Modelling the Economic Opportunities For Development of Marginal Hill Country in a South Island High Country System

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by
Dave Ingham

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The South Island high country makes up 15% of New Zealand's total land area. Farm systems in this environment are typified by large expanses of low producing land and extensive livestock operations. Increasingly the potential to increase system intensity in the high country through developed and specialised pastures is being realised and as a result there is a growing interest in high country land development.

This interest and potential for increase in farm productivity and profitability from land development form the basis for this study. The feasibility and economic opportunity for development of marginal hill land in a South Island high country environment was investigated based on farmer case study information, and computer based modelling using Farmax Pro and Microsoft Excel linear programming.

Five scenarios were produced to highlight a range of land use options and potential development outcomes above that of the baseline, Oversown Hill, model. Development scenarios include, intensively cropped pasture of Plantain/Red Clover on both areas of flat and steep topography, permanent grass/clover pasture on steep topography, and a Selective Development scenario combining areas of undeveloped land, intensive Plantain/Red Clover, and Fodderbeet winter forage crop.

The scenarios were produced based on a combination of historic data gathered from farmer interviews and assumptions drawn from appropriate literature. All scenarios were constructed and analysed using Farmax Pro and then reproduced in a Microsoft Excel linear programme as a means of result validation. Scenarios were based on production from a Romney maternal ewe flock with the driver being to maximise livestock productivity from the available area, 100ha. The key metric for success of development scenarios was profitability, measured as EBIT/ha.

Keywords: Hill country development, South Island high country, Farmax, Pasture Improvement, Land development, Farm profitability, Linear Programme, Plantain, Red Clover, Fodderbeet

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Table of Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1. General Introduction

Inverary Station is a 4087ha high country sheep and beef farm, situated near Mt Somers, Canterbury. The station is owned by John and Anne Chapman, the third generation of this family on this property, and who employ farm manager, Bert Oliver, to oversee the mixed breeding and finishing operation. Owners John and Anne Chapman have developed areas of the property during their farming career, however, they believe there is still scope for further development and higher returns. One of the key issues they face when determining which land areas to develop is choosing where the greatest return for investment will be made. With significant areas of both easier and steeper contoured land, producing a range of different pasture qualities and quantities, the issue for the Chapman's is therefore, is it best to invest in development in the lowest producing areas where the greatest change will be made, focus on maximising production off more potentially intensive land areas, or a combination of both.

The purpose of this study is to model potential hill country development on Inverary Station and analyse economic returns if such development were to occur. The study will highlight necessary steps to achieve such development, quantify the cost ($/ha) of development, and indicate the economic and farm management feasibility of undertaking such an investment. The goal of development is to enhance the ability to finish a greater proportion of livestock, reducing economic variability and impact of market fluctuation.

The developed system produced will be based on a range of theoretical and real data. Data for the development of land will come from interviews with the Chapmans' based on true costings and figures from their previous development. Data for pasture production levels, livestock classes and prices, and animal performance will be based on a combination of both data from interviews, and theoretical data from the Farm Technical Manual (Askin & Askin, 2012), Financial Budget Manual (Trafford & Trafford, 2011), MPI Farm Monitoring Reports (Ministry of Primary Industries, 2012), and Farmax default values (Farmax, 2016).

1.2. Research objectives

The aim of this study is to investigate the feasibility of development of marginal hill country land, with the key objectives detailed in the research questions below. To achieve this a combined case study and quantitative research approach will be taken. The initial step will be to interview the farming team, to gain actual and historical data from their development experience. This data will be used to build scenarios in the computer based farm modelling tool, Farmax Pro, to highlight viability and profitability of a range of development scenarios. Finally the scenarios will be recreated using an optimisation model, Linear Programme with Microsoft Excel, to investigate the feasibility of the results produced in Farmax.

1.3. Research Questions

Questions sought to be answered are:

- What is the development cost ($/ha) for development of different hill country land classes?
- What is the potential increase in livestock production as a result of development?
- What is the economic viability/profitability of investment in this land development?

1.4. Research Approach

1.4.1. Farm Interview

The interviews with the farming team will focus on the cost of development based on their data from previous land development. They will also include questions around the current farming system, pasture production, livestock classes, and livestock production. The interviews will be split into 3 sections which will be, current farming system, development, and management factors/farmer goals. A full list of interview questions can be found in the appendix.

The information gained from this interview will form the basis of the data used to produce the Farmax models.

1.4.2. Farmax Modelling

Scenario analysis will be completed using a computer based modelling tool, Farmax Pro. Farmax is a resource developed by AgResearch and is designed to model the pastoral farming system. Farmax is based on over 20 years AgResearch research, to develop what is now the leading decision support tool for New Zealand pastoral farmers (Farmax, 2016).

Data from the farm interviews will be used in conjunction with theoretical data and values, from the Lincoln University Financial Budget Manual, Farm Technical Manual, and default Farmax values to produce a baseline model farm. This baseline farm will be used to replicate the average current production on an oversown hill country block at Inverary. From this base model a range of scenarios will be produced, designed to replicate a range of development options. These scenarios will then be able to be compared to the base model to analyse; difference in profitability of the baseline and developed farm systems, difference in pasture supply curves and the impact this has on livestock operations, and the difference in resilience to climatic variation between the original and developed systems.

1.4.3. Linear Programme

Finally, a linear programme will be produced, with scenarios set up based upon those in Farmax, and used to validate the results as found from the Farmax modelling.

Linear programming is a computer based modelling tool used to optimise a given system (Williams, 2000). It takes a mathematical approach to solve a systems problem, with the most common practice being to optimise profit given a range of financial and biological constraints. Energy is the most limiting feed constituent in majority of New Zealand pastoral systems (Rattray, Brookes, & Nicol, 2007) and thus megajoules of metabolisable energy per kilogram of dry matter (MJME/kgDM) will be the currency of use for determining feed supply and demand within the programme. Land area, livestock performance, and replacement/culling rates will be fixed to remain constant. The model will then be given the option to:

- Select whether or not scenario development is feasible
- Select the proportion of each stock class to include in the system and set the stocking rate for the appropriate level of production.

These outputs will be limited by constraints which will restrict factors so as to stay within biological, economic, and environmental feasibility.

The focus of the results section will be on the output from the Farmax modelling, which will give a true indication of potential production and profits, the linear programme is useful for validation of these results, however it is not intended for figures to be taken as actuals as they are based around a rudimental set of constraints. But they should provide reassurance with the ranking and relativity of the different scenarios.

1.5. Dissertation Outline

This dissertation consists of six chapters, as presented below:

Chapter 1 **Introduction**

Chapter 2 **Literature Review –** Contains an extensive review of available literature, including description and limitations of high country farm systems, development options in such environments, as well as farm systems theory and its influence on decision making.

Chapter 3 **Methodology –** Description of the methodology used in this research project.

Chapter 4 **Results –** Results for baseline model and all development scenarios. This includes, data directly from farm interviews, Farmax modelling and outputs as well as comprehensive scenario comparison, and Microsoft Excel output including linear programme used for validation.

Chapter 5 **Discussion –** Discussion of results as shown in Chapter 4.

Chapter 6 **Conclusion –** A summary of modelling results and conclusions from this research, along with limitations of the research and future research recommendations.

Chapter 2
Literature Review

2.1 Introduction

The purpose of this review is to cover a range of literature from scientific and industry research, gaining perspectives and information from, the first, the most recent, and the best articles, as related to this study. Topics covered in this chapter include, farm systems theory, description and limitations of high country systems, common methods of land development, and the effect of climate on production in high country farm systems. This review will supply necessary background knowledge, as well as highlight gaps in the literature for which results of this study aim to fill.

2.2 Whole Farm System Theory

The successful outcome of farm management is to achieve the goals and objectives of its owners. These include both profit and non-profit goals of the farming business, with goals and ambitions for each farm business dependant on the expectations of both owners and managers. A goal of increasing importance to many farmers is the creation of a sustainable farm system along with other attributes including environmental goals and natural resource protection, economic priorities, production goals, family/life quality objectives, local community activities and influences. Ultimately a farm system works on the basis of producing products to generate profit to ensure business viability without impacting the sustainability of resources or relationships (Kelly & Bywater, 2005). Analysis of the system deliberately considers the relationships between components, as no one component acts independently of another and recognises that addition of new components to a system creates a new dynamic that is likely to alter the overall system performance.

The whole farm systems approach, which is becoming more recognised and commonly used, differs from the traditional reductionist approach, which isolates individual components of the system. Contrastingly, whole farm system approach takes a holistic view, understanding each component of the farming system and how they interact, with belief that each component is interconnected and explicable only by reference to the whole system. The goals and objectives of the farm owners/farm family are a key component of the farm system, as they influence the direction and magnitude of any change.

Kelly and Bywater (2005) state four key properties need to be considered when analysing the farm system; productivity, stability, resilience, and equity. Productivity is the resultant output of desired product per unit of input, and can be compared in either physical or monetary terms. Stability is how consistent this production is given small and re-occurring disturbing forces, for example annual fluctuation in product prices. The resilience of the system is its ability to withstand severe and generally unpredictable disturbing forces. This considers both ability to manage the disturbance but also to be able to recover from this disturbance. Resilience is a key factor determining the sustainability of a system. The fourth factor, equity, refers to the evenness of distribution of the costs and returns from the given inputs and outputs of the system. Equity looks at this distribution in both the short and long term of the system. Both sustainability and management of the farm system should reflect effects on people, environment, resources, and finance. With the four properties of analysis, as mentioned above, needing to be applied to each of these facets of the system to gain full perspective when analysing the farm system.

The Law of Diminishing Returns governs biological systems, and works on the basis that the response of each additional unit of input will have a reduced production response to that of the previous unit of input. Thus the ratio of output relative to input will decrease as input level increases. The impact of this for farm systems is that maximising production generally does not relate to a maximised profitability (Dowle & Doyle, 1988). Optimum production level is thus not a fixed value and is instead a variable, dependant on input and product price.

The economic environment of the New Zealand agricultural industry is extremely volatile, largely as a result of production uncertainty driven by climatic and biological effects, and variability in product returns as a result of dependence on commodity markets. A major challenge of New Zealand pastoral farmers has been the inability to respond quickly to the rapidly changing economic environment. The key competitive advantage to farmers has instead traditionally been that of low input pasture based systems which are able to operate profitably at low product prices (Shadbolt, 1981). High input/more intensive farm systems are generally more reliant on various inputs to maintain production level, thus giving them high costs of production which is difficult to alter in unfavourable market conditions. Low input systems are generally more flexible in their level of production/input costs and thus are less effected in times of adverse product prices.

2.3 High Country Farming Systems

High country farm systems consist of those in the mountainous backbone of the South Island stretching from Southland to Marlborough, and consist 15% of New Zealand total land area (FAO, 2009). High country systems are extensive and dominated by high altitude tussock grassland, with improved pastures limited to flat and rolling land on the limited area of valley floors and river terraces. These systems are characterised by extremes, and generally have the lowest mean annual temperatures of New Zealand pastoral areas and the greatest monthly variation (Scott, et al., 1995). Allan (1985) described low winter temperatures resulting in minimal pasture production from mid-April to mid-October in the high country. Moisture is a key limiting factor to pasture production during the growing season, with high climatic variability requiring adaptive systems able to manage the risk of feed shortage. Thus land use has been historically typified by expansive areas and low stocking rates, less than 1SU/ha, with stock breeds being selected for their hardiness and ability to survive the low input and often feed restricted systems (Scott, et al., 1995).

The key source of income has historically been fine wool production from merino sheep, which have proved to perform well in the high altitude environment since their introduction in the early 1800's. Prior to 1984 high country systems held a higher stocking rate and had moderately higher pasture production as a result of SMP's and farm subsidies. Farmers were offered a minimum price for every stock unit on the property and thus encouraged to increase stocking rate. In addition to this inputs such as fertiliser were heavily subsidised and thus application was feasible and pasture production boosted as a result of increased soil fertility. Following abolishment of subsidies and SMP's in 1984 farm profitability dropped by over 50% in one year and hit high country farmers particularly hard (Hunt, Van Den Dungen, & Rosin, 2011). Since this time it has seen high country systems shift to a minimal input approach, reduction in stock numbers to levels more sustainable without SMP's, and system diversification. The key shifts in system diversification were to increase proportion of cattle and move from a sole fine wool production to dual purpose meat and wool production.

The current average high country operation consists of 80% sheep and 20% cattle. The key source of income is still from wool at 45% of net cash income, but a considerable decrease from the 70% of farm income typically seen prior to the 1980's. Sales of sheep and cattle progeny make up the bulk of additional income with sheep sales contributing 27% and cattle sales of 16% (Ministry of Agriculture and Forestry, 2009). Of these livestock sales they are predominantly store stock, with general practice to sell majority of progeny (less replacements) at weaning. This takes significant stock pressure off the property allowing pastures to recover during autumn prior to the onset of winter. Merino sheep are still the largest sheep breed in the high country however there is an increase in the number of dual purpose sheep being used or merino ewes mated to a terminal ram. Two main cattle breeds continue to predominate in the high country, Angus and Hereford, due largely to their hardiness and resilience (Morris, 2013).

In contrast to other New Zealand pastoral regions the high country is dominated by native and unimproved grasslands. Tussock species dominate majority of pastures, with historically oversown areas having a higher production level and dominated by the low yielding but persistent pasture species Browntop (Scott, Keoghan, & Allan, 1996). On average 10-20% of farm area would be/have the ability to be of improved pastures and as stated by Matthews et al. (1999) of this minor proportion of land up to 80% of total pasture production can be attributed. Overall farm carrying capacity can be strongly influenced by the development and improvement of pastures on this 10-20% of land, with a consequential increase in stocking rate of up to 4SU/ha as opposed to 1SU/ha or less in a completely undeveloped system.

2.4 Key Limitations to Pasture Production in High Country Systems

2.4.1 Aluminium Toxicity & pH

Aluminium (Al) toxicity is where phytotoxic Al species (primarily Al^{3+}) are at concentrations in soil solutions that have adverse effects on plant growth (Berenji, 2015). Most Al in soil is bound to ligands, forming aluminosilicates and precipitates, or occur in other non-phytotoxic forms (Delhaize & Ryan, 1995). At pH>5 generally greater than 80% of soluble Al is hydrolysed. Al entering solution co-ordinates with H_2O to undergo hydrolysis. As the extent of hydrolysis increases charge density of Al molecules decrease, and increased polymerisation, intermediate in precipitation process, occurs (Menzies, 2003). Thus higher pH results in increased precipitation and less phytotoxic Al in solution (Figure 1), however solubility of Al increases as pH decreases, as phytotoxic forms of Al are released from precipitates (Delhaize & Ryan, 1995).

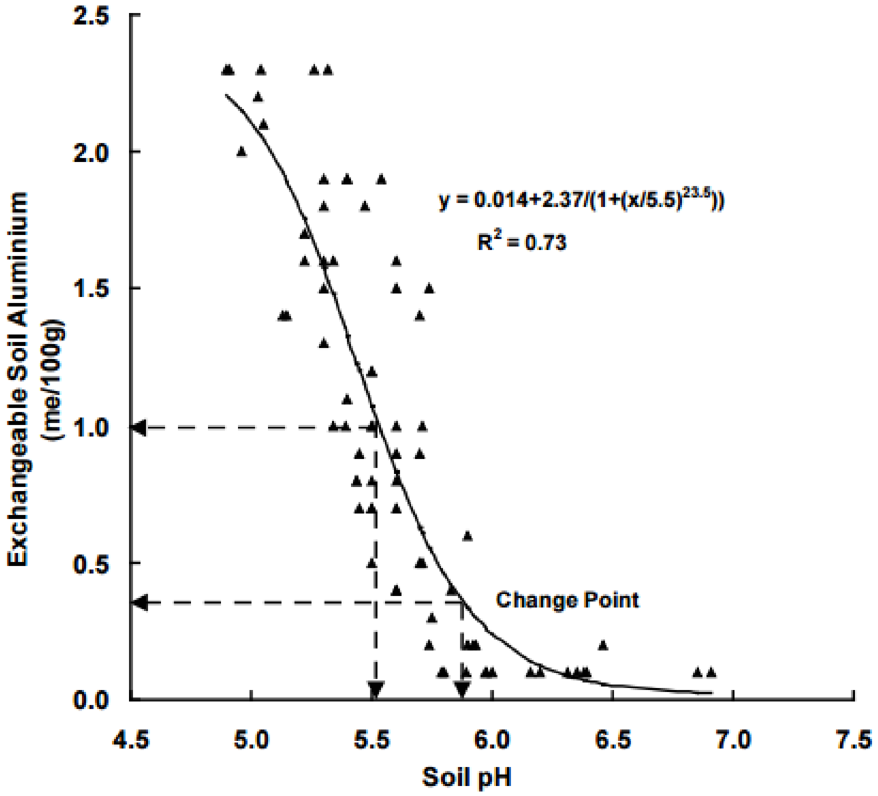

Figure 1: Relationship between exchangeable soil aluminium and soil pH, at Lees Valley, North Canterbury. (Moir & Moot, 2010).

Al toxicity is of particular importance in New Zealand due to the large presence of acid soils in hill and high country pastoral systems. Acid soils by definition are those of pH < 7, which is measured in terms of H^+ and Al^{3+} in soil solution (Berenji, 2015). Soil acidification naturally occurs as soils age and weather, as a result of base cations being leached from the soil. This results in an imbalance between base cations and acidic H^+ and Al^{3+} ions (Delhaize & Ryan, 1995). Soil acidification is particularly dramatic in South Island high country due to accelerated weathering processes, and economic constraints to liming inputs as a result of limited input of extensive pastoral systems (Scott, Round-Turner, & Ryde, 1995).

Al is recognised as a common growth limitation on acid soils, with phytotoxic forms of Al entering solution and effecting both plant and root functions. Typically roots are the most effected with Al toxicity resulting in inhibition of primary root growth, root brittleness and occasionally resulting in a necrotic state (Menzies, 2003).

pH has not been shown to have any adverse effects on pasture production or persistence. However low pH is a key contributing factor to aluminium toxicity as mentioned above, and also has effects which limit the availability of certain soil nutrients, most importantly phosphorous.

Mitigation of low pH should be the first step in trying to remediate issues such as aluminium toxicity and phosphorous deficiency (Berenji, 2015). Application of lime ($CaCO_3$) is the most common and cost effective form of raising soil pH, however the effect of liming varies greatly with different soil types and depth of acidity (Michael, 1985). McIntosh (1980) reported that on average South Island soils applied with 1t/ha lime raised the average soil pH by 0.14 units, however the magnitude of effects varied from 0 to 0.32 depending on initial pH and soil type. Moir and Moot's (2010) study had similar findings for a field trial in the Lees valley, with average soil pH changes of 0.15 units/ t lime. When this was separated into soil horizons the top 0-7.5cm had a change of 0.28 units/t lime compared to only 0.03 units/t lime for the lower 15-30cm depth.

This highlights a key limitation of surface lime application in soils where acidity is spread throughout the profile. In such circumstances liming will be ineffective as plant root growth will be limited below depths of 7.5-10cm. The potential for subsoil lime application, to remediate subsoil acidity, has been identified however more research is required to show its potential effects. In cases where soil acidity cannot be remediated by application of lime, it instead becomes a case of finding pasture species able to tolerate low pH and potentially high Al concentrations and low phosphorous availability.

2.4.2 Soil Nutrient Deficiency

The two key limiting nutrients in high country systems are nitrogen and phosphorous. Similarly to the reasons for why pH is often low in these systems, these two essential nutrients are generally deficient as a result of limited fertiliser and lime application due to economic constraints (Scott, Round-Turner, & Ryde, 1995).

Phosphorous is an essential plant nutrient which is generally taken up by the plant as the phosphate ion (PO_4^{3-}) from the soil solution and labile fraction. The majority of phosphate is absorbed by mycorrhizal fungi at the root tips (Figure 2) before being distributed around the plant for a number of functions. A key role of phosphorous in plants is in areas of high metabolic activity, leaf, shoot, root, and seed development. Phosphorous plays an important role in photosynthesis, regulating starch and sugar synthesis (Hart, 1980). Phosphorous (P) is also a key constituent of the ATP molecule which is responsible for the transport of chemical energy within the plant, providing energy enabling processes such as development to occur.

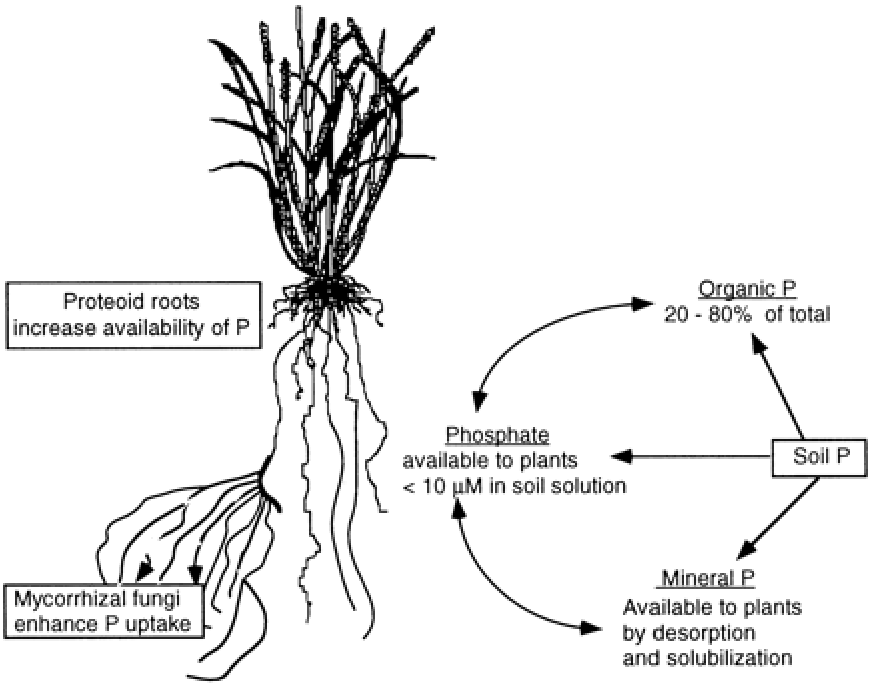

Figure 2: Phosphorous uptake by plants from soil (Schachtman, Reid, & Ayling, 1998)

Plant available P generally only makes up a small fraction of soil P as the majority of P can become bound in the soil, unavailable for plant use (Condron, 1986). As the soil surface positive charge increases, the electrostatic attraction of hydrous oxide colloids becomes greater to exchangeable P and as a result P becomes adsorbed to the colloid surface (unavailable for use). The lower the pH the higher the positive charge of colloid surfaces, and as a result an increase in P adsorption (Condron, 1986). Thus low plant available phosphorous levels in South Island high country soils is largely a result of inadequate soil pH. Soil phosphorous deficiency has flow on adverse effects for pasture production, most significantly legume performance and thus a decrease in nitrogen fixation.

The availability of phosphorous therefore becomes crucial for not only individual plant function but also sward yield and quality. With sufficient plant available phosphorous both desired grass and legume species are able to dominate the sward yet when soils become P deficient plants with low phosphorous requirements dominate (Hart, 1980). In most New Zealand pastoral systems the species which dominate in P deficient soils are of low and dense growth, e.g. Browntop and Hieracium, and as a result smother out legumes and desired grass species. To develop/maintain high quality pastures it is crucial to have adequate plant available phosphorous.

2.4.3 Difficulty in Legume Establishment/Persistence

As mentioned above the difficulty in maintaining high legume content in high country pastures is largely a result of low soil pH resulting in potential Al toxicity issues and deficiency in plant available soil phosphorous. In many New Zealand pastoral systems there are limited fertiliser inputs largely driven by cost and topography. As a result such systems rely on legumes as the key source of Nitrogen (N) input. Brown and Green (2003) stated four key roles of legumes in the future of hill and high country systems: persist within a general purpose pasture, fix nitrogen, improve summer feed quality, and to improve year round feed quality through specialist crops and pastures. The atmospheric N fixed by legumes is generally the key source of N input into extensive systems, with N fixation critical as N is often the most limiting nutrient for such pastures (Scott, 2003). The fixed nitrogen can be used by companion grass species to increase DM yield as well as quality (ME) therefore increasing legume content results in an increase in total sward quantity and quality.

Where possible liming of acidic soils should be the initial strategy to improve legume abundance however in some soils where acidity and Al toxicity is spread throughout the soil profile, liming may not be an effective measure to improve the soil. This is because lime has been shown to be particularly effective in the top 0-7.5cm soil fraction however below this effectiveness decreases with near negligible effects below 15cm (Moir & Moot, 2010). Thus large increases may be seen in the topsoil pH however legume growth will still be restricted due to Al toxicity effecting roots in the lower soil fractions.

In circumstances where soil acidity and Al toxicity cannot be remediated through liming or it is uneconomic to do so, the strategy should be instead to find a legume species which is able to tolerate such soil conditions. Limited study has been done comparing the tolerance of legume species to low pH/Al toxic soils, however by extrapolating results from a number of trials a rough ranking can be produced: *Lupinus polyphyllus = Lotus pedunculatus > Trifolium repens > Trifolium subterraneum > Medicago sativa* (Davis, 1981) (Andrew, Johnson, & Sandland, 1973). There is a large range in legume tolerance to acid soils and Al toxicity with species such as Lucerne being particularly sensitive with growth generally limited below pH 5.8 (Berenji, 2015). Species such as Russel Lupin however are particularly tolerant to adverse soil conditions and able to thrive where other legumes could not persist (Berenji, 2015).

2.5 Land Development in High Country Systems

Increasingly flat and intensive land is being consumed by higher return farming operations including dairy and arable, with sheep and beef being pushed onto higher more marginal ground. Approximately 10% of New Zealand's total land area is occupied by high country farming systems, however they hold only 5% of livestock, and are responsible for 3-5% of NZ farm income (FAO, 2009). Development is an essential component of such systems, allowing farms to increase carrying capacity and stay competitive/profitable, ensuring the long term economic sustainability of the operation. Majority of practices used for hill country development are concepts that have been around for many years however land development in high country systems is still low with reluctance from many farmers to invest in development (Hunt, Van Den Dungen, & Rosin, 2011). This is largely due to risk averse thinking, with the traditionalist approach of low cost and minimum input (Kavoi, Hoag, & Pritchett, 2010).

There are several methods that will be discussed for physical land development however before looking at such investment there are cheaper and lower risk opportunities through fine tuning farm management practices. Investment in physical land development will not yield true potential and could result in unsatisfactory results if these factors have not been considered first (Frengley & Anderson, 1989). These options include subdivision, capital fertiliser application, and stocking intensity/stock management. Subdivision provides many gains including reduction in nutrient transfer, better feed utilisation, and ability to better manage feed surpluses and shortages. Baker & Associates (2012) analysed the return on investment in subdivision and found return would be expected to be no less than 27%, a high ROI with only medium risk. Capital fertiliser application is the next option and can be used to both boost the production of current sward species and also encourage growth of legumes and more favourable pasture species. When analysed by Baker and Associates this was also seen as a medium risk option with a potential ROI of 25-35%. Also increasing stocking rate and rotationally grazing as opposed to continuous stocking was found to improve evenness of grazing within a block and encouraged non-selective utilisation, breaking down thick swards and preparing the pasture for future oversowing (Gaukrodger, 2014).

A key consideration to be made with any development is the management factor and management ability. Development, especially on a larger scale, is going to result generally in not only an increase in stocking rate and intensity but also in a stock policy change and the incorporation of more finishing (Gaukrodger, 2014). It needs to be evaluated that if such development were to occur, does the management ability and goals meet the changes that would result from development. As ultimately the outcome of any change in farm management/farm system is largely dependent on the ability of the manager (Frengley & Anderson, 1989).

2.5.1 Methods for Land Development

Oversowing "Spray & Pray"

A method used for many years especially in areas where it is too steep to cultivate. Original success rates were extremely varied and often establishment rates were less than 1% (Morris, 1970). This was largely due to two reasons, the use of the wrong pasture species/cultivars, and inability to compete with tussocks and other thatchy sward components. Pasture species originally used were "national cultivars" that were bred primarily for intensive lowland systems. Unsurprisingly they were not suited to this different environment and often failed to reach full potential resulting in regeneration to low producing dominant species such as Browntop and Hieracium. Success of oversowing has been drastically increased as a result of breeding for specific cultivars/species and the large increase in herbicide use (Frengley & Anderson, 1989).

Oversowing typically involves application of non-selective herbicide followed by spreading of seed and fertiliser, and post emergence weed control. One or two short rotation crops are used to build organic matter and break down old pasture thatch before returning to permanent pasture in the second or third year (Gaukrodger, 2014). Findings of Gaukrodger (2014) estimated cost of development as $2,100 to $2,350, similar to the costings, $2,000/ha, of Southland farmer (Lindsay, Lindsay, & Lindsay, 2016).

Advantages of this practice include that minimal capital outlay is required as all application is by contractor, helicopter. As the soil surface is not broken the risk of both wind and water erosion is reduced. Another key advantage stated by Morris (1970) is that it is a cheap method and can rapidly cover large areas, with terrain and vegetative covers not restrictive to the area able to be developed. Some disadvantages include that initial establishment may be poor and is heavily reliant on rainfall post oversowing. Low soil moisture is a large issue as the seed is not embedded in the soil but only sitting on the surface thus prone to drying out and cracking (Morris, 1970). The other key issue other than establishment is potential weed pressure post-strike. If weeds do stress the crop post emergence this can result in large development cost increase as herbicides need to be applied aerially.

Conventional Cultivation

Pasture renewal on hill country able to be accessed by machinery have used physical means, bulldozing and cultivation, to clear and contour land for many years. Such development is considered high risk as the soil structure is being altered and can upset available topsoil. In addition to this ground is left bare for extended periods thus increasing the risk of soil erosion (Gaukrodger, 2014). Conventional cultivation typically involves the spraying or burning of resident sward before two to three passes of cultivation to produce a fine and even seedbed. Seed is then drilled into the soil and similarly to over sowing general convention is a rotation of crops to build organic matter levels before drilling permanent pasture in the second or third year (Morris, 1970). Analysis by Baker and Associates Limited found up to 26% return on investment could be achieved if stock policy was suitably changed to incorporate development, but if no change was made negative return was likely (Gaukrodger, 2014). The advantages of this method is that pasture is produced with even establishment, greater certainty of success, and generally of higher production in initial years. But this method is more expensive than others and considerable capital outlay is required if there is not sufficient access to contractors. Also the developed area is out of pasture for a greater length of time due to cultivation period and there is high risk of erosion as soil is left bare (Morris, 1970).

Direct Drilling

The third pasture renovation option and one of growing popularity in hill country development is direct drilling. Although a method which has been used since the 1960's it has only come into real popularity in hill country systems over the past decade. This is largely as a result of farmers becoming more aware of the potential effects of soil erosion and vulnerability of the soil in a full cultivation method. On top of this direct drilling has received a greater level of attention and supported by experimentation results has proven itself to be a successful renovation option (Davies, 2012).

Direct drilling initially requires removal of the resident pasture by either burning or herbicide application with the first crop then drilled directly into the stubble of the previous pasture or after a fallow period. A chisel plough or sod seeder are used to drill both fertiliser and seed into the subsurface without destroying the cover of the previous sward (Morris, 1970). Similarly to the other two methods previously mentioned initially one or two green feed crops are drilled to build organic matter and break previous pasture thatch before then drilling into a permanent pasture (Gaukrodger, 2014).

Direct drilling is a relatively cheap establishment method, cheaper than both full cultivation and oversowing (Gaukrodger, 2014). The other key advantage is that the soil structure and surface is retained thus dramatically reducing the risk of soil erosion from what is potential by full cultivation. However like full cultivation this method is limited to areas where the topography is tractor accessible. The establishment of the crop is quick and even but initial production can be expected to be lower than full cultivation but will match production in one to two years. Risk of failure is generally low as seed is being drilled into the soil and as the soil surface is not broken soil moisture levels are retained (Morris, 1970).

2.5.2 Cost of development

Published data about cost of development is relatively limited, with majority of references from prior to 1990. In addition to this there were no publications able to found which directly compared the cost of development and resultant production between the three methods and as resources range over a period of thirty years prices given between references cannot be compared. It can be said though that direct drilling will be the cheapest method of development with both oversowing and full cultivation considerably more expensive. Initial higher yields can be expected from cultivated or direct drilled pastures than that of oversown however these two methods are limited to ground which is able to be driven with machinery. A key factor to consider with cost of development and production, as stated by Gaukrodger (2014), is that it is difficult to quantify the cost of development. As the direct development costs may remain relatively constant between properties or even blocks but the required cost of preparation changes dramatically, dependant on the initial state and the input required. The preparation prior to development, improving pH, fertility and subdivision, are key to development success and it is these factors which will heavily influence the overall costs.

2.6 Climatic Effects on High Country Production

2.6.1 Description and Effects of Dryland Pastoral Systems

Approximately 19% of the East coast of the South Island is affected by periodic drought/summer dry conditions annually. Average rainfall in such areas is generally 650-700mm/annum or below. This is about half the rate of annual evapotranspiration, which means a dry period usually develops through summer and autumn (Scott, 2003). The severity of summer dry differs greatly depending on the area and the weather for the given season, with an El Niño weather pattern generally resulting in drier than average summers and having widespread drought effects across the East Coast of New Zealand (NIWA, 2016). These dry summer conditions have a large impact on pasture production and as a result become one of the key considerations and factors effecting management for such systems. Specifically, in dryland East Coast systems the aim is to get lambs off the property prior to the onset of summer water stress. This reduces grazing pressure for capital stock over the dry period, and also has the financial incentive of selling lambs while demand is greater than supply, a balance which quickly shifts when the dry period sets in (Shadbolt, 1981). In dryland areas spring pasture growth is usually reliable as soil moisture is non-limiting and pasture growth rate increases as a response to rising temperature (Rickard & Radcliffe, 1976). Dryland farmers therefore require pastures that supply a high yield of quality feed early in the spring that will also perform and persist through the summer dry conditions.

2.6.2 Farm Management Approaches to Mitigate Impacts of Climatic Variation

The use of irrigation is one potential strategy to mitigate impacts of climate change and summer dry conditions. Irrigation is used widespread throughout Canterbury within dairy and arable farming, 58 and 23% of use respectively, but use within sheep and beef farms is limited to only 18%. Currently 500,000ha within Canterbury is irrigated, with the additional potentially irrigable land estimated as 350,000 to 600,000ha (Saunders & Saunders, 2012). Of this potentially irrigable land a significant proportion is in the foot hills and valley floors of the Canterbury high country. The impact of irrigation on pasture production in dry land environments is significant particularly over the summer and autumn periods where water stress is removed (Houlbrooke, Paton, Littlejohn, & Morton, 2010). The increase in pasture production as a result of irrigation have been quantified in several studies with dry matter production increased by anywhere from 5 to 11tDM/ha/yr (Houlbrooke, Paton, Littlejohn, & Morton, 2010) (Peri, Moot, McNeil, Varella, & Lucas, 2002). Irrigation has been found to alter the composition of the pasture sward, with grass species becoming dominant under irrigated conditions and smothering legume species. This results in a reliance in many cases on the use of nitrogen fertiliser, as legume content and subsequent nitrogen fixation becomes significantly reduced (Houlbrooke, Paton, Littlejohn, & Morton, 2010). Other factors limiting the potential for irrigation use in dryland pastoral systems include the large capital outlay required to develop infrastructure for irrigation systems. A cost which would be unfeasible or uneconomic to service for many extensive sheep and beef operations. In such instances where the use of irrigation would not be feasible or practical the focus for mitigation should instead be on identifying pastoral species more tolerant to dry conditions.

An increasing amount of study has been conducted into pasture species which are more persistent in dry land environments and more tolerant of extended dry periods, with specific emphasis on increasing sward legume content, increasing total annual dry matter production, and increasing pasture survivability and persistence in harsh summer conditions. One option which has the potential to take the role of perennial ryegrass white clover swards in dry land environments is Cocksfoot. Cocksfoot (*Dactylis glomerata*) is the second most grown pasture species in dryland conditions after perennial ryegrass (*Lolium perenne*) (Charlton & Stewart, 2000).The potential of cocksfoot as the dominant dryland pasture species and compatible companion legume species has been the focus of several studies, including those of Brown et al (2006), Mills and Moot (2010), and Moot (2010).

Cocksfoot is a drought tolerant perennial grass species that grows well through summer dry conditions. It has growth adaptations allowing performance and persistence unrivalled by other grass species in this environment. Some adaptations allowing this performance include its extensive root system, high pasture pest tolerance, and endophyte free which results in few summer animal health issues (Hackney, 2007). Cocksfoot's deep, extensive root system provides the ability to extract a greater amount of soil water and for longer periods in extended drought than other pasture species (Volaire, 2001). Cocksfoot is also reported to have a high tolerance for pasture pests (Hackney, 2007) which can put additional stress on struggling summer pastures. Although unknown what causes this increased pest resistance the effect was shown by Henderson (1979), who compared several grass species when treated with and without insecticide. Yield increase from insecticide application for cocksfoot was only 3t DM/ha over the four years, compared with up to 8t DM/ha increase for other perennial ryegrass species. Not only does this result in an increase in annual pasture production, but also a potential economic saving as a result of reduced requirements for pasture pest control. Mills (2014) dryland study at Lincoln quantified live weight (LWT) production of sheep on Cocksfoot/Sub-clover and Ryegrass/White clover over an eight year period. Cocksfoot produced a total of 7270kgLWT/ha, 28% higher than that of the ryegrass sward. The Cocksfoot/Sub-clover sward produced 13tDM/ha in the first year and 10tDM/ha in the final year, far greater than then 10.5 and 8.3tDM/ha produced respectively by the Ryegrass sward.

Nitrogen is a key limiting factor in dryland pastures, and is a crucial nutrient for successful DM production of high quality cocksfoot in such environments. Morris (2011) found in some eight year old dryland pastures if legume content is less than 6% of total sward composition then total available N for cocksfoot would be limited. It is thus crucial that Cocksfoot is grown in conjunction with clovers, so as to maintain a persistent sward of high quality (Charlton & Stewart, 2000). A vital role of legumes is the ability to compete with grasses rapid spring growth as temperature and moisture become non-limiting but also the ability to survive and persist through summer dry conditions.

Legume incorporation in dryland pastures is critical for high quality and persistent pasture production however few species have proven to be suitable companions able to survive such conditions. Subterranean clover has proved to be a suitable companion species, able to compete with vigorous spring growth and able to survive and persist summer dry conditions. As an annual clover, sub clovers growth patterns fit in well with dryland grass species such as cocksfoot. Vigorous spring growth ensures it is not smothered by rapid grass growth, and is able to persist in dry summer conditions by setting seed in late spring and dying out over the summer months (Hyslop, Slay, & Moffat, 2003). Sub clovers dryland potential as a companion to cocksfoot has been quantified by Brown et al (2006) who compared dry matter production of cocksfoot sown with four separate clovers in a dryland environment.

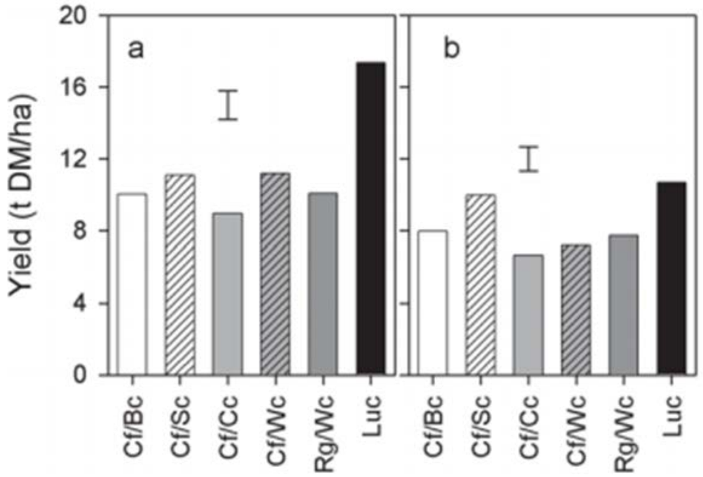

Figure 3: Annual dry matter production of cocksfoot sown in conjunction with, Balansa, Subterranean, Caucasian, and White clovers, with ryegrass/white clover and Lucerne controls (Brown et al, 2006)

Subterranean clover competed on par with that of white clover in the wet spring of 2004-05 (Figure 3/a) both producing 12t DM/ha which is significantly greater than the other two species who each produced <10t DM/ha. Clear difference in results came in the dry summer of 2005-06 (Figure 3/ b) in where sub clover clearly out produced the three other clovers producing approximately 10t DM/ha compared with <8t DM/ha for the other three clover species. The 2005/06 results show that white clover is not a compatible species to be grown in dryland conditions, as it is outcompeted for moisture over the summer months due to its shallow rooting system (Brown, Moot, Lucas, & Smith, 2006). Sub clover has proven to be the most suitable companion species in dry land environments with its annual growth pattern allowing it to both compete during rapid spring growth and survive dry summers by entering a state of dormancy after setting seed. The production of cocksfoot/sub-clover pastures has only been outperformed in dryland conditions by that of Lucerne monocultures.

Lucerne is a tap rooted perennial legume that has been grown across New Zealand for over 100 years. It is known for its persistence and resilience in dry land environments, which is largely attributed to its tap root which can extend over 2m into the soil profile. This allows it to continue to extract soil water in dry periods long after that of other fibrous rooted pasture species (Berenji, 2015). Lucerne is most generally grown as a monoculture and used as a specialist crop for stock finishing. In environments where water is non-limiting Lucerne can yield over 20tDM/ha/yr. and in dryland conditions can produce 12-16tDM/ha/yr. (Langer, 1968) (Peri, Moot, McNeil, Varella, & Lucas, 2002). Despite Lucerne's advantages of being able to persist long into dry periods as a result of its tap root and able to produce high yields, its use is limited by some key disadvantages. Firstly that it is extremely sensitive to acidic soils and aluminium toxicity, not being able to persist below a pH of 5.8. This limits its use where soils are strongly acidic and unable to be remediated by surface lime application (Berenji, 2015). Secondly is that Lucerne is a specialty crop and needs to be treated differently to other pasture species. The two key differences are that Lucerne is not tolerant to set stocking due to its high growing point and therefore needs to be rotationally grazed, and also that Lucerne is predominantly winter dormant and requires an extensive rest period following final autumn grazing (Langer, 1968). These factors will not be of any adverse effect if using Lucerne as a specialist finishing option however may not be suitable if trying to be used as a replacement for a perennial pasture species. Where suited it is a dominant dryland pasture species, however, its use may not be suited in all management systems.

Chapter 3
Methodology

3.1 Introduction

This study was carried out in three parts. Firstly, a case study interview with Mid Canterbury farmers John and Anne Chapman and farm manager, Bert Oliver, was used to gather actual and historic information around their farm system and experience with development. Secondly, scenario modelling using Farmax Pro was used to determine the feasibility and profitability of a range of development options, as well as to give comparison between scenarios and against the base model. Thirdly, Farmax models were reproduced in a linear programme using Microsoft Excel, the results from this model were used to validate those of the Farmax models.

This chapter summarizes methodology used to collect and analyse information throughout this research project. It also highlights how the interview participants were selected and any confidentiality issues.

3.2 Data Collection

A case study approach was used for this research as a method to gather specific information from actual farm data about current farm system and individual experience with land development. The Chapmans', Inverary Station, were selected to be involved in this research project due to their farm system and land type typifying that of many Canterbury hill and high country farms, and that the Chapmans' historically and at present have been involved in hill country development. Prior involvement in hill country development has the advantage that there is actual data and documented performance, giving a greater level of certainty when using this information to model scenarios and predict future performance.

An interview template was prepared in advance and forwarded through to the interview participants (Appendix A). The template included a comprehensive set of tables to be filled out with farm data of both the undeveloped and developed farm systems, as well as a set of questions to further this data and gain information as to the objectives and risks of development. By making the questions available in advance, it was hoped that a higher level of quantitative data was able to be achieved as it gave the farmer time to find and prepare the necessary budgets, invoices, and other information sources.

The interviews were carried out in June 2016, informal interviewing with both John Chapman and farm manager, Bert Oliver, they continued through the year via email and phone calls. The interviews were semi structured asking a mixture of quantitative and qualitative research questions. The aim of the interviews was to collect specific information on land development strategies and costs, as well as production and performance results for both developed and undeveloped areas. The interviews were in depth and looked to gain as much information possible around the current system and development, as this data would form the basis of the base and scenario models. The initial main interview was also recorded by Dictaphone, so that any information that was discussed in addition to that in the template, could be reviewed at a later date.

Permission for the interview to take place and for it to be recorded was received prior to the interview. The farmer was made aware that the research was being conducted as part of the requirements for an Agricultural Science Degree Honours dissertation at Lincoln university, and that the final document would be published.

3.3 Data Analysis

3.3.1 Farmax Modelling

Farmax Pro is a farm modelling software that has been developed based on over 20 years of AgResearch research to assist in making tactical and strategic farm management decisions on sheep, beef, and deer farms. The programme can be used to both monitor and model farms, to predict animal, farm, and financial performance. For this research Farmax Pro was used as a modelling tool, with the key output being comparison of financial performance for a range of different development scenarios.

The monthly pasture growth output in Farmax is based on the pasture type and climate, this can either be produced manually or from generic Farmax pasture and climate data. This pasture growth curve (metabolisable energy supply) is the key determinant in the feasibility of the farm model. This coupled with animal demand, from number and class of animal determined by the person modelling, will put the farm in either a feasible or infeasible state. Where the model is infeasible animal demand exceeds available pasture supply, taking supply below minimum pasture covers. To be a realistic farm scenario the model must be in a feasible state.

For all scenarios modelled the livestock levels were set to a level of maximum feasibility. This is where livestock levels are increased to a point at which the model becomes infeasible and then reduced to the point of highest feasibility. This technique was used to ensure consistency in the level of stocking intensity between scenarios.

Five scenarios were investigated using Farmax.

- Oversown Hill – To simulate a typical hill/high country pasture dominated by Browntop (*Agrostis capillaris)* and Yorkshire fog (*Holcus lanatus)*, with a history of topdressing.

- Developed Permanent – The same land type as that of the Oversown Hill, but developed into a new permanent pasture of Perennial Ryegrass (*Lolium perenne)* or Cocksfoot (*Dactylis glomerata).*

- Flat Intensive – Flat to rolling hill country which can all be accessed by truck and tractor. Developed into an intensively cropped pasture such as Plantain (*Plantego lanceolate) /* Red Clover (*Trifolium pratense),* set up in a five-year rotation.

- Steep Intensive – Steep hill country which has limited truck and tractor access, able to be drilled (downhill) but all fertiliser and spray is required to be aerially applied. This scenario has had the same land development and same intensive cropping regime as that of the Flat Intensive, but is of a different land class.

- Selective Development – Utilising proportions of the land area to maximise summer and winter ME supply, but the bulk of the land remains undeveloped as in the Oversown Hill scenario. 66% of land area remains undeveloped, the same as the Oversown Hill, 25% is put into an intensively cropped pasture, the same as the Flat Intensive pasture, and the remaining 9% is put into a high yielding winter crop such as fodder beet (*Beta vulgaris)*.

Table 1: Average metabolisable energy (ME), and annual pasture yield (kgDM/ha/yr.) of Farmax modelled scenarios

Land use	**Average ME**	**Yield (KgDM/ha/yr.)**	**Total ME Supply (MJME/ha/yr.)**
Oversown Hill	9.5	6,000	57,000
Developed Permanent	12	12,000	144,000
Flat Intensive	12	10,000	120,000
Steep Intensive	10.2	10,000	102,000
Selective Development: Native pasture (66%) Intensive pasture (25%) Fodder beet (9%)	 9.5 12 12.5	 6,000 12,000 16,000	 37,620 36,000 16,000

Constant factors between scenarios

As many variables as possible were kept constant between these scenarios so as to try and isolate the difference in pasture production and supply curve, and cost of production as the two key variables to be analysed. To achieve this, for all scenarios these factors were kept constant:

- Each scenario was set to a fixed area of 100ha, and land type of South Island High Country
- All scenarios ran a maternal Romney ewe flock. Ewes were of an average live weight of 65kg shorn annually, ewes are mated to a Romney ram lambing 125% (to weaning). All hogget's are kept on farm, with a replacement rate of 20% mixed age ewes.
- Lambs are weaned at a constant date of the 27th January, at an average live weight of 28kg. In scenarios where lamb finishing is possible, lambs are finished to a live weight of 38kg with lambs above this weight drafted out monthly. In all scenarios all lambs (except replacement ewe lambs) are off farm by the 1st of June.
- All product prices were produced by the Farmax model. These product prices come from an online database which is updated weekly with schedule actuals from the major processing and livestock selling plants.
- Scenarios are all set in the long term modelling function

For all scenarios which include land development (Developed Permanent, Flat Intensive, and Steep Intensive) there is also a cost per hectare included in the expenses to represent an annual loan repayment for the capital cost of initial land development. The principal ($170/ha/yr.) is represented under the Rent/Lease title, and the interest payment ($22/ha/yr.) is represented under the Interest title. (Appendix B).

Variables between scenarios

Oversown Hill

For this scenario the pasture was set to the Farmax default "low quality pasture" to simulate a Browntop dominant pasture. The growth curve for this pasture was produced manually based on Beef and Lamb growth rate data derived from Ben and Anna Toddhunters' property. The growth rates were then proportionally increased to achieve an annual yield of 6,000kgDM/ha.

The expenses were set to the Farmax default set of South Island high country, with some costs altered so as to match the interview data. The costs altered for this scenario were the fertiliser cost ($91/ha) and weed and pest ($34/ha) (Appendix B).

Developed Permanent

Pasture was set to the Farmax default "high quality pasture" to simulate a new permanent ryegrass or cocksfoot pasture. The growth curve was also produced manually based on Beef and Lamb pasture growth data derived from, Ben and Anna Toddhunters' property (Farmax, 2016). The growth rates were then proportionally increased to achieve an annual yield of 10,000kgDM/ha.

A new expenses page was created called, South Island High Country (2). This was produced from the Farmax default South Island High Country 2016, with a number of costs altered. Costs altered were, fertiliser ($91/ha), weed and pest ($60/ha), regrassing ($33/ha), as well as wages being set to double that of the Oversown Hill to represent the increase in labour requirement as a result of development.

Flat Intensive

A new pasture type "plantain/red clover" was produced, to accurately represent the quality and yields achieved by the Chapmans' with this sward. Energy content was altered so as to achieve an average ME of 12/kgDM. The pasture yield and its growth curve were produced based on interview data, with annual yield of 12,000kgDM/ha/yr.

As with previous scenarios a new expenses page was produced, South Island High Country (3). The costs altered were, fertiliser ($130/ha), weed and pest ($250/ha), regrassing ($62/ha), and wages also altered to double that of the Oversown Hill, to represent the increased demand from development (Appendix B).

Steep Intensive

Pasture type was set to plantain/red clover, the same pasture which was created in the Flat Intensive model. The growth curve was then proportionally altered so as to achieve an annual yield of 10,000kgDM/ha.

A new expenses page was produced, South Island High Country (4). The costs altered were, fertiliser ($91/ha), weed and pest ($386/ha), regrassing ($99/ha), and as with the two other developed scenarios the wages were double that of the Oversown Hill (Appendix B).

Selective Development

Selective Development consists of areas of Oversown Hill pasture, Flat Intensive pasture, as well as fodder beet. Majority of the land area, 66%, is in Oversown Hill pasture. This proportion of the block has identical pasture quality, production, and expenses as that of the Oversown Hill scenario. 25% of the area is in plantain/red clover, with this proportion of the block set up identically to that of the Flat Intensive scenario.

The remaining 9% of the area is in Fodder Beet crop. The crop is taken off the default Farmax default, fodder beet, with yield altered to 16,000kgDM/ha/yr. The expenses for this crop are taken from interview data, $1,400/ha.

For this scenario both the plantain/red clover and fodder beet are considered to be forage crops. The costs per hectare for plantain/red clover are equal to that of the intensive scenarios, however in this scenario the costs are shown under “feed/crops/grazing” (Appendix B).

Table 2: Variable costs for Farmax scenarios. Those altered from the South Island High country default figures, all values come from interview data

Land Type	**Fert. Applied**	**Fert. Cost ($/ha/yr.)**	**Spray application**	**Spray Cost ($/ha/yr.)**	**Resowing**	**Resowing cost ($/ha/yr.)**	**Total cost ($/ha/yr.)**
Oversown Hill	200kg SS 30% Plane applied	91	Spray Matagouri 1 in 5 years, plane applied (Metsulfuron, Pulse) 1hr/ha Spot Spray	34	No resowing cost	0	**125**
Steep Permanent	200kg SS 30% Plane applied	91	1 spray annually, for first 5 years (Dictate) plane applied then 2hr/yr. spot spray	60	Regrass 1 in every 15 years Cocksfoot drilled on a $/hr basis, can only drill down steep faces	33	**185**
Flat Intensive	350kg SS 15%, Bulky applied	130	3x spray, ground applied (Dictate, Sequence, Gramoxone) 1hr Spot spray	250	Regrass every 1 in 5 years plantain + clover drilled on a $/ha basis	62	**442**
Steep Intensive	200kg SS 30% Plane applied	91	3x spray, 2x plane, 1x helicopter (Dictate, Sequence, Gramoxone) 1hr spot spray	386	Regrass every 1 in 5 years plantain + clover drilled on a $/hr basis, can only drill down steep faces	99	**576**

3.3.2 Linear Programme

A linear programme (LP) was produced to validate the findings from the Farmax modelling. The LP was produced using the Microsoft Excel, Add-In, Solver. The model was solving using the Simplex solving method, designed for linear problems, with the objective set to maximise profit. Several constraints were put on the model to keep outcomes within fundamental biological and economic limits.

The five scenarios which were analysed using Farmax were all replicated to be analysed in the LP. The growth curves, yields, and quality of each pasture block were set up equal to that of those for each scenario in the Farmax model. Costs were set up on a per hectare basis for each scenario with costings equal to that of the variable expenses as produced from the interview data. This annual variable cost Includes:

- Wages
- Fertiliser
- Weeds, pest, and disease
- Regrassing
- Principal and interest payment for developed blocks

Table 3: Annual service cost ($/ha/yr.) for each scenario analysed

Scenario	Cost ($/ha/yr.)
Native Oversown	181
Developed Permanent	328
Flat Intensive	746
Steep Intensive	889
Selective Development	505

Feed demand was produced independently for each stock class based on mega joules of metabolisable energy (MJME) requirements, and calculated on a fortnightly basis. MJME figures and equations were taken from (Rattray, Brookes, & Nicol, 2007). Maintenance, LW gain/loss, pregnancy/lactation, and shearing were all factors included when calculating feed demand. The LP was based on a maternal ewe flock identical to that in Farmax, all stock data is the same as that used in Farmax.

The flock structure was similar to that in the Farmax model, however also includes a terminal ewe flock. Which includes all ewes after the 6 tooth year, with all terminal ewes culled post weaning. Ewes are still considered a Romney ewe, lambing 125% (to wean), with lambs weaned in January at 28kgLW. Capital stock are given an annual maintenance cost, which is based on an animal health cost per stock unit for South Island High Country averages, this cost is derived from the Financial Budget Manual (Askin & Askin, 2012).

All scenarios were given a maximum land area of 100ha, the programme was then given the choice to either select to use a scenario option or not, how much of the land area it should utilise, number of ewes, and what markets lambs would be sold in. These decisions were constrained by the feed supply of the given scenario and its profitability. If the programme chose not to select the use of a given scenario it was deemed that it was not a profitable land use option and thus not feasible.

Chapter 4

Results

4.1 Initial Development Cost

Table 4: Itemised capital development cost ($/ha), for development from Matagouri and native pasture

	Rate/ha	$/ha
Lime	5t	140
1st spray	6L Roundup	90
2nd spray	6L Roundup	90
Tracking		25
Water	1 Trough + Pipe	85
Seed	Plantain + Legume	220
Capital Fertiliser	220kg DAP	220
Drilling		250
Fencing	Labour + Material	900
Total		**2020**

The initial (capital) development cost includes all necessary steps to take an undeveloped area into the first developed crop or pasture. This includes fertiliser and lime, spraying and drilling, but also all necessary infrastructure for development. In nearly all cases this requires significant subdivision, so that developed feed can be better utilised through grazing pressure, tracking and laneways to allow suitable access, and the installation of a water system as subdivision reduces access to natural sources.

This capital cost, regardless of topography, remained relatively constant across farm areas indicating that the initial land development cost is relatively constant for a given environment. This hypothesis was furthered by the development cost produced from interview data being very similar to that produced from the Lincoln University Financial Budget Manual (Askin & Askin, 2012) for a theoretical development of Canterbury High Country. The total cost for this theoretical scenario gave an initial development cost of $1,940/ha, only $80/ha different from the $2,020 produced from interview data.

Capital cost can thus be considered to remain relatively constant across topographies for a given environment, unless there are specific areas with significant land limitation which require large capital investment to remediate. For example, aluminium toxicity, acidic soils, extensive drainage requirement.

Table 5: Terms and annual repayment requirement, to service capital development cost by an amortised loan

Initial Development ($/ha)	2,020.		**Annual Payment ($/ha)**	**194.61**
Interest rate	5%			
Loan Term	15			

If the capital land development cost was to be serviced by an amortised loan, with a term of 15 years and interest rate of 5% per annum (Askin & Askin, 2012), it would require an annual repayment of $194.61/ha. Thus land development has to result in an increased gross revenue per hectare in excess of $195 to service the initial development cost, an increased return of less than this would be below breakeven point and development would not be a financially feasible option.

As capital development cost is a relatively fixed cost per hectare it is not going to be a key variable when determining whether or not to develop land. It is instead the annual (service) cost per hectare which will be the key determinant when deciding whether or not to develop land. The maintenance cost is largely determined by the topography and intensity of the system for that area, with a combination of the two determining the annual cost for pasture maintenance. It will be this cost coupled with the achieved production and associated economic benefits which will be the true determinant for the feasibility of land development.

4.2 Feasibility of Land Development Options

Table 6: Variable costs ($/ha/yr.) for each development scenario

Scenario	*Wages*	*Fertiliser*	*Weed & Pest*	*Regrassing*	*Principal & Interest*	*Total*
Oversown Hill	56.48	91	34	0	0	**181.48**
Developed Permanent	112	91	60	33	194.61	**490.61**
Flat Intensive	112	130	250	62	194.61	**748.61**
Steep Intensive	112	91	386	99	194.61	**921.61**

There are several key variable costs which have large fluctuations dependant on the farm system. It is these costs as seen in Table 6 which make up the annual service cost per hectare. This cost, coupled with production are the key determinants of profitability of a scenario, as if expenses are increasing disproportionally to the gain in production then there is ultimately going to be a net loss.

The Oversown Hill has the lowest expenses, as it has no regrassing or capital repayments, other expenses are also relatively small due to the extensive low input nature of native pasture systems. This is offset by the low energy content and yield of the pasture resulting in poor production levels. The Oversown Hill acts as the base line model which all other scenarios can be compared against, to be feasible any alternative has to have a greater profit ($/ha) than that of the Oversown Hill.

All development scenarios have higher expenses than that of the Oversown Hill due to the higher inputs of development to achieve an increased production. All developed scenarios have the same wage and principal expense, and it is primarily the weed and pest, and regrassing costs which have the largest influence on the annual service cost per hectare. Both of the intensive blocks have high regrassing, and weed and pest costs due to the regular spray requirement and the rotation policy of pastures renewed every five years. The Steep Intensive pasture has an exceptionally high cost which is high inputs coupled with the fact that spraying has to be done aerially and that paddocks can only be drilled downhill due to the topography, and thus effectively doubling the regrassing cost. The Developed Permanent pasture in comparison is a relatively cheap developed pasture option, due to a less intensive pasture management approach. Pastures are sprayed minimally and the pasture rotation is extended to 15 years thus dramatically reducing the annual cost of regrassing.

Table 7: Average Energy content (MJME/kgDM) and pasture yield (kgDM/ha/yr.) of development scenarios

Scenario	***Energy Content***	***Pasture Yield***
Oversown Hill	9.5	6,000
Developed Permanent	10.2	10,000
Flat Intensive	12	12,000
Steep Intensive	12	10,000

The high annual service cost of the intensive pastures is offset by the high quality plantain/red clover pasture that can be produced (Table 7). Both intensive pastures have an average energy content of 12MJME/kgDM, however the Steep Intensive pasture is only able to achieve a yield of 10,000kgDM/ha due to the steeper topography and more variable soil/growing conditions. The Developed Permanent pasture is able to grow an equal yield of pasture, with only a moderate reduction (1.8MJME/kgDM) in energy content.

Table 8: Profit and Loss statement, Farmax Pro, for all scenarios. Includes key income sources and farm expenses.

FARMAX — **Compare Forecast Profit and Loss**

Jul 16 - Jun 17

			Model 1 Oversown hill	Model 1 Developed Permanent Pasture	Model 1 Flat Intensive	Model 1 Steep Intensive
Revenue	Sheep	Sales - Purchases	36,834	69,547	107,171	92,988
		Wool	13,159	24,159	32,927	28,549
		Capital Value Change	0	0	-117	0
		Total	**49,993**	**93,706**	**139,981**	**121,537**
	Total Revenue		**49,993**	**93,706**	**139,981**	**121,537**
Expenses	Wages	Wages	5,648	11,200	11,200	11,200
		Management Wage	400	400	400	400
	Stock	Animal Health	3,278	6,040	8,834	7,659
		Shearing	5,118	9,429	13,791	11,958
	Feed/Crop/Grazing	Regrassing	0	3,300	6,200	9,900
	Fertiliser	Fertiliser (Excl. N & Lime)	9,100	9,100	13,000	9,100
		Lime	105	105	105	105
	Other Farm Working	Weed & Pest Control	3,400	6,000	25,000	38,600
		Vehicle Expenses	336	336	336	336
		Fuel	271	271	271	271
		Repairs & Maintenance	3,195	5,886	8,609	7,465
		Freight & Cartage	734	1,353	1,979	1,716
		Electricity	659	1,214	1,775	1,539
	Standing Charges	Administration Expenses	282	282	282	282
		Insurance	165	165	165	165
		ACC Levies	62	62	62	62
		Rates	208	208	208	208
	Total Farm Working Expense		**32,962**	**55,351**	**92,217**	**100,966**
	Depreciation		758	758	758	758
	Total Farm Expenses		**33,720**	**56,109**	**92,975**	**101,724**
Economic Farm Surplus (EFS)			**16,274**	**37,597**	**47,005**	**19,814**
Other Expenses		Rent/Leases	0	17,000	17,000	17,000
		Interest	1,149	3,129	3,129	3,129
Farm Profit before Tax			**15,125**	**17,468**	**26,876**	**-315**
Farm Profit per ha before Tax			**151**	**175**	**269**	**-3**

EFS is a measure of farm business profitability independent of ownership or funding, used to compare performance between farms.

EFS should include an adjustment for unpaid family labour and management. This can be added to the expense database as management wage.

Table 8 shows that the gross revenue is highest in the two intensive scenarios. The third highest gross revenue is from the Developed Permanent pasture, followed by the lowest revenue scenario the Oversown Hill. This result showing that all development scenarios result in an increased income per hectare above that of the base model. The two intensive pastures had significantly higher revenues, between $27,000 and $45,000 greater than that of Developed Permanent, this is largely due to the pasture supply curve of the intensive blocks. The intensive blocks plantain/red clover sward has equi-seasonal pasture supply allowing for lambs to be kept on farm and finished. This is in contrast to the grass based native oversown and developed permanent pastures which limited summer quality and supply meaning all lambs are required to be exited store at weaning.

The key output of this table is the farm profit per ha before tax, this allows us to compare all scenarios equally taking into account both revenue and expenses. The Oversown Hill shows the baseline level of profitability, $151/ha, this figure acts as the breakeven point for the other scenarios. The most profitable scenario is the Flat Intensive, producing a profit of $269/ha, which is 178% more profitable than that of the Oversown Hill. Developed Permanent is the second most profitable scenario producing a profit of $175/ha, this has a profitability $94/ha lower than that of the Flat Intensive but still 116% more profitable than the Oversown Hill block. The least profitable scenario was the Steep Intensive, which failed to achieve a profit per hectare and instead made a loss of $3/ha. This shows that the intensive pasture cropping regime on steep country is not a feasible option, with the revenue from this scenario not outweighing the high cost of production as shown above in Table 8.

Both the Developed Permanent pasture and the Steep Intensive pasture were then altered to a level of maximum production to see if this had any significant effect on the farm profit per hectare before tax. The Developed Permanent scenario was altered so as to have 50 less ewes but finishing all lambs to 38kgLW, thus increasing the overall scenario revenue. The Steep Intensive block had pasture production increased to 12,000kgDM/ha/yr., equal to that of the Flat Intensive pasture, and thus allowing more stock to be carried and a higher scenario revenue.

Table 9 below shows as predicted that both the Developed Permanent and Steep Intensive scenarios perform better when put into a scenario of maximum production. However, there was no significant change in profitability per hectare. Developed Permanent still remained less profitable than Flat Intensive, even with lambs finished to the same weight, but still more profitable than the Oversown Hill. The Steep Intensive scenario also had no significant change, even at maximum production was still less profitable than the Oversown Hill reinforcing the result that this is an unfeasible development option.

Table 9: Developed Permanent and Steep Intensive maximum production, profit and loss statement. Farmax Pro

FARMAX — Compare Forecast Profit and Loss

Jul 16 - Jun 17

			Model 1 Oversown hill	Model 1 [illegible]	Model 1 Flat Intensive	Model 1 [illegible]
Revenue	Sheep	Sales - Purchases	36,829	74,853	107,165	107,165
		Wool	13,179	23,085	32,965	32,962
		Capital Value Change	0	0	-142	-142
		Total	**50,008**	**97,938**	**139,988**	**139,985**
	Total Revenue		**50,008**	**97,938**	**139,988**	**139,985**
Expenses	Wages	Wages	5,648	11,200	11,200	11,200
		Management Wage	400	400	400	400
	Stock	Animal Health	3,278	6,172	8,830	8,831
		Shearing	5,118	9,635	13,786	13,786
	Feed/Crop/Grazing	Regrassing	0	3,300	6,200	9,900
	Fertiliser	Fertiliser (Excl. N & Lime)	9,100	9,100	13,000	9,100
		Lime	105	105	105	105
	Other Farm Working	Weed & Pest Control	3,400	6,000	25,000	38,600
		Vehicle Expenses	336	336	336	336
		Fuel	271	271	271	271
		Repairs & Maintenance	3,195	6,015	8,606	8,606
		Freight & Cartage	734	1,383	1,978	1,978
		Electricity	659	1,240	1,774	1,774
	Standing Charges	Administration Expenses	282	282	282	282
		Insurance	165	165	165	165
		ACC Levies	62	62	62	62
		Rates	208	208	208	208
	Total Farm Working Expense		**32,960**	**55,873**	**92,204**	**105,604**
	Depreciation		758	758	758	758
	Total Farm Expenses		**33,718**	**56,631**	**92,962**	**106,362**
Economic Farm Surplus (EFS)			**16,290**	**41,306**	**47,026**	**33,623**
Other Expenses		Rent/Leases	0	17,000	17,000	17,000
		Interest	1,149	3,129	3,129	3,129
Farm Profit before Tax			**15,141**	**21,177**	**26,897**	**13,494**
Farm Profit per ha before Tax			**151**	**212**	**269**	**135**

EFS is a measure of farm business profitability independent of ownership or funding, used to compare performance between farms.

EFS should include an adjustment for unpaid family labour and management. This can be added to the expense database as management wage.

4.3 Productivity of Pasture Development Options

The aim of this section is to identify which pasture option allows for the highest level of livestock productivity, which can be used as a proxy for per hectare profitability. Livestock productivity is not determined solely by pasture yield, but instead a combination of pasture yield, quality, and pasture supply across the year.

Figure 4 below shows that the pasture supply curve of the undeveloped pasture (Oversown Hill) and the new permanent pasture of the Developed Permanent scenario have a very similar pasture supply curve. The new pasture of the Developed Permanent block is of higher pasture quality, average 10.2MJME/kgDM as opposed to 9.5MJME/kgDM average supplied from the oversown hill block. The Developed Permanent also has a higher pasture yield, 10,000kgDM/ha/yr. compared to only

6,000kgDM/ha/yr. from the Oversown Hill. This gives the Developed Permanent scenario a far higher annual energy supply per hectare, however the trend of the supply curve remains relatively consistent to that of the Oversown Hill. The supply of both scenarios sees very little supply during the autumn and winter period, with a large peak in pasture production between October and February.

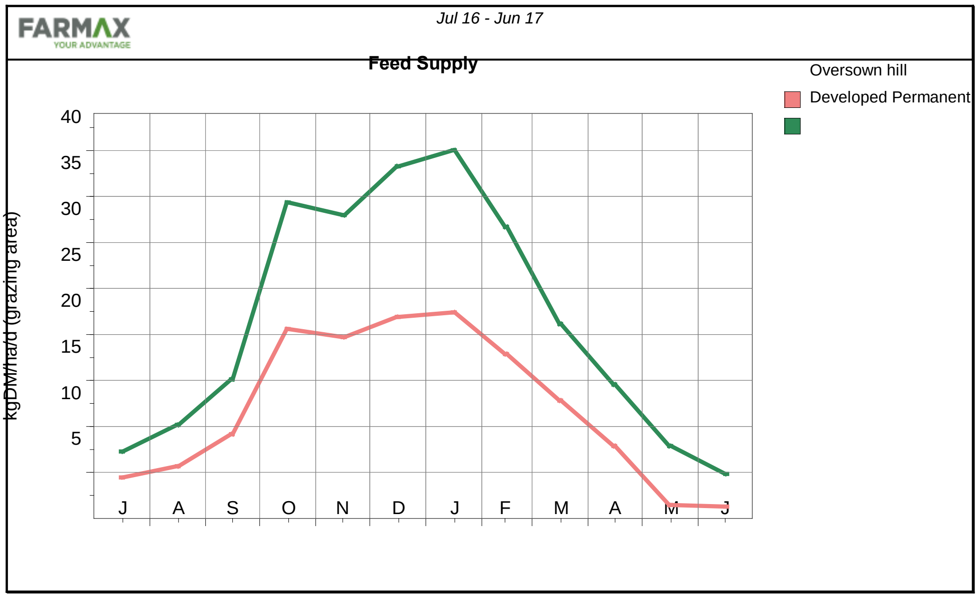

Figure 4: Comparison between pasture supply of Oversown Hill and Developed Permanent, represented as kgDM/ha/d

This large peak in pasture supply results in pasture production in excess of demand during this period, and inability to consume excess pasture results in pasture going reproductive and quality being greatly reduced. Although total pasture produced appears high, the actual animal carrying capacity of these two scenarios is relatively low. This is because there is only one or two months in spring where there is significant pasture supply of high quality, there is then a bulk of low quality feed over summer and little pasture produced during autumn and winter.

Table 10: Comparison of lamb sales between Oversown Hill scenario and Developed Permanent

FARMAX	Jul 16 - Jun 17	Model 1		Model 1		Difference	
Stock Class		Oversown hill		Developed Permanent			
		Store	Works	Store	Works	Store	Works
Ewe	Number Sold		73		136		63
	Weight (kg)		24.8 (cw)		24.8 (cw)		0.0
	$/head		68.98		68.91		-0.07
Ewe Hogget	Number Sold		72		132		60
	Weight (kg)		13.4 (cw)		13.3 (cw)		0.0
	$/head		33.05		32.97		-0.08
Ewe Lamb	Number Sold	191		350		159	
	Weight (kg)	23.2		23.2		0.0	
	$/head	48.61		48.59		-0.02	
Mixed Lamb	Number Sold	383		701		318	
	Weight (kg)	30.2		31.6		1.4	
	$/head	64.71		67.72		3.01	
All Sheep	**Number S...**	**574**	**145**	**1051**	**268**	**477**	**123**
	Weight (kg)	**27.9**	**19.1 (cw)**	**28.8**	**19.2 (cw)**	**0.9**	**0.0 (cw)**
	$/head	**59.35**	**51.14**	**61.35**	**51.21**	**1.99**	**0.07**

Table 10 highlights this point, with both scenarios only able to produce store lambs due to the limitation of pasture supply in summer and autumn post weaning. In both scenarios lambs are forced to be sold at weaning due to inability to retain stock on farm as a result of feed restriction. The Developed Permanent scenario produced double the amount of lambs of the Oversown Hill due to increased pasture supply allowing an increase in ewe numbers. However, the key limitation of this development is that increased pasture supply has not been matched to demand (Figure 5) and thus reliant on lamb sales through the volatile and often low returning store lamb market.

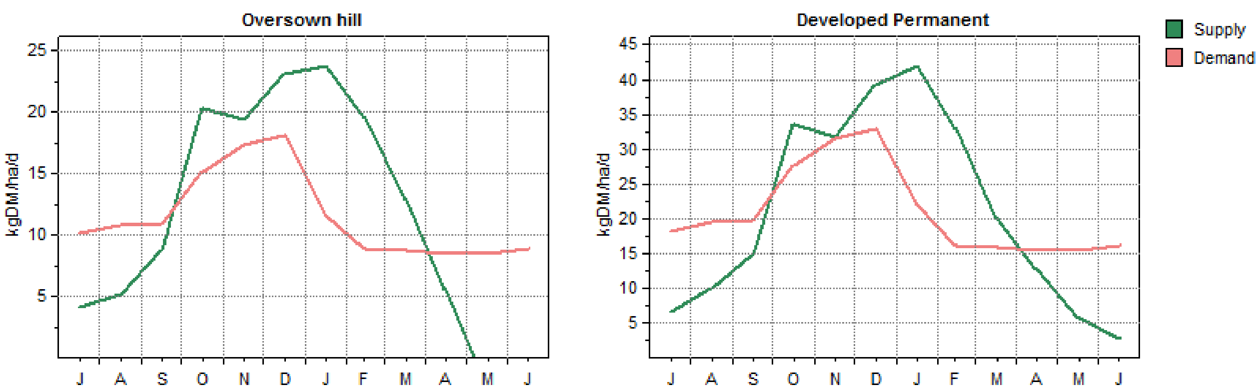

Figure 5: Comparison between supply and demand relationships of Oversown Hill and Developed Permanent scenarios

The Flat Intensive pasture with the plantain/red clover sward was seen as a potential option to provide a more even pasture supply throughout the year, better matching supply to animal demand. Figure 6 shows the supply curve of the Flat Intensive scenario (same supply curve as Steep Intensive) is more evenly distributed across the year than the steeply peaked Developed Permanent supply curve. The plantain/red clover provides early spring production, and growth continues further into the autumn than the grass based Developed Permanent, with an additional key benefit that the sward maintains quality throughout the summer period. The scenarios of Flat and Steep Intensive (plantain/red clover sward) have a more even pasture supply which better matches to demand, however still has insufficient pasture supply during the winter period.

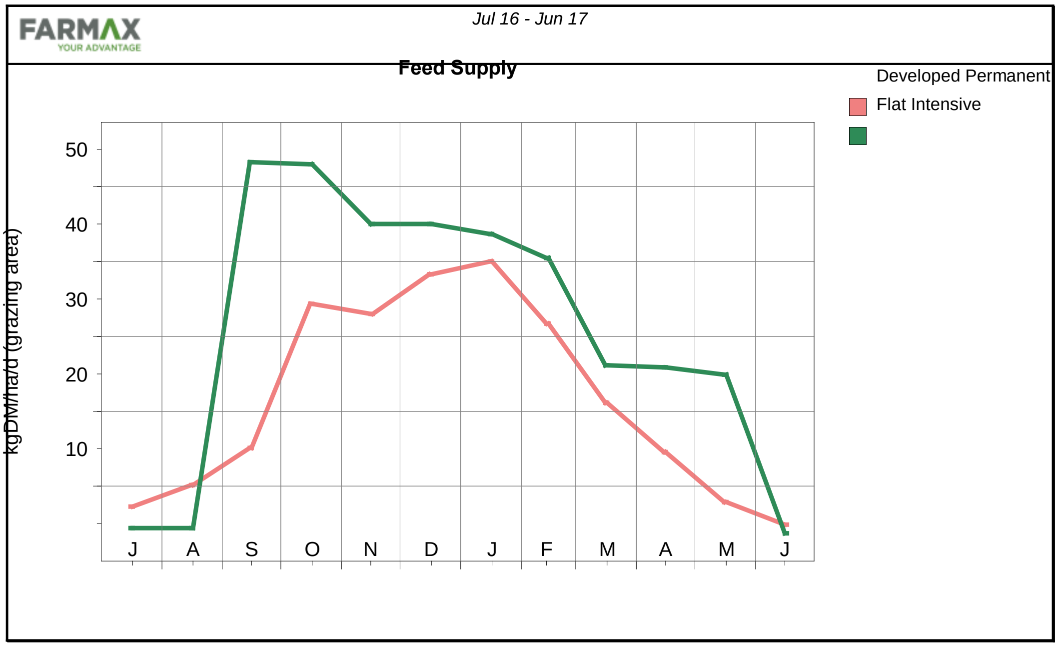

Figure 6: Comparison of pasture supply curves of Developed Permanent and Flat Intensive

The more evenly distributed pasture supply enables majority of lambs from the two intensive scenarios to be kept on farm and finished as prime lambs to a live weight of 38kg (Table 11). This results in an increase in average lamb value per head of $14 dollars. Not only does this result in an increased profit but it increases the level of flexibility as opposed to being locked in to a system where lambs had to be sold store.

Table 11: Comparison of lamb sales between Developed Permanent, Flat Intensive, and Steep Intensive scenarios

FARMAX YOUR ADVANTAGE		Jul 16 - Jun 17 Model 1		Model 1		Model 1	
Stock Class		Developed Permanent		Flat Intensive		Steep Intensive	
		Store	Works	Store	Works	Store	Works
Ewe	Number Sold		136		184		160
	Weight (kg)		24.8 (cw)		24.8 (cw)		24.8 (cw)
	$/head		68.91		68.96		68.94
Ewe Hogget	Number Sold		132		180		156
	Weight (kg)		13.3 (cw)		13.3 (cw)		13.4 (cw)
	$/head		32.97		32.96		33.00
Ewe Lamb	Number Sold	350		478		415	
	Weight (kg)	23.2		23.2		23.2	
	$/head	48.59		48.59		48.59	
Mixed Lamb	Number Sold	701			956		829
	Weight (kg)	31.6			17.2 (cw)		17.2 (cw)
	$/head	67.72			81.68		81.70
All Sheep	**Number S...**	**1051**	**268**	**478**	**1320**	**415**	**1145**
	Weight (kg)	**28.8**	**19.2 (cw)**	**23.2**	**17.7 (cw)**	**23.2**	**17.7 (cw)**
	$/head	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Collectively these different scenarios show that no one pasture or forage plant is able to produce an even energy supply throughout the year. To combat this issue, it was hypothesised the use of a combination of pasture/forage species in selective areas, so as to better achieve an equi-seasonal energy supply. Figure 7 below shows the use of Oversown Hill pasture, Flat Intensive pasture, and fodder beet to achieve an even energy supply. It shows that fodder beet can be used to boost energy supply during the winter months when both pasture and plantain/red clover supply is limited, and the high quality and yield of plantain/red clover offers a high spring to autumn energy supply and thus enabling increased carrying capacity.

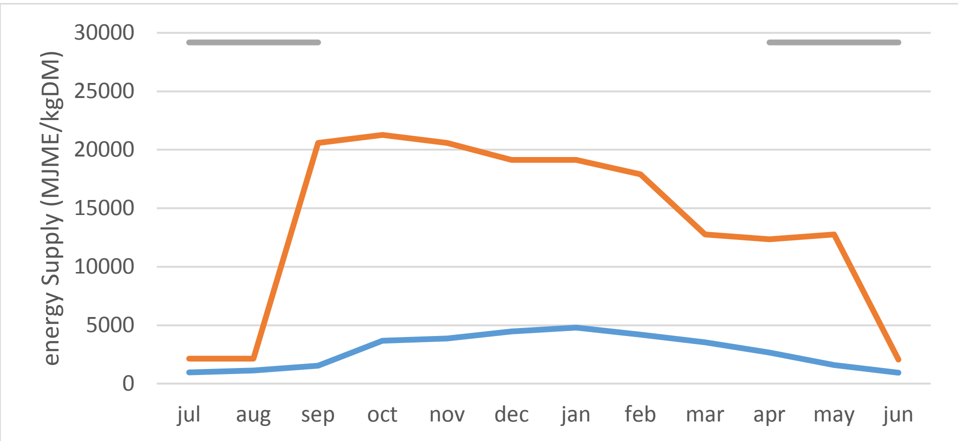

Figure 7: Effect of range of plant species used to achieve an even annual energy supply. blue = Oversown Hill pasture; orange = Flat Intensive, plantain/red clover; grey = fodder beet

4.4 Selective Development

A scenario was created on Farmax Pro to show how a combination of plant species, as seen in Figure 7, could be used in conjunction to achieve an even energy supply and thus increased livestock production. This scenario, called Selective Development, consisted of 66ha of undeveloped oversown hill pasture, 25ha of Flat Intensive plantain/red clover, and 9ha of fodder beet for winter energy supply. Figure 8 shows that the energy supplied from the combination of forages matches animal demand very evenly throughout the year. This shows that the small proportion, 33%, of developed area is able to boost energy supply when it is lacking from the native oversown pasture. In addition to this it enables grazing pressure to be focused on the oversown pasture during spring, thus utilising its spring growth while it is still in a high quality vegetative state.

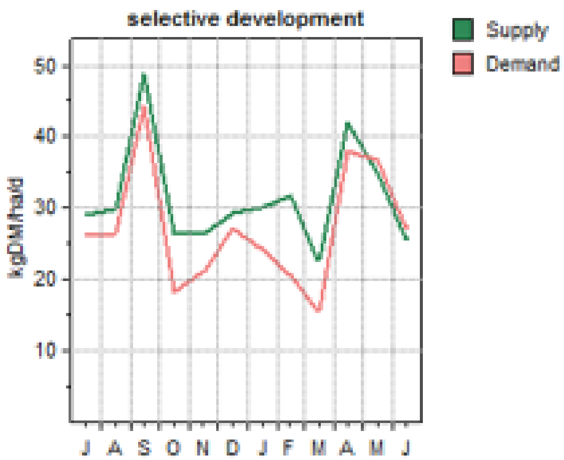

Figure 8: Pasture supply and animal demand relationship for the Selective Development scenario

This even supply of energy throughout the year allows all lambs to be kept on farm and finished to 38kgLW, the same finishing regime as the Flat Intensive scenario. This results in an increase in per head lamb value of approximately $45 from that of the Developed Permanent pasture. This enabled the Selective Development scenario to achieve a revenue $53/ha greater than that of the Developed Permanent pasture (Table 12) but with approximately 70 less lambs. The Selective Development scenario carries 110 less ewes than that of the Developed Permanent scenario, however is still able to achieve increased revenue due to the increased value in finishing lambs. This production is second only to that of the Flat Intensive scenario which is able to finish all lambs but also carry higher ewe numbers.

Table 12 also shows that the Selective Development scenario has far lower total farm expenses than that of both the Flat Intensive and Developed Permanent scenarios. This is largely due to the fact that only 33% of the land area of Selective Development has been developed, with the remaining 66% in an undeveloped state. This gives this scenario the advantage in that the high annual cost associated with development is limited to one third of the scenario, with the remainder being in a low cost state. In addition to this the capital required for development is far lower in the Selective Development scenario, reducing financial pressure and requirement of loans and debt servicing.

Profit per hectare for the Selective Development scenario is $100 greater than that of the baseline model, Oversown Hill. The Selective Development is the second most profitable scenario at $280/ha, $69/ha less than that of the Flat Intensive, and $53/ha greater than that of the Developed Permanent pasture. This shows that even with limited land development the scenario is able to compete with and outperform entirely developed scenarios. This result is produced through ability to finish lambs, coupled with the low average per hectare cost from selective investment in development.

Table 12: Comparison of profit and loss statements for scenarios: Oversown Hill, Developed Permanent, Flat Intensive, and Selective Development. Farmax Pro

FARMAX YOUR ADVANTAGE

Compare Forecast Profit and Loss

Jul 16 - Jun 17

			Model 1 Oversown hill	Model 1 Developed Permanent	Model 1 Flat Intensive	Model 1 Selective development
Revenue	Sheep	Sales - Purchases	39,598	74,735	115,227	80,279
		Wool	13,160	24,181	32,924	20,502
		Capital Value Change	0	-25	-117	-351
		Total	**52,758**	**98,891**	**148,034**	**100,431**
	Total Revenue		**52,758**	**98,891**	**148,034**	**100,431**
Expenses	Wages	Wages	5,648	11,200	11,200	10,073
		Management Wage	400	400	400	400
	Stock	Animal Health	3,278	6,037	8,834	5,846
		Shearing	5,118	9,425	13,791	9,128
	Feed/Crop/Grazing	Forage Crops	0	0	0	27,050
		Regrassing	0	3,300	6,200	0
	Fertiliser	Fertiliser (Excl. N & Lime)	9,100	9,100	13,000	6,097
		Lime	105	105	105	105
	Other Farm Working	Weed & Pest Control	3,400	6,000	25,000	2,278
		Vehicle Expenses	336	336	336	336
		Fuel	271	271	271	271
		Repairs & Maintenance	3,195	5,884	8,609	5,698
		Freight & Cartage	734	1,352	1,979	1,310
		Electricity	659	1,213	1,775	1,175
	Standing Charges	Administration Expenses	282	282	282	282
		Insurance	165	165	165	165
		ACC Levies	62	62	62	62
		Rates	208	208	208	208
	Total Farm Working Expense		**32,962**	**55,340**	**92,217**	**70,483**
	Depreciation		758	758	758	758
	Total Farm Expenses		**33,720**	**56,098**	**92,975**	**71,241**
Economic Farm Surplus (EFS)			**19,038**	**42,793**	**55,059**	**29,189**
Other Expenses		Rent/Leases	0	17,000	17,000	0
		Interest	1,149	3,129	3,129	1,149
Farm Profit before Tax			**17,889**	**22,664**	**34,930**	**28,040**
Farm Profit per ha before Tax			**179**	**227**	**349**	**280**

EFS is a measure of farm business profitability independent of ownership or funding, used to compare performance between farms.
EFS should include an adjustment for unpaid family labour and management. This can be added to the expense database as management wage.

4.5 Result validation using Linear Programme

A linear programme was produced using Microsoft Excel data add-in 'Solver'. A simplex model was designed with the objective set as profit maximisation. The purpose of analysis by linear programme was to validate the results of the Farmax analysis, and ensure feasibility of such scenarios.

Table 13: Linear programme results for the five analysed scenarios.

Scenario	**hectares utilised**	**Lamb Sales**
Native Oversown	100	442
Developed Permanent	100	791
Flat Intensive	100	969
Steep Intensive	0	0
Selective Development	100	695

Table 13 above shows how many hectares were utilised for each scenario, and if it was economically feasible to utilise any land of that scenario. It also shows the number of lamb sales made for each scenario, which can be used as a proxy for the profitability of the scenario.

The linear programme validated the results of the Farmax modelling. All scenarios except that of the Steep Intensive were feasible land use options, agreeing with the results from Farmax analysis. Similarly the Flat Intensive scenario remained the most profitable option, with the baseline model, Oversown Hill, still a feasible but least profitable land use option.

Chapter 5

Discussion

5.1 Decision process: Prior to development

For all development scenarios it was found that the capital development cost was constant at a value of $2020/ha. This is because regardless of topography, initial sprayings were aerially applied due to Matagouri cover, drilling was a fixed cost of $250/ha due to low speed and difficulty sowing, and that all areas needed subdivision and installation of necessary infrastructure. This capital cost of $2020/ha and individual unit prices are for a given area for a specific development and is not implying this is the fixed development cost for all land classes and locations. Instead, this is supposed to highlight that within a given environment, regardless of topography, capital development cost will be relatively constant, unless there are areas requiring remediation of a significant limitation prior to development.

Even with some variance, capital development cost will not be the key variable which determines the feasibility of development. For this example, as long as the annual loan payment of $194.61/ha (Table 5) can be met as a result of increased production, then the capital development is feasible and becomes a sunken cost. Once determined that the capital development cost can be serviced, it is the annual maintenance cost per hectare which will be the key variable determining the feasibility of development.

The maintenance cost is largely determined by the topography and intensity of the system. This cost coupled with production outcome and associated economic benefits will be the true determinant for the feasibility of land development.

As the feasibility of development is predominantly determined by the combination of annual maintenance cost per hectare and resultant production per hectare the decision making process should be focused on the long term potential returns and benefits as opposed to short term gains. Land development and such capital investment result in an increased level of production and often a shift in production system type, in this case a shift from store stock to prime production. Such a change in the farm system requires a change in farmer/manager mind-set to succeed. If there is not the desire to develop the farm system or farmers are not prepared to adopt new practices, then the success of development will likely be limited. Without adaption of the farm system to maximise the potential of development, the original system would not have sufficient production to service the annual maintenance cost. Thus decisions to develop should not only focus on productivity and profitability but also consider age, stage and goals of the farmer.

The first and most crucial step in the development process must be to clearly outline goals and objectives to be achieved from land development. This requires not just stating that want increase pasture supply of higher quality but highlighting specific objectives. Factors such as, determining when increased energy supply is most needed, what will be the key use of increased energy supply, and what will be achieved from the increased energy supply as a result of development. Without clear objectives and drivers, the outcome from development can be ineffective and unsatisfactory as seen in Figure 1.

In this example the baseline model, Oversown Hill, was completely developed into a permanent pasture. Pasture production and quality were increased but this only resulted in an increased peak production, with little increase in production during supply deficit autumn and winter. This development saw an increase of double the amount of lambs available for sale but those lambs were still required to be sold store due to lack of pasture supply post weaning. Due to unclear objectives, in this case trying to achieve prime lamb production, the full potential of development was not achieved and as a result the full value was not captured. Clearly defining objectives and tailoring land development to meet those objectives is thus a crucial factor in the decision making process, successful planning prior to development will ensure its success.

5.2 Decision Process: Where to develop

Development of an entire property is an unrealistic goal and on most hill and high country properties is physically and financially infeasible. A strategy of where to focus development and where to develop first is thus necessary to ensure the greatest benefits can be made for the whole farm system. Trying to view the farm as a homogenous unit will be difficult and confuse the process of choosing where to develop. Instead the farm should be broken down into smaller blocks/sections and initially be viewed as individual units, whilst remembering they are all components of the whole farm system.

First divide into land classes and remove areas where development is infeasible, and break the remaining areas into blocks of geographic locality. By dividing into blocks of geographic locality, as opposed to from least to most intensive areas, the areas chosen to be developed can complement the areas of undeveloped land as opposed to having isolated areas of intensive land. Having pockets of intensively developed land, where possible, in specific areas can increase the productivity of surrounding undeveloped land due to ability to increase grazing pressure at specific periods in the year. Once divided into blocks the next step is deciding which areas to target for development.

Initial development should focus on areas where the greatest returns will be made so as to achieve the objectives of development. Initially the largest returns will be made from developing low producing flat to rolling country. Development of the lowest producing land will result in the greatest increase in energy supply per hectare, initially targeting areas of easier topography will mean a lower per hectare maintenance cost giving increased flexibility for any initial variability in results. Table 7 shows that on flat to rolling land an intensive pasture of Plantain/Red Clover was able to achieve an annual yield of 12,000kgDM/ha at an average quality of 12MJME/kgDM, and Table 6 showing that this result could be achieved at a maintenance cost of $748.61/ha/yr., $173/ha/yr. cheaper than a similar result on steep land.

Development will be a staggered process over several years focusing first on the lowest producing easier country and progressing through higher producing and easier to medium topography land. Once desired development in such areas has been achieved, and if subsequent development is sought, the next areas of development should be steeper topography where it is still possible to drill with a tractor. The focus of development in such areas should not be that of intensively cropped pastures due to the excessive annual maintenance cost as a result of requirement to fly on sprays and fertilisers (Table 6). Instead focus on steeper topography land should be establishment of a permanent pasture of high legume content, so as can still be high yielding and of high quality (Table 7) but of far lower annual input than an intensively cropped pasture (Table 6).

When determining areas of land to develop focus should not be solely on the area of development, careful consideration should also be given to subdivision of surrounding pasture blocks. Developed areas have an increased energy supply resulting in an increased stocking intensity and thus ability to apply grazing pressure, not only on the developed area but also on surrounding blocks. Increased stocking intensity and energy supply from developed areas means surrounding undeveloped blocks can be grazed more intensely in times of high production and vegetative growth. This effect coupled with subdivision of undeveloped blocks can result in marked increase in quality and production from undeveloped blocks surrounding developed areas. Quantification of the increased production from undeveloped areas as a subsequent result of development is difficult, this concept and effects of increased stocking intensity and subdivision however are supported by theories discussed in the literature review (2.5. Land Development in High Country Systems). For the relatively small and low risk investment in subdivision of surrounding areas a significant increase in productivity of the land can be gained. This effect can largely influence the impact development has on the whole farm system, resulting in an increased level of farm profitability and a realisation in the value that can be gained from land development.

5.3 Benefits of Selective Development strategy

The concept of Selective Development requires a mind-set and thinking approach inclusive of the whole farm system, as opposed to a traditional mind-set where the area to be developed is viewed in isolation. The theories of whole farm system approach are discussed in the literature review (2.2. Whole Farm System Theory) and are based around the belief that the farm system should be viewed holistically, understanding each component and considering factors such as management goals, biological factors, sustainability, and profitability. By considering the whole farm system when developing, the rewards gained are not limited solely to the developed area, but positively influence the entire farm system.

The key of the Selective Development strategy is to achieve an energy supply which is equal to that of the desired energy demand. The focus of this development is around best utilising the resident undeveloped pasture, with areas of development designed not to supersede this production but boost energy supply when production from the native pasture is in a deficit. This focus has resulted in only one third of the land area needing to be developed to achieve the production goals/objectives.

This reduced development area also means that there is far lower capital requirement than that of fully developed scenarios. The benefits of this are there is less pressure on the whole farm system for debt servicing and lower financial risk due to the lower gearing level. This development is able to achieve a level of profitability per hectare comparative to that of fully developed scenarios, the key benefits of this strategy however are that there is far lower financial risk and requirement for only one third the capital requirement. For these reasons coupled with the more feasible option of only developing small pockets of farm area, such a strategy would be far more applicable and achievable in a high country farm scenario. Ability to boost production and shift from reliance on store markets to prime production, from a relatively low capital input, could significantly impact the resilience and reliability of farm productivity.

Having sufficient feed to keep and grow lambs/calves on farm post weaning increases the power the farmer has in their sale. The longer the period the farmer can hold or grow these animals, the greater the power the seller has. Reliance on store stock production and the requirement to sell progeny at or around weaning due to feed restriction, results in selling into a highly volatile and often unfavourable market. As majority of farmers in a given area share weaning dates within a month, and summer dry conditions resulting in feed deficit also effect the same people within a geographic area, this results in many producers exiting large numbers of progeny over the space of only one to two months. As price is determined by a relationship between supply and demand, selling during peak supply results in the price received dictated by demand and often depressed. If however farmers have a feed supply which means progeny can be retained, sale can be delayed until demand increases and the price is more favourable. Ideally development would result in the ability to finish lambs for slaughter, where higher returns can be gained. However, if this is not possible or not possible for all progeny, much value can still be gained from the ability to hold stock past weaning and sell at a time when the market is more desirable.

Chapter 6

Conclusion

This chapter will give answers to the research questions as stated in Chapter 1, and also highlight areas of limitation in this research and provide recommendations for potential areas of future research.

The literature showed historic land development on high country properties has been limited due to the cost of development and uncertainty as to potential production, with farmers instead reliant on the scale of their properties to reach production goals. The extensive nature and low productivity has seen majority of systems producing store stock, which are typified by volatile and often low returns. This study aimed to address these issues and highlight the significant gains in productivity and profitability that can be made from land development.

6.1 Answers to Research Questions

- **What is the development cost ($/ha) for development of different hill country land classes?**

The capital cost for complete land development was found to be $2,020/ha, this figure remained constant regardless of the land type or topography. The capital development cost was thus shown to not be the key determining factor for feasibility, it was instead the annual maintenance cost ($/ha) post development which would determine the feasibility of a land development option.

The key factors which altered the annual maintenance cost were the topography of the land and the intensity of the pastoral system. Areas where fertiliser and spray had to be flown on were more expensive than easier topography land where all applications could be made by truck or tractor. The intensity of the system determined how much fertiliser and spray was applied and how often, and also how often pastures were re-sown.

The intensive system was the most profitable on the easier topography land where all fertiliser and spray applications were ground based. This same intensive system was not feasible on steeper topography land where regular fertiliser and spray application coupled with aerial application resulted in an annual maintenance expense which outweighed returns. Instead on the steeper topography sowing directly into a permanent pasture, lower intensity and input, was a more feasible development option.

- **What is the potential increase in livestock production as a result of development?**

All development options resulted in an increased livestock production of over double that of the baseline model, Oversown Hill. However, the development options which were the most profitable were not those which maximised livestock production, but those where development enabled a shift from store to prime stock production.

The Developed Permanent pasture had the second highest livestock production but due to the steep growth curve of the entire grass based system all lambs were required to be sold store at weaning due to the lack of summer pasture supply. In comparison the Selective Development scenario produced 100 (10.5%) less lambs with only 33% of the developed area than that of the Developed Permanent and due to the even annual energy supply was able to finish all lambs to 38kgLW. Even with significantly less lambs this shift to prime production resulted in an increased profit of $53/ha.

The effects of a shift in system where pasture supply allows for options such as prime stock production are greater than the increased productivity alone. Where supply is able to match desired demand across the year an increased level of power is given to the farmer in the sale of these stock. Instead of a reliance on selling stock at a given period in the year and being at the mercy of the spot market on the day, sufficient feed supply on hand gives the ability to dictate when the animals are sold and wait for the most desirable market conditions. Such a system dramatically reduces exposure to market volatility, making the farm system more resilient, and ensuring more reliable and often higher returns.

- **What is the economic viability/profitability of investment in this land development?**

Four development scenarios were investigated in this study, looking at a range of development options on different land classes. Three of the four development scenarios were feasible, producing a level of profitability above that of the baseline model, Oversown Hill.

The one scenario which was not feasible was the Steep Intensive, its high input coupled with the expense of aerial fertiliser and spray application resulted in an annual maintenance cost which exceeded that of the increased production. Instead on steep areas a feasible development option was that of the Developed Permanent pasture. This scenario was still of relatively high pasture production and quality but had far lower input and thus expense, resulting in a profitable outcome.

The most profitable development option was the Flat Intensive scenario. This had the same intensively cropped pasture regime as the Steep Intensive however the easier topography meant fertiliser and spray could be ground applied, dramatically reducing the annual maintenance cost. Although the most profitable development option, the Flat Intensive will not be the most practically applicable or physically feasible in the setting of the majority of high country properties. Few properties would be entirely of easy to medium topography, let alone able to source capital to develop its entirety. Instead the Selective Development scenario, which combines areas of both Flat Intensive and Oversown Hill, is a more practical and achievable option for hill and high country farmers.

The selective development scenario was the second most profitable behind that of the Flat Intensive. It was able to achieve this level of profitability however through only one third the developed area of the other scenarios. Instead of targeting complete development this scenario aimed for development which supplemented the production of undeveloped areas and to boost energy supply in times of deficit. This approach enabled a shift in the farm system from store stock production to higher value prime stock production. The ability to achieve this increase in productivity and profitability from a smaller area of development meant there is far lower capital requirement, reducing financial risk. Achieving a shift in the farm system to that of higher production of more reliable returns should be among the top goals of any farm development strategy, ability to do this with low to medium capital input and risk should make this an achievable option.

6.2 Concluding Statement

There is significant potential for gains in productivity and profitability from land development, as well as greater leverage around timing and weights of livestock sales and increased production certainty from pastures that are more resilient to climatic variables. There are several development techniques and many pasture species which can be used to improve pasture production in the high country with the choice of development strategy and pasture option dependent on the individual property, its environment, and its limitations.

Common limitations include aluminium toxicity and soil acidity, soil nutrient deficiency, climatic extremes and variability and restriction in available funds for capital development. The climatic variability and environmental diversity of the high country means there is no silver bullet for land development options, instead it is a case of finding strategies and solutions which are best suited to individual farm systems and environments. A development strategy needs goals and objectives designed to achieve a specific purpose. Where successful development strategies can be implemented it will allow farmers to maximise the lands productive capacity and transform areas of traditionally low production.

6.3 Limitations

The research approach for this study combined the use of case study and quantitative theoretical modelling. The use of a single case study farm provided sufficient data and information to carry out this study, however investigation of multiple properties would have given a broader data set and allowed any inconsistencies within each case study to be highlighted. The data for this research was based on information from the case study farm and relevant scientific literature, however as with all theoretical modelling some assumptions are required to be made. Where possible assumptions made were based on sound research and the use of these assumptions were identified where used throughout.

6.4 **Future Research Opportunities**

This study was based on theoretical modelling using Farmax Pro and Linear Programming. There is the opportunity for field research using farmlets to be carried out in the future to reinforce the results from this study with results from field data.

Current research in farm development in hill and high country systems is predominantly focused on individual plant species and remediation of individual farm system limitations. The majority of studies look at these factors in isolation, looking at their individual effect or performance, not at the impact they have on the whole farm system and the interaction with other facets of the farm system.

There is a need for future research specifically on land development in hill and high country and the effects on the whole farm system not just on that of developed areas. Quantification of the costs of development and potential increases in farm system performance and profitability would make such research of more interest to farmers and hopefully highlight benefits, encouraging more farmers to investigate the potential for development within their farming systems.

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Appendix A

Interview Template

Section 1: Prior to development

Sheep

Dam Breed:

Breeding females

Opening number, 1 July: Closing number, 30 June: *(should be the same if steady-state model)* Mating date: Number mated: Body weight at mating: Circle one: Guess / Weighed Scanning % *(if known)*: Lambing / calving %: Weaning %: Weaning date: Average lamb/calf liveweight at weaning: Circle one: Guess / Weighed
Describe all sales and purchases of breeding ewes or cows over the year

Event	Month	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Opening number				Live	
Total deaths					
Closing number				Live	

Rams / Bulls

Total number:		
Dominant breeds:		
Average liveweight *(if known)*:		Month weighed:
Culling	Number:	Month:
Deaths per year	Number:	
Purchases	Number:	Month:
Replacements kept	Number:	

Lamb Sales

Event	Month	Age *(months)*	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Starting animals:						
Total deaths:						
E.g. Works sale	*Dec*	*3*	*200*	*15kg*	*carcass*	*1000*

Cattle

Dam Breed:

Breeding females

Opening number, 1 July:
Closing number, 30 June: *(should be the same if steady-state model)*
Mating date:
Number mated:
Body weight at mating: Circle one: Guess / Weighed
Scanning % *(if known)*:
Lambing / calving %:
Weaning %:
Weaning date:
Average lamb/calf liveweight at weaning: Circle one: Guess / Weighed

Describe all sales and purchases of breeding ewes or cows over the year

Event	Month	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Opening number				Live	
Total deaths					
Closing number				Live	

Rams / Bulls

Total number:		
Dominant breeds:		
Average liveweight *(if known)*:		Month weighed:
Culling	Number:	Month:
Deaths per year	Number:	
Purchases	Number:	Month:
Replacements kept	Number:	

Progeny sales

Event	Month	Age *(months)*	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Starting animals:						
Total deaths:						
E.g. Works sale	*Dec*	*3*	*200*	*15kg*	*carcass*	*1000*

Pasture Production and dominant pasture blocks

Pasture Block 1:

If you have any measurements of pasture covers or growth rates through the year these would be very useful, please attach these as a separate document.

Pasture type:

Typical pasture species on block:

Typical pasture quality: Low / Medium / High (circle one)

Annual pasture production if known (t DM / ha):

Has this been measured or is it a guess?

Briefly describe the typical growth pattern for this block.

When does growth pick up in spring?

Month of peak growth?

How well does the block produce in summer?

When does growth drop away in autumn?

Is there any useful growth in winter?

Any other comments?

Animals

What animals are grazed on this block, and when?

Pasture Block 2:

If you have any measurements of pasture covers or growth rates through the year these would be very useful, please attach these as a separate document.

Pasture type:

Typical pasture species on block:

Typical pasture quality: Low / Medium / High (circle one)

Annual pasture production if known (t DM / ha):

Has this been measured or is it a guess?

Briefly describe the typical growth pattern for this block.

When does growth pick up in spring?

Month of peak growth?

How well does the block produce in summer?

When does growth drop away in autumn?

Is there any useful growth in winter?

Any other comments?

Animals

What animals are grazed on this block, and when?

Pasture Block 3:

If you have any measurements of pasture covers or growth rates through the year these would be very useful, please attach these as a separate document.

Pasture type:

Typical pasture species on block:

Typical pasture quality: Low / Medium / High (circle one)

Annual pasture production if known (t DM / ha):

Has this been measured or is it a guess?

Briefly describe the typical growth pattern for this block.

When does growth pick up in spring?

Month of peak growth?

How well does the block produce in summer?

When does growth drop away in autumn?

Is there any useful growth in winter?

Any other comments?

Animals

What animals are grazed on this block, and when?

Cropping

Previous crop: *May be pasture.* ***Cultivated:*** *State month and type (full cultivation, min-till, direct drill)*
Fate: *Include where relevant - Is the crop grazed or harvested? What stock is it fed to? What block is it fed out on? For instance, the fate could read "Grazed, heifers"; "silage -> hill block, cows"; "harvested, sold" etc.*
Irrigation & Fertiliser: *Only if differs from remainder of block. Include fertiliser drilled with seed.*

Previous crop	Crop Type	Yield *(if known)*	Area	Fate	Month				Sown to	Irrigation	Fertiliser		
					cultivated	1st grazed	last grazed	resown			Type	Rate	Month

Farm Working Expenses

($/year)			$ Total	$ / ha	$ / SU
Wages	Wages				
	Management Wage				
	Total Wages				
Stock	Animal Health				
	Shearing				
	Total Stock				
Feed Crops & Grazing	Conservation				
	Cash Crops				
	Forage Crops				
	Purchased Feeds				
	Regrassing				
	Grazing				
	Total Feed/Crops/Grazing				
Fertiliser	Fertiliser (Excl. N & Lime)				
	Nitrogen				
	Lime				
	Total Fertiliser				
Other Farm Working Expenses	Irrigation Charges				
	Weed & Pest Control				
	Vehicle Expenses				
	Fuel				
	Repairs & Maintenance				
	Freight & Cartage				
	Electricity				
	Other Expenses				
	Total Other Farm Working				
Standing	Administration Expenses				
	Insurance				
	ACC Levies				
	Rates				
	Total Standing Charges				
Other	Rent/Lease				
	Interest				
	Principal				
	Drawings				
	Taxation				
	Total Other Expenses				
	Total Expenses				

Section 2: Developed

<u>Sheep</u>

Dam Breed:

Breeding females

Opening number, 1 July:
Closing number, 30 June: *(should be the same if steady-state model)*
Mating date:
Number mated:
Body weight at mating: Circle one: Guess / Weighed
Scanning % *(if known)*:
Lambing / calving %:
Weaning %:
Weaning date:
Average lamb/calf liveweight at weaning: Circle one: Guess / Weighed

Describe all sales and purchases of breeding ewes or cows over the year

Event	Month	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Opening number				Live	
Total deaths					
Closing number				Live	

Rams / Bulls

Total number:
Dominant breeds:
Average liveweight *(if known)*: Month weighed:
Culling Number: Month:
Deaths per year Number:
Purchases Number: Month:
Replacements kept Number:

Lamb Sales

Event	Month	Age *(months)*	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Starting animals:						
Total deaths:						
E.g. Works sale	*Dec*	*3*	*200*	*15kg*	*carcass*	*1000*

Cattle

Dam Breed:

Breeding females

Opening number, 1 July:
Closing number, 30 June: *(should be the same if steady-state model)*
Mating date:
Number mated:
Body weight at mating: Circle one: Guess / Weighed
Scanning % *(if known)*:
Lambing / calving %:
Weaning %:
Weaning date:
Average lamb/calf liveweight at weaning: Circle one: Guess / Weighed

Describe all sales and purchases of breeding ewes or cows over the year

Event	Month	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Opening number				Live	
Total deaths					
Closing number				Live	

Rams / Bulls

Total number:		
Dominant breeds:		
Average liveweight *(if known)*:		Month weighed:
Culling	Number:	Month:
Deaths per year	Number:	
Purchases	Number:	Month:
Replacements kept	Number:	

Progeny sales

Event	Month	Age *(months)*	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Starting animals:						
Total deaths:						
E.g. Works sale	*Dec*	*3*	*200*	*15kg*	*carcass*	*1000*

Trading Stock

Event	Month	Age *(months)*	Number removed / added	Average weight *(if known)*	Live or carcass weight?	Flock / herd size
Starting animals:						
Total deaths:						
E.g. Works sale	*Dec*	*3*	*200*	*15kg*	*carcass*	*1000*

Pasture Production and dominant pasture blocks

Pasture Block 1:

If you have any measurements of pasture covers or growth rates through the year these would be very useful, please attach these as a separate document.

Pasture type:

Typical pasture species on block:

Typical pasture quality: Low / Medium / High (circle one)

Annual pasture production if known (t DM / ha):

Has this been measured or is it a guess?

Briefly describe the typical growth pattern for this block.

When does growth pick up in spring?

Month of peak growth?

How well does the block produce in summer?

When does growth drop away in autumn?

Is there any useful growth in winter?

Any other comments?

Animals

What animals are grazed on this block, and when?

Pasture Block 2:

If you have any measurements of pasture covers or growth rates through the year these would be very useful, please attach these as a separate document.

Pasture type:

Typical pasture species on block:

Typical pasture quality: Low / Medium / High (circle one)

Annual pasture production if known (t DM / ha):

Has this been measured or is it a guess?

Briefly describe the typical growth pattern for this block.

When does growth pick up in spring?

Month of peak growth?

How well does the block produce in summer?

When does growth drop away in autumn?

Is there any useful growth in winter?

Any other comments?

Animals

What animals are grazed on this block, and when?

Pasture Block 3:

If you have any measurements of pasture covers or growth rates through the year these would be very useful, please attach these as a separate document.

Pasture type:

Typical pasture species on block:

Typical pasture quality: Low / Medium / High (circle one)

Annual pasture production if known (t DM / ha):

Has this been measured or is it a guess?

Briefly describe the typical growth pattern for this block.

When does growth pick up in spring?

Month of peak growth?

How well does the block produce in summer?

When does growth drop away in autumn?

Is there any useful growth in winter?

Any other comments?

Animals

What animals are grazed on this block, and when?

Cropping

Previous crop: *May be pasture.* ***Cultivated:*** *State month and type (full cultivation, min-till, direct drill)*
Fate: *Include where relevant - Is the crop grazed or harvested? What stock is it fed to? What block is it fed out on? For instance, the fate could read "Grazed, heifers"; "silage -> hill block, cows"; "harvested, sold" etc.*
Irrigation *&* ***Fertiliser****: Only if differs from remainder of block. Include fertiliser drilled with seed.*

Previous crop	Crop Type	Yield *(if known)*	Area	Fate	Month				Sown to	Irrigation	Fertiliser		
					cultivated	1st grazed	last grazed	resown			Type	Rate	Month

Farm Working Expenses

($/year)			$ Total	$ / ha	$ / SU
Wages	Wages				
	Management Wage				
	Total Wages				
Stock	Animal Health				
	Shearing				
	Total Stock				
Feed Crops & Grazing	Conservation				
	Cash Crops				
	Forage Crops				
	Purchased Feeds				
	Regrassing				
	Grazing				
	Total Feed/Crops/Grazing				
Fertiliser	Fertiliser (Excl. N & Lime)				
	Nitrogen				
	Lime				
	Total Fertiliser				
Other Farm Working Expenses	Irrigation Charges				
	Weed & Pest Control				
	Vehicle Expenses				
	Fuel				
	Repairs & Maintenance				
	Freight & Cartage				
	Electricity				
	Other Expenses				
	Total Other Farm Working				
Standing	Administration Expenses				
	Insurance				
	ACC Levies				
	Rates				
	Total Standing Charges				
Other	Rent/Lease				
	Interest				
	Principal				
	Drawings				
	Taxation				
	Total Other Expenses				
	Total Expenses				

Development
What expenses were associated with the land development programme, and what was the total cost per hectare of development?

What was the cropping rotation used to develop land into improved pastures?

What is the establishment cost for each crop/ new pasture used throughout development?

What was the maximum area of land that was happy to have out of pasture and beginning development per year?

How many ha of land was retained in forage crops/ rotated at the completion of the development period?

Section 3: Management factor and goals

What were perceived to be the key limitations/risks of the farming system prior to development?

What were the key goals/desired outcomes from development?

What level of risk do you believe was associated with investment in this development project?

What are the medium-long term goals for the farm and owners?

Appendix B

Farm Expense Pages

($/year)		Jul 16 - Jun 17 **Model** (tick to use)	Timing	$ Total	$ / ha (100)	$ / SU (757)
	Wages		Monthly	4,921	49.21	**6.50**
Wages	Management Wage		Monthly	288	2.88	**0.38**
	Total Wages			**5,208**	**52.08**	**6.88**
	Animal Health	**2,714** ☑	As Incurred	2,714	27.14	3.59
Stock	Shearing	**2,787** ☑	As Incurred	2,787	27.87	3.68
	Velveting	**0** ☑	As Incurred	0	0.00	0.00
	Total Stock			**5,501**	**55.01**	**7.27**
	Conservation	**0** ☑	As Incurred	0	0.00	0.00
	Cash Crops	**0** ☑	As Incurred	0	0.00	0.00
Feed, Crops & Grazing	Forage Crops	**0** ☑	As Incurred	0	0.00	0.00
	Purchased Feeds	**0** ☑	As Incurred	0	0.00	0.00
	Regrassing	**0** ☑	As Incurred	0	0.00	0.00
	Grazing	**0** ☑	As Incurred	0	0.00	0.00
	Total Feed/Crops/Grazing			**0**	**0.00**	**0.00**
	Fertiliser (Excl. N & Lime)		Oct, Apr	9,100	**91.00**	12.02
Fertiliser	Nitrogen	**0** ☑	As Incurred	0	0.00	0.00
	Lime		Oct, Apr	130	**1.30**	0.17
	Total Fertiliser			**9,230**	**92.30**	**12.19**
	Irrigation Charges		Custom	64	**0.64**	0.08
	Weed & Pest Control		Monthly	3,400	**34.00**	4.49
	Vehicle Expenses		Monthly	267	**2.67**	0.35
Other Farm Working	Fuel		Monthly	279	**2.79**	0.37
	Repairs & Maintenance		Monthly	2,846	28.46	**3.76**
	Freight & Cartage		Monthly	727	7.27	**0.96**
	Electricity		Monthly	522	5.22	**0.69**
	Other Expenses		Monthly	**0**	0.00	0.00
	Total Other Farm Working			**8,106**	**81.06**	**10.71**
	Administration Expenses		Monthly	274	**2.74**	0.36
	Insurance		Monthly	151	**1.51**	0.20
Standing	ACC Levies		Jul, Jan	68	**0.68**	0.09
	Rates		Jul, Oct, ...	212	**2.12**	0.28
	Total Standing Charges			**705**	**7.05**	**0.93**
Total Farm Working Expense				**28,750**	**287.50**	**37.98**
Depreciation			Monthly	773	**7.73**	1.02
Total Farm Expenses				**29,523**	**295.23**	**39.00**
	Rent/Lease		Monthly	235	**2.35**	0.31
	Interest		Monthly	929	**9.29**	1.23
	Principal		Monthly	**0**	0.00	0.00
Other	Drawings		Monthly	**0**	0.00	0.00
	Taxation		Jul, Oct, ...	**0**	0.00	0.00
	Total Other Expenses			**1,164**	**11.64**	**1.54**
	Total Expenses			**30,687**	**306.87**	**40.54**

	($/year)	Jul 16 - Jun 17 *Model* (tick to use)		Timing	$ Total	$ / ha *(100)*	$ / SU *(1,395)*
Wages	Wages			Monthly	11,200	**112.00**	8.03
	Management Wage			Monthly	400	**4.00**	0.29
	Total Wages				**11,600**	**116.00**	**8.32**
Stock	Animal Health	4,980	☐	Monthly	6,040	60.40	**4.33**
	Shearing	5,116	☐	Monthly	9,429	94.29	**6.76**
	Velveting	**0**	☑	As Incurred	0	0.00	0.00
	Total Stock				**15,469**	**154.69**	**11.09**
Feed, Crops & Grazing	Conservation	0	☐	Monthly	0	**0.00**	0.00
	Cash Crops	0	☐	Monthly	0	**0.00**	0.00
	Forage Crops	0	☐	Monthly	0	**0.00**	0.00
	Purchased Feeds	0	☐	Monthly	0	**0.00**	0.00
	Regrassing	0	☐	Monthly	3,300	**33.00**	2.37
	Grazing	0	☐	Monthly	0	**0.00**	0.00
	Total Feed/Crops/Grazing				**3,300**	**33.00**	**2.37**
Fertiliser	Fertiliser (Excl. N & Lime)			Oct, Apr	9,100	**91.00**	6.52
	Nitrogen	0	☐	Monthly	0	**0.00**	0.00
	Lime			Oct, Apr	105	**1.05**	0.08
	Total Fertiliser				**9,205**	**92.05**	**6.60**
Other Farm Working	Irrigation Charges			Custom	0	**0.00**	0.00
	Weed & Pest Control			Monthly	6,000	**60.00**	4.30
	Vehicle Expenses			Monthly	336	**3.36**	0.24
	Fuel			Monthly	271	**2.71**	0.19
	Repairs & Maintenance			Monthly	5,886	58.86	**4.22**
	Freight & Cartage			Monthly	1,353	13.53	**0.97**
	Electricity			Monthly	1,214	12.14	**0.87**
	Other Expenses			Monthly	**0**	0.00	0.00
	Total Other Farm Working				**15,060**	**150.60**	**10.80**
Standing	Administration Expenses			Monthly	282	**2.82**	0.20
	Insurance			Monthly	165	**1.65**	0.12
	ACC Levies			Jul, Jan	62	**0.62**	0.04
	Rates			Jul, Oct, ...	208	**2.08**	0.15
	Total Standing Charges				**717**	**7.17**	**0.51**
Total Farm Working Expense					**55,351**	**553.51**	**39.68**
Depreciation				Monthly	758	**7.58**	0.54
Total Farm Expenses					**56,109**	**561.09**	**40.22**
	Rent/Lease			Monthly	17,000	**170.00**	12.19
Other	Interest			Monthly	3,129	**31.29**	2.24
	Principal			Monthly	0	**0.00**	0.00
	Drawings			Monthly	**0**	0.00	0.00
	Taxation			Jul, Oct, ...	**0**	0.00	0.00
	Total Other Expenses				**20,129**	**201.29**	**14.43**
	Total Expenses				**76,238**	**762.38**	**54.66**

FARMAX	($/year)	*Jul 16 - Jun 17* **Model** (tick to use)	**Timing**	**$ Total**	**$ / ha** *(100)*	**$ / SU** *(2,040)*
	Wages		Monthly	11,200	**112.00**	5.49
Wages	Management Wage		Monthly	400	**4.00**	0.20
	Total Wages			**11,600**	**116.00**	**5.69**
	Animal Health	7,188 ☐	Monthly	8,834	88.34	**4.33**
Stock	Shearing	6,972 ☐	Monthly	13,791	137.91	**6.76**
	Velveting	**0** ☑	As Incurred	0	0.00	0.00
	Total Stock			**22,625**	**226.25**	**11.09**
	Conservation	0 ☐	Monthly	0	**0.00**	0.00
	Cash Crops	0 ☐	Monthly	0	**0.00**	0.00
Feed, Crops & Grazing	Forage Crops	0 ☐	Monthly	0	**0.00**	0.00
	Purchased Feeds	0 ☐	Monthly	0	**0.00**	0.00
	Regrassing	0 ☐	Monthly	6,200	**62.00**	3.04
	Grazing	0 ☐	Monthly	0	**0.00**	0.00
	Total Feed/Crops/Grazing			**6,200**	**62.00**	**3.04**
	Fertiliser (Excl. N & Lime)		Oct, Apr	13,000	**130.00**	6.37
Fertiliser	Nitrogen	0 ☐	Monthly	0	**0.00**	0.00
	Lime		Oct, Apr	105	**1.05**	0.05
	Total Fertiliser			**13,105**	**131.05**	**6.42**
	Irrigation Charges		Custom	0	**0.00**	0.00
	Weed & Pest Control		Monthly	25,000	**250.00**	12.25
	Vehicle Expenses		Monthly	336	**3.36**	0.16
Other Farm Working	Fuel		Monthly	271	**2.71**	0.13
	Repairs & Maintenance		Monthly	8,609	86.09	**4.22**
	Freight & Cartage		Monthly	1,979	19.79	**0.97**
	Electricity		Monthly	1,775	17.75	**0.87**
	Other Expenses		Monthly	**0**	0.00	0.00
	Total Other Farm Working			**37,970**	**379.70**	**18.61**
	Administration Expenses		Monthly	282	**2.82**	0.14
	Insurance		Monthly	165	**1.65**	0.08
Standing	ACC Levies		Jul, Jan	62	**0.62**	0.03
	Rates		Jul, Oct, ...	208	**2.08**	0.10
	Total Standing Charges			**717**	**7.17**	**0.35**
Total Farm Working Expense				**92,217**	**922.17**	**45.20**
Depreciation			Monthly	758	**7.58**	0.37
Total Farm Expenses				**92,975**	**929.75**	**45.57**
	Rent/Lease		Monthly	17,000	**170.00**	8.33
	Interest		Monthly	3,129	**31.29**	1.53
	Principal		Monthly	0	**0.00**	0.00
Other	Drawings		Monthly	**0**	0.00	0.00
	Taxation		Jul, Oct, ...	**0**	0.00	0.00
	Total Other Expenses			**20,129**	**201.29**	**9.87**
	Total Expenses			**113,104**	**1,131.04**	**55.44**

FARMAX ($/year)		Jul 16 - Jun 17 Model (tick to use)		Timing	$ Total	$ / ha (100)	$ / SU (1,769)
Wages	Wages			Monthly	11,200	**112.00**	6.33
	Management Wage			Monthly	400	**4.00**	0.23
	Total Wages				**11,600**	**116.00**	**6.56**
Stock	Animal Health	6,234	☐	Monthly	7,659	76.59	**4.33**
	Shearing	6,046	☐	Monthly	11,958	119.58	**6.76**
	Velveting	**0**	☑	As Incurred	0	0.00	0.00
	Total Stock				**19,617**	**196.17**	**11.09**
Feed, Crops & Grazing	Conservation	0	☐	Monthly	0	**0.00**	0.00
	Cash Crops	0	☐	Monthly	0	**0.00**	0.00
	Forage Crops	0	☐	Monthly	0	**0.00**	0.00
	Purchased Feeds	0	☐	Monthly	0	**0.00**	0.00
	Regrassing	0	☐	Monthly	9,900	**99.00**	5.60
	Grazing	0	☐	Monthly	0	**0.00**	0.00
	Total Feed/Crops/Grazing				**9,900**	**99.00**	**5.60**
Fertiliser	Fertiliser (Excl. N & Lime)			Oct, Apr	9,100	**91.00**	5.14
	Nitrogen	0	☐	Monthly	0	**0.00**	0.00
	Lime			Oct, Apr	105	**1.05**	0.06
	Total Fertiliser				**9,205**	**92.05**	**5.20**
Other Farm Working	Irrigation Charges			Custom	0	**0.00**	0.00
	Weed & Pest Control			Monthly	38,600	**386.00**	21.82
	Vehicle Expenses			Monthly	336	**3.36**	0.19
	Fuel			Monthly	271	**2.71**	0.15
	Repairs & Maintenance			Monthly	7,465	74.65	**4.22**
	Freight & Cartage			Monthly	1,716	17.16	**0.97**
	Electricity			Monthly	1,539	15.39	**0.87**
	Other Expenses			Monthly	**0**	0.00	0.00
	Total Other Farm Working				**49,927**	**499.27**	**28.22**
Standing	Administration Expenses			Monthly	282	**2.82**	0.16
	Insurance			Monthly	165	**1.65**	0.09
	ACC Levies			Jul, Jan	62	**0.62**	0.04
	Rates			Jul, Oct, ...	208	**2.08**	0.12
	Total Standing Charges				**717**	**7.17**	**0.41**
Total Farm Working Expense					**100,966**	**1,009.66**	**57.08**
Depreciation				Monthly	758	**7.58**	0.43
Total Farm Expenses					**101,724**	**1,017.24**	**57.51**
	Rent/Lease			Monthly	17,000	**170.00**	9.61
Other	Interest			Monthly	3,129	**31.29**	1.77
	Principal			Monthly	0	**0.00**	0.00
	Drawings			Monthly	**0**	0.00	0.00
	Taxation			Jul, Oct, ...	**0**	0.00	0.00
	Total Other Expenses				**20,129**	**201.29**	**11.38**
	Total Expenses				**121,853**	**1,218.53**	**68.89**

	($/year)	*Jul 16 - Jun 17* **Model** (tick to use)		Timing	$ Total	$ / ha *(100)*	$ / SU *(1,350)*
Wages	Wages			Monthly	10,073	100.73	**7.46**
	Management Wage			Monthly	400	**4.00**	0.30
	Total Wages				**10,473**	**104.73**	**7.76**
Stock	Animal Health	4,568	[ ]	Monthly	5,846	58.46	**4.33**
	Shearing	4,239	[ ]	Monthly	9,128	91.28	**6.76**
	Velveting	**0**	[x]	As Incurred	0	0.00	0.00
	Total Stock				**14,974**	**149.74**	**11.09**
Feed, Crops & Grazing	Conservation	0	[ ]	Monthly	0	**0.00**	0.00
	Cash Crops	0	[ ]	Monthly	0	**0.00**	0.00
	Forage Crops	**27,050**	[x]	As Incurred	27,050	270.50	20.03
	Purchased Feeds	0	[ ]	Monthly	0	**0.00**	0.00
	Regrassing	0	[ ]	Monthly	0	**0.00**	0.00
	Grazing	0	[ ]	Monthly	0	**0.00**	0.00
	Total Feed/Crops/Grazing				**27,050**	**270.50**	**20.03**
Fertiliser	Fertiliser (Excl. N & Lime)			Oct, Apr	6,097	**60.97**	4.52
	Nitrogen	0	[ ]	Monthly	0	**0.00**	0.00
	Lime			Oct, Apr	105	**1.05**	0.08
	Total Fertiliser				**6,202**	**62.02**	**4.59**
Other Farm Working	Irrigation Charges			Custom	0	**0.00**	0.00
	Weed & Pest Control			Monthly	2,278	**22.78**	1.69
	Vehicle Expenses			Monthly	336	**3.36**	0.25
	Fuel			Monthly	271	**2.71**	0.20
	Repairs & Maintenance			Monthly	5,698	56.98	**4.22**
	Freight & Cartage			Monthly	1,310	13.10	**0.97**
	Electricity			Monthly	1,175	11.75	**0.87**
	Other Expenses			Monthly	**0**	0.00	0.00
	Total Other Farm Working				**11,067**	**110.67**	**8.20**
Standing	Administration Expenses			Monthly	282	**2.82**	0.21
	Insurance			Monthly	165	**1.65**	0.12
	ACC Levies			Jul, Jan	62	**0.62**	0.05
	Rates			Jul, Oct, ...	208	**2.08**	0.15
	Total Standing Charges				**717**	**7.17**	**0.53**
Total Farm Working Expense					**70,483**	**704.83**	**52.20**
Depreciation				Monthly	758	**7.58**	0.56
Total Farm Expenses					**71,241**	**712.41**	**52.76**
	Rent/Lease			Monthly	0	**0.00**	0.00
Other	Interest			Monthly	1,149	**11.49**	0.85
	Principal			Monthly	**0**	0.00	0.00
	Drawings			Monthly	**0**	0.00	0.00
	Taxation			Jul, Oct, ...	**0**	0.00	0.00
	Total Other Expenses				**1,149**	**11.49**	**0.85**
	Total Expenses				**72,390**	**723.90**	**53.61**