,059,978	-1,081,178	-1,081,178	-1,102,802	-1,102,802	-1,124,858	-1,124,858
	0		0		0		0		0										
	487,265		514,387		540,782		566,646		592,150		617,441		642,649		667,892		693,274		1,012,655
-136,434		-144,028		-151,419		-158,661		-165,802		-172,883		-179,942		-187,010		-194,117		-283,543	
889,650		898,289		906,963		915,671		924,412		933,184		941,986		950,816		959,672		11,551,092	
789,984		782,014		774,084		766,193		758,340		750,525		742,749		735,011		727,311		8,582,631	
359,137		360,181		361,465		362,931		364,531		366,221		367,965		369,727		371,476		7,888,637	
318,903		313,559		308,507		303,684		299,042		294,538		290,138		285,811		281,532		5,861,373	

Marginal Return

Marginal Return											
Year	0	1	1	2	2	3	3	4	4	5	5
		cash	tax	cash	tax	cash	tax	cash	tax	cash	tax
Real Pre finance and tax cash flow	-5,141,075	780,167		772,963		765,795		758,662		751,564	
Real Post finance and tax cash flow	-5,082,547	328,451		321,381		314,993		309,161		303,784	
		Pre Finance and Tax		Post Finance and Tax							
	Real IRR	13.38%		-0.62%							
		Discount rate	Pre	Post		-0.62%					
	Real NPV	2%	6,291,852	981,330							
		4%	4,542,538	1,554,324							
		6%	3,158,043	2,015,006							
		8%	2,050,863	2,389,111							
		10%	1,156,408	2,695,869							

6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15
cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax	cash	tax
744,501		737,472		730,478		723,518		716,592		709,700		702,842		696,018		689,227		3,387,135	
298,778		294,071		289,607		285,335		281,214		277,209		273,290		269,433		265,614		708,948	