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Partial land use diversification for long term sustainability and resilience of sheep and beef farms

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Table of Contents

Executive Summary

This project was completed to understand if sheep and beef farmers in NZ can use partial land use diversification to improve environmental sustainability and farm business resilience. The reason this was studied is because farmers in New Zealand are facing environmental, social, institutional, and financial pressures. Many sheep and beef farmers in will likely need to make adaptions to their farm systems to remain profitable, improve environmental sustainability and to create more resilient farm systems for the future, one way of adapting the farm systems is through land use diversification. A literature review was completed, and a series of farmers and industry professionals were interviewed. This data was then assessed through thematic analysis. Diversification for agriculture is defined as the addition of another source of farm-based income to the existing income stream and it includes the introduction of additional faming enterprises. Land use diversification can have numerous benefits in sheep and beef farms including, enhanced environmental outcomes, improved profitability and cashflow, enhanced farm resilience, more succession opportunities and better integrated farm system. The downfalls highlighted were increased risk to the farm system during development and early stages of land use change, the initial financial outlay for development and increased complexity. To reduce the risks of land use change, a comprehensive planning process is required. Some key steps include business planning and goal setting, understanding the biophysical resources, farm planning, matching the land use to land use capacity, climate and soil conditions, farm system modelling and evaluation and trialing. If farmers in New Zealand can successfully transition their sheep and beef farms to diversified land use systems, it will likely transform the sheep and beef industry throughout the country to overcome environmental challenges and create long term sustainable and resilient farm systems. Some recommendations to farmers assess the farm as if it is a blank canvas and understand different land use opportunities within the farm system. More research needs to be done on land use options available for different regions. There is the opportunity to better understand and develop how farmers could you collaboration and catchment groups to aid in the success of land use diversification.

Acknowledgments

I would like to acknowledge all involved in putting the Kellogg Rural Leadership Programme together, it has been a great opportunity for me and many others. Patrick and Scott, you have been so helpful and insightful throughout the course so I would like to thank you for your time. Thanks to Beef + Lamb New Zealand, for allowing me the time to take part in this programme. Thanks to my family and friends for being supportive throughout the programme and offering pieces of advice and suggestions for people I can interview. I want to say a big thank you to everyone that I interviewed, you were all very open and shared a lot of insightful knowledge about your farm systems and businesses. Lastly, I want to acknowledge my fellow Kellogg cohort in the K46 programme, you have all been so great to get to know, and very supportive throughout the process.

1.0 Introduction

Over the last 100 years in New Zealand the transformation from indigenous forest towards predominantly pastoral landscapes has been beneficial for food production and for the New Zealand economy through exports. Intensification of pastoral land has improved our livestock productivity through improved lambing and calving percentages, increased growth rates of livestock and reduced time to slaughter and this has ultimately improved the profitability of sheep and beef farms throughout New Zealand. However, intensification and poor matching of land use to land type along with a lack of attention paid to the impacts on the adjacent natural systems and receiving environments has created challenges around land degradation, biodiversity, greenhouse gas (GHG) emissions and water quality. The depletion of natural capital (soils, vegetation, and waterways) may compromise New Zealand's long term productive capacity and threaten food and water security (Dominati, Maseyk, Makay, & Renel, 2019). Globally and locally, we are seeing increasing social, cultural, and regulatory and financial pressures to reduce our footprint on the environment. This is creating a movement towards sustainable intensification in agriculture worldwide.

New Zealand sheep and beef farms are facing increased costs on farm and an increase in regulation and compliance requirements on farm. Beef + Lamb New Zealand recently announced that the on-farm inflation rate of sheep and beef farms is 10.2%, the highest it's been in 40 years (Beef + Lamb New Zealand Economic Service, Sheep and Beef On-farm Inflation, 2022). Regulation is restricting some management practices on farm, restricting land use options and/or imposing limits to farmers (e.g., synthetic nitrogen fertilizer limits). In 2025 farmers will need to start paying for their greenhouse gas (GHG) emissions through the Emissions Trading Scheme (ETS) or He Waka Eke Noa (HWEN).

We are likely to see the effects of climate change on farm in the coming years. These include increased temperatures, changing seasonality of rainfall, more extreme weather events along with further water limitations in the drier regions are all expected (Ausseil, et al., 2019).

Sheep and beef farmers in New Zealand will likely need to adapt their farm systems, on order to remain resilient, environmentally sustainable, and profitable. There are several ways in which farmers can adapt their farm system, from simple management changes, to altering stock classes or ratios or changing land use. I believe a combination of these adaptions will need to take place on farms to ensure resilience and environmental sustainability. One key strategy that farmers can use to enhance the environment and improve business resilience is through partial land use diversification. This is when farmers diversify their farming enterprise by changing the land use on a proportion of their farm. There are numerous land use options, from planting natives or production forestry, to viticulture, horticulture, apiculture or even sheep or goat milking. However, some of these may be constrained by the biophysical resources of the land. If landowners take the time to understand their natural capital and biophysical resources on farm and alter the land use of certain areas of the farm to better suit the natural resources, then we may be able to create win-win situation. Partial land use diversification has the potential to enhance the existing farm system and the environment. If the agricultural industry in New Zealand can sustainably transition farm systems to restructure using land use change and innovation to mitigate negative consequences to the environment and improve the resilience of farm systems, then we may be in for a brighter future.

This study explored the idea of partial land use change on sheep and beef farms. The reason for this study is because in the current environment there is an opportunity for farmers to diversify their systems, for improved profit, environmental sustainability, and farm business resilience. Sheep and beef farmers are passionate about what they do, therefore the study explored options that farmers could take where the core of their business remains as sheep and beef farming, and we diversify

small areas of the farm to improve profitability and environmental sustainability. There is plenty of research available on what drives landowners towards land use change. However, there is limited New Zealand data on the outcomes of land use change in recent decades. Therefore, the study explored the concept of assessing your farm as if it's a blank canvas. These include identifying the areas of land on farm which are either low performing or high risk to the environment and altering the land use of these areas for improved sustainability and resilience. The study investigated the decision making and planning process for farmers to undertake when deciding on land use options along with the benefits and limitations to land use change.

2.0 Aim and Objectives

2.1 Aim

The aim of this project is to understand if sheep and beef farmers in NZ can use partial land use diversification to improve environmental sustainability and farm business resilience.

2.2 Objectives:

- ☐ Understand if it is a realistic option for landowners to use partial land use diversification on small areas of the farm to improve environmental and financial sustainability, while sheep and beef farming remains the core of their business.
- ☐ Understand if splitting the farm into land management units and accessing the limitations of the natural resources aid farmers in improving environmental sustainability without reducing farm revenue
- ☐ To understand the decision making and planning process to ensure that the land use change has a positive effect on the environment and is worthwhile for the farm business.
- ☐ Discover if partial land use diversification will improve the long-term resilience of the farm so that we have viable sheep and beef farms for the next generation.

3.0 Methodology

To gather information in this project a literature review and a series of semi structured interviews was undertaken

In the literature review the research focused mostly on sheep and beef farms in New Zealand. The study investigated why sheep and beef farmers should consider land use diversification and reviewed land evaluation and the decision-making process for land use diversification. The benefits and limitations to diversification were also investigated. The papers I read, included a combination of scientific articles and case studies of farmers who have diversified worldwide.

A series of semi structured interviews with sheep and beef farmers who have done partial land use diversification on their farm were completed. I wanted to investigate a range of different land use options which farmers have diversified to, to find out if there were similar benefits and implications no matter what land use farmers change to.

Four industry professionals were interviewed, including land management and environmental consultants, a forestry consultant and an agricultural investment expert. These interviews were done to further ground truth the on-farm outcomes of diversification (which we found in the farmer interviews) and to learn more about the implications and benefits partial land use change to the agricultural sector in NZ. Insights were gathered into what planning process of partial land use change to ensure short and long-term enhancement of the environment, financial sustainability, and

farm resilience. Any suggestions on if the agricultural sector or community could aid farmers through the transition of land use change were investigated.

After gathering the information from the literature review and interviews, thematic analysis was used to compare and analyze all the answers to my interviews. This method was used because it helps to identify key themes from a very broad data set.

4.0 Literature Review

4.1 Pressures farmers in NZ are facing

The Agricultural sector in New Zealand is rapidly changing, there are social, environmental, cultural, and financial pressures driving farmers towards land considering land use change. Costs on farm are rising, on farm inflation in the last year has risen to 10.2% (Beef + Lamb New Zealand Economic Service, Sheep and Beef On-farm Inflation, 2022). It is predicted that climate change will have an impact on our farm systems in the future (Ausseil, et al., 2019). All these factors are likely to increase the risk on sheep and beef farms, both environmentally and financially.

Social pressures

As a country we pride ourselves in producing high quality and environmentally sustainable products which feed the world. For many years New Zealand has had a reputation for being 'clean and green', this has been a great marketing tool for us worldwide. However, to keep this reputation we will need to prove, that food production does not have negative consequences to the environment and that we are farming sustainably. We are a nation that relies on exports with 88% of beef and veal exported and 95% of lamb and mutton is exported worldwide (Blueprint for partnership with the New Zealand Government, 2020). The meat industry in NZ relies on the removal of tariffs and non-tariff barriers (NTB's) to improve the economics of our exports in a highly competitive global market (Blueprint for partnership with the New Zealand Government, 2020). This needs to continue in the future so that farmers in New Zealand continue to see high value for their red meat throughout a fluctuating global market. Consumers around the world are changing, many are willing to pay more for high quality ethically sourced, sustainable, and low emission food products. Farmers in New Zealand will therefore need to prove that the food we produce is sustainably produced with low emissions, this will be essential for securing trade deals for our exports in the future. The NZ government has recognized this and over the past 20 years we have seen an increase in environmental regulation in the agricultural sector.

Environmental Regulation and pressures

In the past 25 years land use has intensified through increasing the number of livestock her hectare, increasing the yields per hectare and by adding more fertilizer and irrigation. This intensification has benefited the economy but also has had adverse effects on the environment (Wynyard, 2016). The NZ public and the government has recognized this along with the need to prove globally that we are producing high quality food which has little or no impact on the environment with low emissions. As a result, we have seen more environmental regulation to ensure that farming practices don't degrade the environment. Below is a summary of some of the regulations which are driving change and adaption on sheep and beef farms in New Zealand. These regulations are creating beneficial

outcomes for all New Zealanders, however for many of these regulations there are either added costs or reduced production within the farm system.

Essential Freshwater and Te Mana o te Wai

Essential freshwater is part of the new national direction (Te Mana o te Wai) to protect and improve our rivers, streams, lakes and wetlands (Essential Freshwater: Te Mana o te Wai factsheet, 2020). The essential freshwater package aims to stop further degradation of our fresh water, start making immediate improvements so water quality improves within 5 years and reverse past damage to bring our waterways and ecosystems to a healthy state within a generation.

Sheep and beef farming impacts water quality through nitrogen leaching, overland flow, phosphorus and sediment runoff. Mitigation factors include riparian fencing and planting, erosion control on steep hill country, avoid pugging, and careful management of crops, particularly in winter (van Reenan, 2012). It is important for farmers throughout New Zealand to meet the essential freshwater regulations because this will enhance the environment for future generations. However, fencing off waterways, planting riparian buffers and erosion control on sheep and beef farms adds a large cost to the farm system.

Emissions Trading Scheme and He Waka Eke Noa

There has been a recognition worldwide that we need to limit global warming by reducing greenhouse gas (GHG) emissions. NZ signed up to the Paris Agreement in 2016, a legally binding international treaty on climate change. The Emissions Trading Scheme (ETS) is the Governments main tool for reducing GHG emissions and meeting domestic and international climate change obligations. NZ's GHG emissions are small on a global scale however with a large number of exports worldwide it is an opportunity to show leadership internationally through innovation of the sector (Vibart, et al., 2021).

The ETS aims to reduce NZ's GHG emissions by:

- requiring businesses to measure and report on their greenhouse gas emissions
- requiring businesses to surrender one 'emissions unit' (known as an NZU) to the Government for each one tonne of emissions they emit
- limiting the number of NZU's available to emitters (i.e., that are supplied into the scheme).

The Government sets and reduces the number of units supplied into the scheme over time. This limits the quantity that emitters can emit, in line with New Zealand's emission reduction targets (MFE,2022). The Agricultural sector currently must report its emissions through the NZ ETS however it does not have to pay for its emissions through the NZ ETS surrender obligations. Instead, the government has agreed to work with the Primary Sector Action Climate Partnership to reduce GHG emissions through He Waka Eke Noa (MFE, 2022). He Waka Eke Noa (HWEN) is a partnership between industry, IWI and the Government involving a 5-year programme towards the implementation of framework that aims to reduce GHG emissions while building farm resilience to climate change.

There are two key reasons why the ETS and HWEN will have an impact on sheep and beef farming in New Zealand:

☐ Paying for emissions will be costly

Once the agricultural sector starts paying for their emissions (2025) it is likely to have a huge cost to sheep and beef farms (Beef + Lamb New Zealand, 2022). Agriculture is the single largest contributor (48.1%) to NZ total GHG emissions (MFE 2021). On average methane emissions from eccentric fermentation and manure accounted for 80% of total GHG emissions from the sheep and beef farms (Vibart, et al., 2021). This highlights the need to make adaptions to the farm system to reduce methane emissions on sheep and beef farms.

☐ Farmers can get paid for on farm sequestration of carbon

Owners of post 1989 forest land can join the Emissions trading scheme to earn carbon credits (Environment, 2022). HWEN are working on ways in which farmers can claim payment for further sequestration on farm (He Waka Eke Noa, 2022). The increasing price of carbon in the ETS is driving land use change to forestry. Outside investors are purchasing whole farms for planting trees for either permanent carbon, production forestry or for honey operations. It was estimated that in the first six months of 2021 the gross land area of whole farms purchased for planting was 23,052ha (Orme & Orme, 2021). There is increasing commitment from existing sheep and beef farmers, or landowners considering within farm plantings to diversify their income and reduce GHG emissions. This provides a great opportunity for farmers to diversify their farm system, whilst enhancing the environment.

Climate change

Climate change will likely have a large impact on Agriculture nationwide. Below are some climate projections of New Zealand presented by (Bodeker, et al., 2022).

- An increase of mean air temperature by +0.75^{o}C – 1.3^{o}C over land and sea by 2050 and an increase of +0.8^{o}C – 3.1^{o}C by the end of the century relative to 1995-2014 air temperatures.
- Annual rainfall patterns are expected to increase in the west and south of New Zealand due to increased rainfall in winter and spring. There is expected to be less rainfall in the north and east of New Zealand, however we expect to see more summer rainfall in the east of both islands.
- Flooding, drought severity and fire weather are projected to increase throughout the country.
- Mean wind patterns are expected to change with more north easterlies in summer and more intense westerlies in winter.

These projections were reinforced by (Ausseil, et al., 2019) who investigated how some of the projections might impact agriculture in New Zealand, these are summarized below:

- Increased pasture growth rates, particularly in late spring and early summer
- Increased annual pasture yields (due to increased air temperatures)
- The drier regions like the Hawkes Bay will likely see drier conditions in summer and autumn.
- Increased water demand and water stress in drier regions
- The West Coast and Southland will likely be wetter particularly in spring and winter, making it hard to manage livestock in wet conditions.
- Increased likelihood of heat stress in livestock, particularly in summer
- Increased variability in N leaching on pastoral farms throughout NZ

- Increased amounts of N leaching due to more extreme rainfall events. They predicted in Southland nitrogen leaching may increase from 5 to 25 kg $N\text{-}NO_3^-$ ha year, however the amount of Nitrogen leaching is very dependent on soil type.
- Increased variability in production (King, 2012).

This research shows that climate change has both benefits and downfalls to the average New Zealand sheep and beef farm. Increased annual pasture growth rates may lead to more productive farms, stocking rates could be increased to match the feed supply. There will be a need for more trees for shelter on farm to protect the livestock from extreme weather events and heat stress. This will likely bring other benefits such as biodiversity to the farm system. Farmers will need to have more flexible and adaptable farm systems to remain resilient to variable and extreme climatic conditions (Ausseil, et al., 2019).

4.2 Adapting our farm systems

Adapting our farm systems to overcome social pressures, environmental regulations, climate change and increasing costs is going to be crucial for creating resilient farm systems. Risk is a major factor which affects the resilience of our farm business. (King, 2012) stated that there are five sources of risk in agriculture, production (or yield) risk, market risk, institutional risk, human (or personal) risk and financial risk. He suggested that farmers are most impacted by changes to production prices, climatic conditions (particularly rainfall), the global economy and input process. There are many ways in which sheep and beef farmers can adapt their farm systems to minimize risk. (Ausseil, et al., 2019) mentioned that farmers can make tactical, strategic, or transformational change to adapt their systems. Tactical decisions are the short- and medium-term decisions that farmers regularly make e.g., buying or selling of stock or supplementary feed. Strategic change involves changing a known system to another known production system or making substantial changes to the existing system like changing the sheep to cattle ratio, changes in genetics, infrastructure changes. Transformational change is innovation to develop completely new production systems. (Cullen, et al., 2021) stated that adaption options include change to feed base, adjusting livestock management, changing infrastructure and diversification along with improved tactical decision making can help to overcome climate change impacts.

Tactical and strategic adaptions:

Changing feed base refers to adapting our pasture systems for improved pasture or crop production (Cullen, et al., 2021). Some options include improving soil fertility, using deeper rooted and drought tolerant plant species, using pasture species which are more summer active, forage cropping and lifting average pasture covers. Another way we could change the feed base is by carrying larger fodder reserves on farm (Ausseil, et al., 2019). Livestock management can be changed on farm by changing stock ratio, changing stocking rates to match pasture production, changing the ratio for capital and trading stock, changing livestock policies like shifting the lambing and calving date to match pasture production (Cullen, et al., 2021) (Ausseil, et al., 2019). Other ways we can manipulate our livestock systems are by changing genetics or breed, farming different livestock types or classes of stock both of which could be useful for reducing GHG emissions on farm (Vibart, et al., 2021). Research is currently being done on using genetics to reduce methane emissions in sheep. Infrastructure changes may include planting shelter belts to improve shelter for livestock, upgrading farm water infrastructure, all of which are best management practices (Cullen, et al., 2021).

It is going to be crucial for sheep and beef farmers to have flexible farm systems which they can easily and quickly adapt to subtle changes in climate our other uncontrollable factors. They will

need to get better at making tactical decisions in a timely manner. The use of technology e.g., climate forecasting or soil moisture monitoring coupled with understanding the land resources and soils on farm can aid farmers in making these tactical decisions early. Altering the feed base and livestock management/policies and altering infrastructure are all strategic changes that farmers can make to build more resilience into pastural systems and overall farm systems. If farmers do a good job of matching their pasture species and pasture management to the surrounding environment, then altering their stocking policies to meet feed demand then I believe this will build resilience to climate change. I think that managing the pastures and pasture covers as well as understanding our soils and environmental risks on farm will be very important for ensuring we don't further degrade the environment, particularly if we do get more climatic extremes. It will be important for farmers to keep adapting our farm systems over time by making small changes to farm systems as new technology and science arises. Planning and having systems in place to manage climate extremes will be important in making these strategic and tactical changes on farm.

Reducing on farm GHG emissions

The annual biological GHG emissions were modelled on 170 farms by (Vibart, et al., 2021) , they calculated that the average emissions were 3663 kg CO_2 equivalents per effective hectare, with a range from 157 – 7096 kg Co_2 -e/ha. On average methane emissions from eccentric fermentation and manure accounted for 80% of total GHG emissions from the sheep and beef farms studies. This highlights the importance of reducing methane emissions on farm. Total feed production and quality of feed intake drives stocking rate and animal production per ha on sheep and beef farms and these were highly correlated with increasing GHG emissions. Therefore, increasing efficiency of animal production is a key mitigation tool we have for reducing GHG emissions (He Waka Eke Noa, 2022) (Vibart, et al., 2021). Sheep and beef farmers in NZ have proven that we can become more efficient in producing meat. The NZ agricultural sector emissions have declined 30% over the last 30 years primarily associated with a reduction in livestock numbers, whilst maintaining similar levels of production (Vibart, et al., 2021) (He Waka Eke Noa, 2022). If farmers can continue to increase lambing and calving percentages, improve genetics, grow livestock more quickly and become more efficient with fertilizer use then we will likely continue to reduce our emissions per kilogram or meat produced (Vibart, et al., 2021).

Transformational changes: diversification

Diversification is a key transformational change which can be made on farm to adapt to climate change, reduce GHG emissions, reduce environmental degradation and to reduce farm business risk (Renwick, et al., 2019; Agfirst Waikato, 2020; Dorner, et al., 2018; King, 2012; van Zoonneveld, Turmel, & Hellin, 2020). Diversification for agriculture is defined as the addition of another source of farm-based income to the existing income stream and it includes the introduction of additional faming enterprises (Medhurst & Segrave, 2007).

There are a range of different land use configurations which farmers can consider, these include mixed farming, diversification, infrastructure sharing, diversified specialization, intensified diversification, land sparing, land sharing, patchwork and industrial land use symbiosis (Cullen, et al., 2021), the definitions of these are summarised in Appendix 1 and an assessment of the different land use models is shown in Appendix 2. However, if we focus on how landowners can diversify within their existing farm this creates options for changing the enterprise mix, shifting the balance of the enterprise mix (e.g. shifting the balance from livestock to cropping) or changing the land use to grow a new product (Cullen, et al., 2021) (Campbell, White, & Black, 2002) (Medhurst & Segrave, 2007). Given the variability of farmland within sheep and beef farms throughout New Zealand and the pressures that farmers are facing, I believe that partial land use change and land use

diversification could be very beneficial in creating more resilient farm systems. (Smith, 2021) stated that regulatory changes that are driven with environmental, social and market forces behind them point towards the need for land use change in the agricultural sector. Partial land use change allows farmers to stay true to their existing farming system whilst strengthening resilience in the business. While (Weal, 2021) commented that climate change, lowering GHG emissions will result in changes in land use as a mitigation strategy to lower emitters such as forestry and horticulture.

Research has been done in the Waikato and Taranaki investigating different land use options which are suitable for these regions. Feasible land use options included, horticulture, high value crops, viticulture, dairy goats, dairy sheep and forestry (Agfirst Waikato, 2020; Ward, van den Dijssel, Jenkins, Jesson, & Clothier, 2020). Three different modelling systems were used to explore how land use change on farms in NZ can be used to mitigate GHG emissions in the future (Dorner, et al., 2018). They predicted that it is possible for New Zealand to meet their GHG emissions targets by 2050. However, this will require a shift in land use change towards horticulture and forestry along with significant new GHG mitigation technology and a significant decline in sheep and beef numbers, this is shown in Figure 1.

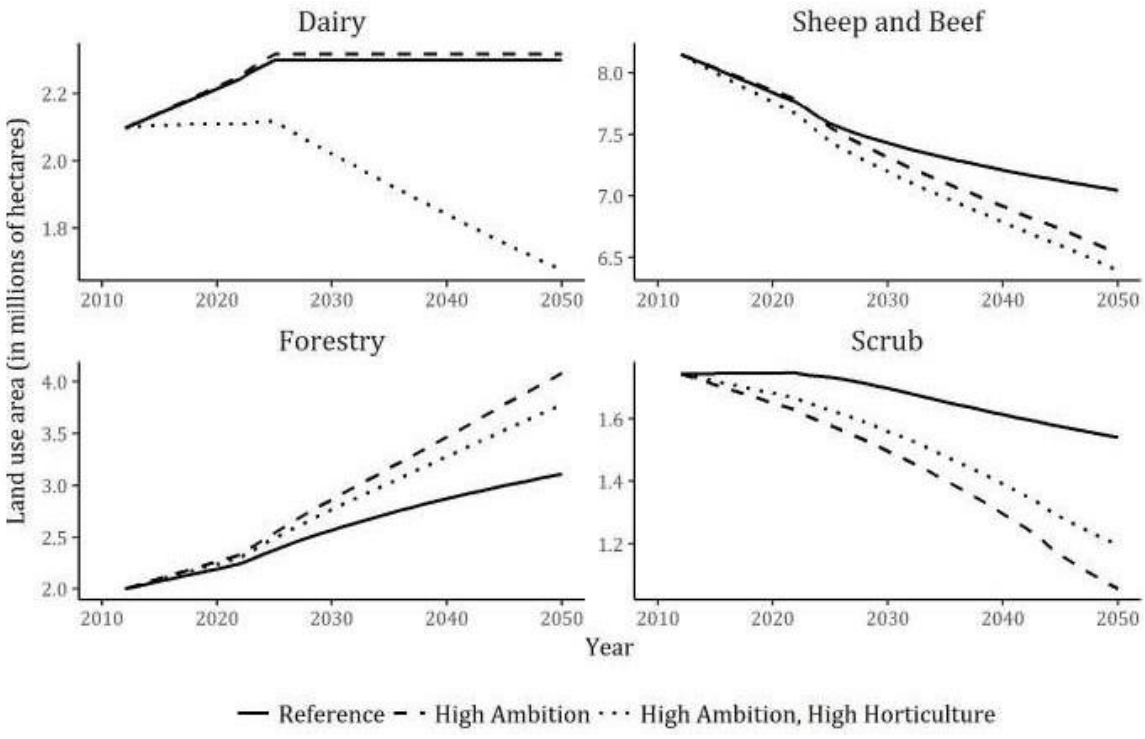

Figure 1. The changes in dairy, sheep and beef, forestry, and scrubland land use across three key scenarios in the LURNZ modelling system to meet New Zealand's 2050 emissions targets (Dorner, et al., 2018).

There are plenty of land use change options available in New Zealand, (Journeaux, et al., 2017) summarized them into the following, forestry to pastoral, current dairying to intensive dairying, pastoral into cropping/horticulture, any land into renewable energy, pastoral to forestry, and land into urban/residential infrastructure. For this report, I am going to focus on two key land use change options because I think they are applicable to most sheep and beef farmers in New Zealand. They are as follows.

1. Pastoral to forestry or agroforestry or reversion to natives

2. Pastoral to cropping/horticulture

4.3 Decision making and planning for land use change

When planning for land use change, it is important to ensure that it will not have negative consequences on the environment, it will enhance the existing farming business and that it is a financially viable option. Good land use decisions depend on being well informed and understanding the tradeoffs between profitability, physical land characteristics and environmental sustainability (Weal, 2021). This was reinforced by (Campbell, White, & Black, 2002) who stated that thorough investigation of diversification options helps reduce risk.

There are multiple factors affecting land use change decisions for farming families, these include biophysical, economic, and technological factors, social, regulations and personal characteristics of the farm owner (Renwick, et al., 2019; Medhurst & Segrave, 2007). Van Zoonneveld, Turmel & Hellin (2020) suggested that there are 7 suggested steps to take for decision making, evaluation and implementation of land use diversification to combat climate change (van Zoonneveld, Turmel, & Hellin, 2020). This decision-making process is shown in Figure 2. This is a great decision-making model; however, it was created based on small farm systems overseas and therefore could be better refined for New Zealand farming systems.

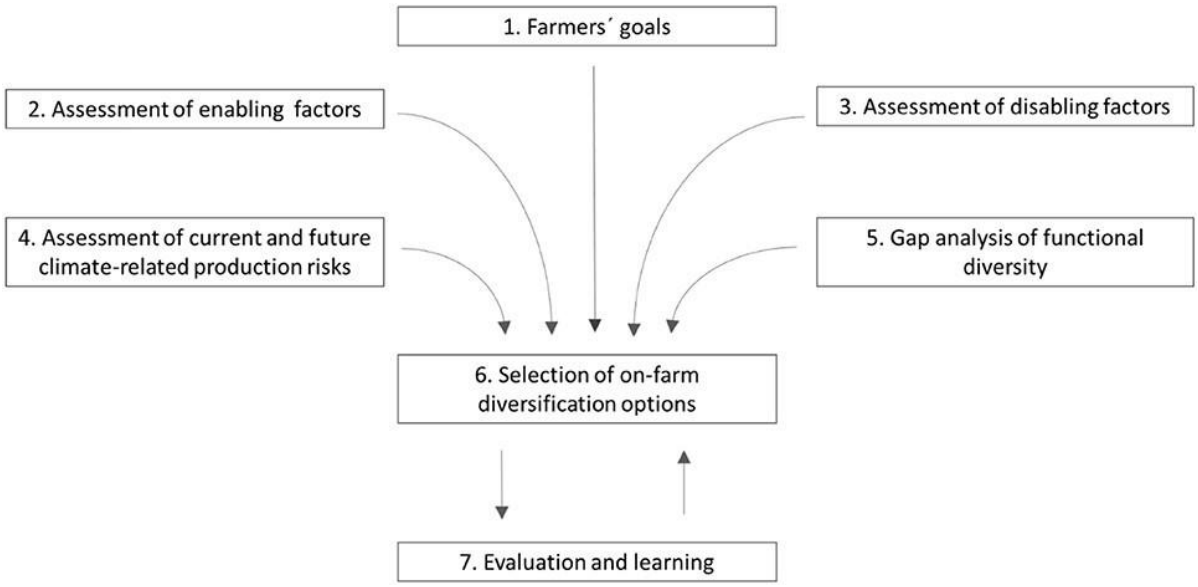

Figure 2: Decision making framework to develop, select, evaluate, and implement on farm diversification strategies, from (van Zoonneveld, Turmel, & Hellin, 2020).

Campbell, White & black (2002) did a series of case studies on farmers in Australia who diversified their farm systems and suggested a series of logical steps to take when considering land use change.

1. Identifying opportunities for diversification and objectives for diversification
2. Resource analysis of land, labour and capital
3. Market research and analysis and market plan
4. Project appraisal to arrange the business structure and understand the financial feasibility

This framework was reinforced by (Journeaux, et al., 2017; Agfirst Waikato, 2020; Ward, van den Dijssel, Jenkins, Jesson, & Clothier, 2020). However New Zealand specific studies had a greater emphasis on understanding the natural and biophysical resources of the farm to ensure that the new land use is farming within the limits of the resource. This is likely because New Zealand has a large variation of soil types, topography, and slope within farms (particularly within sheep and beef farms) and in the past we have seen consequences to the environment which have caused unsustainable land use change (e.g., indigenous forest has been cleared for pastoral land causing erosion).

When (Ward, van den Dijssel, Jenkins, Jesson, & Clothier, 2020) investigated land use options for the Taranaki region they focused on three main categories climate, soil and land conditions and crop choice. Climate factors included growing degree days, winter chilling, frost conditions and rainfall and wind. The soils and land conditions included slope, land use capability, soil types, water availability and susceptibility to weather extremes. Crop choice revolved around identifying what crops could be grown based on the soil, land and climate conditions and what area is available to grow the crop.

While (Agfirst Waikato, 2020) suggested a series of questions to prompt farmers to think on a strategic level when it comes to decision making on land use change, these questions are listed below:

- Why are you considering diversification?
- What financial capacity does the business have for land use change?
- What are you into and why?
- Who are the stakeholders involved?
- What are the skillsets of those involved?
- Where do you see your involvement in value chains?
- What is the farming business appetite for complexity/is there a desire to grow the business?

Understanding the farms natural resources and risks

It is important that farmers understand their natural resources which they rely on when farming. To ensure long term sustainability the farming activity needs to operate within the biophysical limits of the natural environment (Mackay, Dominati, Rendel, & Maseyk, 2018). Land evaluation farm planning and farm system modelling are some key tools which farmers can use to ensure they are farming within their limits.

Land Evaluation

Land evaluation is defined as the assessment of land performance when used for a specific purpose (Mackay, Dominati, Rendel, & Maseyk, 2018). Understanding how different parts of the property respond to different land management practices is an important step to reducing environmental risk and achieving production goals on farm (Fertiliser Association of New Zealand, 2018). Two key strategies in which we evaluate farmland in New Zealand is through mapping land management units and Land use capability mapping.

Land management units (LMU)

Splitting the farm into land management units (LMU's) is a great tool as part of the land evaluation process. A land management unit is defined as "a homogeneous block of land that responded in a similar way under similar management" (Fertiliser Association of New Zealand, 2018). For best management LMU's should be assessed using a combination of physical factors (such as slope, soil

type and aspect), major management factors (this can include effluent areas, irrigated vs dryland) and thorough history and previous use of the land (Fertiliser Association of New Zealand, 2018). Farmers can map out land management units easily themselves and this helps them to better understand their natural resources and some of the biophysical factors affecting on farm production. However, further identification of strengths and weakness and understanding the risks associated with each land management is an important step for farmers to take to ensure they manage the farm well and minimize environmental degradation.

Land Use Capability (LUC)

The land use capability (LUC) classification is a more comprehensive way of evaluating farmland. It has been the primary land evaluation system used in New Zealand to achieve sustainable land development and management on farms and within regions since 1952 (Lynn, et al., 2009). The land use capability classification is defined as a systematic arrangement of different kinds of land according to the properties that determine its capacity for long term sustained production (Lynn, et al., 2009). There are essentially four key physical limitations which are recognized in the LUC classification system and are used to define the class of the land, these are erodibility, wetness, soil, and climate.

The LUC system has two key components to it:

1. Land Resource Inventory (LRI) is an assessment of the physical factors which are critical for long term land use and management. The key factors which are mapped to assess the LRI are rock type, soil type, slope, erosion type and degree and vegetation cover (Lynn, et al., 2009).
2. Land use Capability (LUC) is a subjective measure which uses the LRI to categorize the land into eight classes according to its long-term capability to sustain one or more productive uses (Lynn, et al., 2009).

Figure 3 below summaries the suitability of the different land uses according to the LUC classification of the land. As you can see there are multiple land use options for LUC classes 1-4 and as you move down the scale to an LUC classification of 8 there are less suitable options for the land.

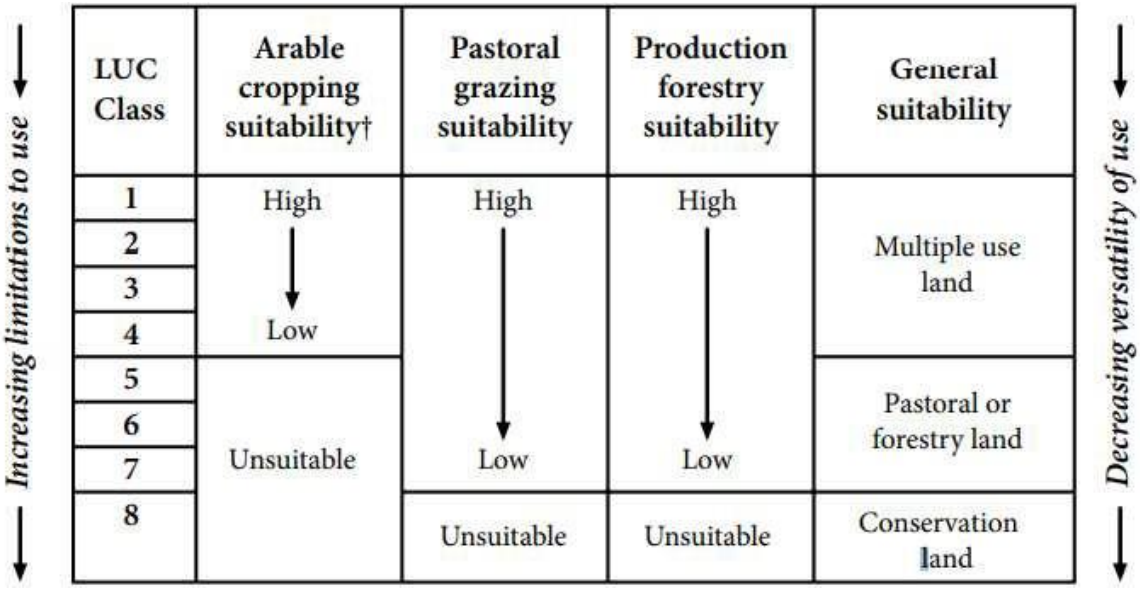

Figure 3: Increasing limitation of land use and decreasing versatility of use from LUC class 1 to LUC class 8 (Lynn, et al., 2009).

While the LUC system is a proven and well utilized land evaluation model in New Zealand, some studies suggest that we should expand the LUC model to create a broader view and which accounts environmental, social and cultural values (Larned, et al., 2017). (Mackay, Dominati, Rendel, & Maseyk, 2018; Lilbourne, et al., 2020) suggested to incorporate ecosystem and biodiversity information in the evaluation. A broader evaluation system would create a shift towards more diverse resilient multi-use farming landscapes. It would encourage framers to have greater emphasis on environmental, cultural, social as well as economic outcomes. While (Larned, et al., 2017) suggested that it would incorporate on and off-site impacts on the environment and may reduce land use pressures on rivers, soils, and receiving environments.

Farm planning

Currently in the NZ agricultural industry we are seeing many different forms of farm plans. Freshwater farm plan (FWFP) regulations are expected to take effect by the end of this year and are used to enhance and improve local water ways (Integrated farm planning Work programme, 2022). Farm environmental plans (FEP) are widely used nationwide, they are a tool used to support farmers to assess and understand their environmental risks, make a plan to manage the risks and demonstrate environmental enhancement over time (Environment Canterbury Regional council, 2022). In some regions farm environment plans are required as part of the regulatory framework and are audited regularly. A farm plan pulls together both the FWFP and FEP, land management units and incorporates farmer goals and objectives to ensure the sustainability and profitability of the farm business (Beef + Lamb New Zealand, 2022). Farm planning is useful for helping landowners understand how land use and land management can result in production gains and environmental enhancement (Mackay, Dominati, Rendel, & Maseyk, 2018).

(Mackay, Dominati, Rendel, & Maseyk, 2018) mentioned that using farm planning in conjunction with land evaluation has improved the outcomes of the environment. Over the years this has expanded to address on farm issues to include nutrient management, riparian management, fencing and planting of waterways and water quality. The inclusion of all the natural resources in farm planning and farm system design and management offers flexibility for the farm system and ensures improved sustainability and greater resilience (Dominati, Maseyk, Makay, & Renel, 2019).

Cross sector collaboration is underway to share data and drive the Integrated Farm Planning Work Programme (Integrated farm planning Work programme, 2022). Integrated farm plans (IFP's) take a whole farm system approach to planning and compliance on farm. They will likely incorporate a farm environmental plan to address GHG emissions, freshwater quality, indigenous biodiversity and the landscape of the farm, animal welfare, biosecurity, business planning, and a health and safety planning. This will reduce duplication for landowners and enable them to better identify risks and opportunities which lift performance and meet the business goals (Integrated farm planning Work programme, 2022).

Modelling

Modelling enables complex systems and situations to be understood and complex problems to be solved (Anastasiadis, et al., 2013). We use modelling to better understand how the social, economic and geographic factors are affected through land use change and to quantify the consequences of a

particular course of action, to explore alternative courses of action and to anticipate and respond to issues that may arise in the near future (Anastasiadis, et al., 2013). Modelling tools, such as Farmax, ARLUNZ, NZ-FARM and NManager can be important step in the process of land use change. However, land use change is too complex for any one model, therefore multiple modelling tools in combination will give farmers a more complete and robust understanding of how a particular land use would affect the environment, the overall farm system and the financial viability of the land use.

Given the importance of modelling it was suggested that we don't have enough quality datasets on land use in New Zealand and it would be beneficial to have improved soil mapping and land use capability in the data available (Hendy, et al., 2018). We need regularly updated GIS maps of land use and more data on the performance of farms, and we need to broaden our modelling to cover a wider range of environmental issues (Hendy, et al., 2018).

4.4 Benefits to partial land use change

It is important to note that there is little data on land use change in New Zealand in recent decades, there seems to be a lot of research done on drivers and barriers of land use change. However, there is limited data on the outcomes of land use change on whole farm systems. This is likely because there has been very little land use change over the past few decades (Journeaux, et al., 2017).

Environmental enhancement

Many studies have shown that through diversification we can improve the environmental footprint of our whole farm system (Maitland, 2020) (Smith, 2021) (Dominati, Maseyk, Makay, & Renel, 2019). If farmers in New Zealand understand their land resources and the surrounding ecosystems, then match the land use to the land type then we will likely see improved environmental outcomes and improved farm resilience to the extreme weather events. Some of the environmental benefits that we have seen in case studies and trials from land use change include improved water quality through reduced nutrient loss into waterways and receiving environments, reduced overland flow, reduced sediment and Phosphorus loss into water ways, and increased biodiversity (Dominati, Maseyk, Makay, & Renel, 2019). (Dominati, Maseyk, Makay, & Renel, 2019) did a case study on a sheep and beef farm in Waikato and proved that it is possible to increase profitability along with having a decreased environmental footprint, this was reinforced by (Agfirst Waikato, 2020; Dodd, Quinn, Thorrold, Parminter, & Wedderburn, 2008).

Table 1: Summary of nutrient and GHG losses modelled from a range of different land uses in the Waikato (Agfirst Waikato, 2020).

Enterprise	Nitrogen (kg N/ha/yr)	Phosphorus (kg P/ha/yr)	Methane (CO^2 Eq/ha/yr)	Nitrous Oxide (CO^2 Eq/ha/yr)	Total GHG (CO^2 Eq/ha/yr)
Dairy Farm	30.0	0.6	7.3	2.5	9.8
Sheep and Beef	13.0	0.5	3.6	1.0	4.6
Dairy Goats	19.0	0.1	Not reported		
Dairy Sheep	17.0	0.2	Not reported		
Maize	6 \ 99 *	0.1	-	0.8	0.8
Lucerne	8	0.1	-	< 0.1	< 0.1
Kiwifruit (Gold)	18	0.3	-	0.4	0.4
Apples	23	0.3	-	0.3	0.3
Chestnuts	12	0.1	-	0.1	0.1
Forestry	2.5	0.1	-	-	-

GHG emissions and carbon stocks

Soil carbon was higher in agroforestry systems, this was likely due to increased below ground carbon through root litter (Jordon, Willis, Harvey, Petrokofky, & Petrokofky, 2020). (Dodd, et al., 2020) found that changing land use from pastoral to forestry greatly increased the above ground carbon stocks and the overall farm system had a negative net GHG emissions because the area under forestry sequestered more CO_2 than the emissions of GHG by the animal production system. All agroforestry systems in the paper by (Jordon, Willis, Harvey, Petrokofky, & Petrokofky, 2020) mitigated some of the emissions associated with the livestock component of the system, through sequestration of the trees.

Changing the land use from pastoral systems to horticulture and cropping is also likely to reduce the GHG emissions, the table below shows that GHG emissions on horticultural and arable land is much lower than on sheep, beef and dairy farms. This is likely because methane is the biggest contributor to agricultural and methane is emitted by livestock.

Table 2: Indicative biological GHG emissions from different land uses (Agfirst Waikato, 2020).

	T CO_2e/ha/yr
Dairy	12.5
Sheep and Beef	3.0
Kiwifruit	0.17
Viticulture	1.03
Apples	0.71
Arable cropping	0.95

*Individual farms can vary significantly from these figures.

Water quality

Agroforestry has shown to have a significant positive effect on water quality. These systems have lower runoff and higher soil infiltration capacity and reduced sediment and phosphorus in the water ways (Jordon, Willis, Harvey, Petrokofky, & Petrokofky, 2020; Dodd, Quinn, Thorrold, Parminter, & Wedderburn, 2008). Riparian strips and shelter belts where livestock were excluded hold even more potential for mitigating livestock induced runoff into water ways. This is reinforced by a study where Manuka was planted for honey production on 42ha of eroding land, wetlands and gullies enhanced existing natural capital stocks along with a range of ecosystem services. The changing management of this land resulted in a 21% reduction in runoff for the whole farm, reduced the risks of the farm contributing sediment and Phosphorus to receiving environments (Dominati, Maseyk, Makay, & Renel, 2019). Similar results were seen by (Dodd, Quinn, Thorrold, Parminter, & Wedderburn, 2008), who planted 160 ha of pines, fenced off waterways and planted riparian buffers around the waterways, they saw declines in sediment (76%) phosphorus (62%) and faecal coliform (43%) in the surrounding waterways.

Soil erosion

The planting of trees is a widely known strategy for stabilizing slopes and reducing soil erosion. In New Zealand in recent decades widespread planting has occurred in erosion prone areas to reverse the negative consequences of vegetation clearing following European settlement. (Jordon, Willis, Harvey, Petrokofky, & Petrokofky, 2020) showed that 71 % of studies investigated showed that agroforestry had a significant positive effect on soil erosion.

Enhanced biodiversity

Land use diversification is likely to increase biodiversity on farm; riparian buffers and agroforestry are obvious examples of increasing biodiversity on farm. Increased biodiversity has a pivotal role providing shelter for livestock, providing natural pest control in cropping and pastoral systems and in building resilient farm systems and communities (Dominati, Maseyk, Makay, & Renel, 2019; Norton & Reid, 2013). Dairy farmers who planted riparian buffers along waterways saw several benefits, it not only improved the biodiversity of the farm, but the farmers saw improvements in the farm's appearance, lower staff turnover, improved ability to attract staff along with increased property values (Dominati, Maseyk, Makay, & Renel, 2019).

Spreads risk

The spreading of risk or having the eggs in multiple baskets is one of the most well cited benefits of land use diversification (Campbell, White, & Black, 2002; Medhurst & Segrave, 2007; Agfirst Waikato, 2020; Journeaux, et al., 2017). In most instances the spreading of risk was discussed in financial and market terms. Many farmers experience financial difficulties through downturns, multiple enterprises reduce the reliance on a particular form of income to remain financially viable. Generally, when one market has a downturn, other markets have a better outcome, and this therefore spreads the financial risks. Other risks on farm include market, climate and personal risk. Land use diversification can also play are role in reducing the risk to the climate and extreme weather events. Trees and shelter enhance livestock survival and production in climate extremes. While different plant and crop species have varying degrees of resilience to climatic conditions.

Improved financial situation

Studies show improved cash flow or improved overall profit as a result of land use diversification. Risk has been spoken about previously, however spreading the risk has a positive impact on the financial outcomes. Three quarters of the studies where agroforestry was investigated show that there was a positive impact on the economics, compared to separate livestock production or trees, however with the onset of the ETS or He Waka Eke Noa, this will likely increase the economics of agroforestry even more (Jordon, Willis, Harvey, Petrokofky, & Petrokofky, 2020). The profit per hectare of land which remained in pasture increased by 5%, with diversification on other areas of the property (Dominati, Maseyk, Makay, & Renel, 2019). Table 3, shows the enhanced economic performance of different land use options when compared to sheep and beef and dairy farms (Agfirst Waikato, 2020). It highlights some significant improvements in cash surplus/ha and some significant opportunities for those that have suitable land and climates for the alternative land uses. Another benefit of cash flow and cash surplus is that it may mean we can invest some of the cash back into the farm, which could lead to improved production, efficiency or environmental stewardship.

Table 3: Analysis of economic performance of different land use options compared with sheep and beef or dairy systems in the Waikato (Agfirst Waikato, 2020).

Enterprise	NPV	IRR	Payback (years)	Total Capital	Cash farm surplus per ha	Area
Sheep and Beef					$388	127
Dairy Farm					$2,444	571
Dairy Goats	$1,645,697	10%	8.5	$4,637,250	$10,410	60 ha development
Dairy Sheep	$1,156,721	12%	7.5	$1,587,500	$4,947	60 ha development
Maize	$36,337	198%	1	$2,420	$3,180	per ha
	$2,249,401	%	1	$139,200	-	60 ha
Lucerne	$26,267	127%	1	$2,050	$2,976	per ha
	$1,576,014		1	$123,000	-	60 ha
Kiwifruit SunGold	$ 469,149	8%	10.5	$2,763,846	$76,000	5 ha
Kiwifruit Hayward	-$122,264	5%	13.5	$1,262,310	$28,000	
Apples	$1,488,737	14%	7.5	$511,274	$24,115	5 ha
Chestnuts	$155,125	9%	12.5	$352,000	$9,850	10 ha development
Forestry (12%) farm Forestry	$29,879	24%	Income at year 28 (harvest)	$2,000	-	Per ha

New skills

A study was done on multiple farmers in Australia who have diversified their farm business. They found a key advantage of diversification was that the farmers enjoyed the challenge of learning new skills (Campbell, White, & Black, 2002).

Livestock production

(Jordon, Willis, Harvey, Petrokofky, & Petrokofky, 2020) modelled the effects of agroforestry on livestock production systems in temperate climates, they mentioned that despite agroforestry systems having lower pasture production (compared to straight pastoral systems), livestock growth rates improved. This shows that agroforestry, shelterbelts or windbreaks within livestock systems has a positive influence on livestock growth rates, milk yield and weather-related mortality, which is likely due to reduced heat and cold stress. With the likely increases in air temperatures due to climate change in the future, this benefit will likely be enhanced. (Dodd, et al., 2020) did a case study where 52% of the steeper and less productive land on the farm system was planted in *P. radiata* for production forestry. They made some changes in cattle classes and sheep breed to fit the farm system and the overall stocking rate was reduced by 55%, however the total production from meat and wool only reduced by 28%.

4.5 Implications to partial land use change

Time and complexity

When it comes to on farm diversification, this takes time. As expected, there is increased workload in the planning and development stages of land use change, however many of the land use alternatives come with increased complexity and time spent after the crop is established. (Campbell, White, & Black, 2002) mentioned in their report that many of their case studies knew

there would be an increased workload, however they didn't expect such a great increase in workload. This workload was increased due to the complexity of the business, (Renwick, et al., 2019) noted there was additional complexity of running multi enterprise operations. This had an impact on social wellbeing (Smith, 2021), it meant less time spent with family, less time off work, and other parts of the farm business were neglected or didn't meet their usual high expectations (Renwick, et al., 2019).

Lack of technical knowledge

Some case studies have shown that farmers have found the diversification process hard because they have lack of technical knowledge on the land use and relating markets (Campbell, White, & Black, 2002). Farmers in the case studies mentioned that it created a steep learning curve and it added risk to the diversification process.

Access to Capital

Access to capital to develop land use change is another barrier (Renwick, et al., 2019; Smith, 2021). Sheep and beef farms generally have a low cash surplus, while land use change can require large development costs, and some crops can take years to before you before they get any returns. This highlights the importance of having the bank involved in land use change planning and having confidence to support the enterprise.

5.0 Findings and Discussion

5.1 Treating farm as a blank canvas for identifying land use change opportunities

There is real opportunity for sheep and beef farmers to analyze the productive and financial performance of different management units within their sheep and beef farms. Land use capability mapping is a great land evaluation resource which splits the farm in to land management units according to the biophysical constraints of the land (Lynn, et al., 2009). However, for less complex farms (which have less variation in slope, soil types and topography), farmers could split their property into land management units themselves. When farmers evaluate the productive and financial performance of the individual land management units of the farm it allows them to identify the underperforming, medium performing and the higher performing areas within the farm. Furthermore, it allows the farmers to identify cost of inputs vs outputs and ultimately profitability of the different land management units within the farm. Alongside this there is potential to recognize the areas within the farm which are high risk or prone to environmental degradation such as soil erosion, sediment and P runoff, nitrate leaching etc.

This would allow landowners to look at their farm with more of a business approach and aid them in realizing the inefficiencies within the farm system. It creates opportunity to model and compare changes in management or changes in land use and estimate the outcomes from these changes. I believe that it will help to remove a bias towards a particular land use, and it will likely help farmers to remove emotional ties from the process. It will likely aid sheep and beef farmers to realise opportunities within their farm system both environmentally and financially.

(Smith, 2021) stated in her Kellogg report that if each landholder transitioned a small underperforming piece of land to an alternative enterprise, then both environmental gains and income diversity can be achieved. I agree with this comment, however I don't think we should restrict land use change to the underperforming areas of the farm. Farmers could potentially make more profit and have great environmental outcomes by transitioning a small area of their best land

to high values crops or horticulture. Or they may see greater benefit in targeting the high-risk areas of the farm and altering the land use of that to reduce environmental degradation. These decisions are complex and at the end of the day it comes down to the requirements and priorities of each individual landowner.

5.2 Case Studies

The Dawkins Family

The Dawkins family own a 602 ha property with a 30ha lease block in Marlborough. The property now consists of:

- 400 ha effective hectares of the property is sheep and beef
- 100 ha is a vineyard
- 95 ha is in plantation pine and amenity trees

The land changes occurred on the property over numerous years. Forestry blocks were planted on the areas of the farm which were erosion prone or less desirable for grazing livestock. Forestry blocks were gradually added to the system over time. The vineyard was planted in two stages, stage 1 was planted in in 2016 and the stage two was planted in 2020.

Planning

Chris and Richard are details people, so prior to land use change they did lots of research themselves. Both Chis and Richard have a very good understanding of the biophysical resources of the land from farming it for numerous years. Prior to the first vineyard development, they engaged with multiple experts in the field. They chose to invest in a vineyard because it was proven in their region, and they were an economic land use which required minimal water (efficient in their climate). They selected a winery, which managed the development of the vineyard. They put full confidence in the winery, however remained very engaged in the process, by having regular meetings with during vineyard development to learn and understand the process. They invested some climate monitoring to ensure they planted varieties which best suited the climate. In the second stage of vineyard development, they managed the development themselves. The vineyard has been climate proofed using frost fans, stored water, and an efficient watering system to overcome potential climate change impacts. When planting forestry, they did their own research to select the tree species and did much of the development themselves. When planting trees they fenced the tree blocks off, which enhanced the subdivision of the property. Waterways have been fenced off and shelterbelts have been added.

Outcomes of diversification

The Dawkins family believe that land use diversification has enhanced their property. The planting of forestry and shelterbelts has been complementary to livestock, they believe that the planting of almost 10% of the farm in forestry has had no impact on the production of livestock. In fact, they mentioned that shelter from forestry and shelter belts has led to improved pasture production and improved livestock performance and in some areas of the farm improved soils (increased topsoil and gradual healing of previously eroded land). They also mentioned that the long-term investment into a 10 ha block of forestry allowed them to purchase a 200ha block of land. Land use diversification created more succession and retirement options for them as a family and it has spread the risk though having eggs in multiple baskets. They mentioned that the different land uses within the farm are compatible with each other, this adds further benefit. Sheep and cattle graze in the vineyard to reduce the need for mowing, this reduces feed pressure on the remaining farm system and forestry adds shelter to the farm. Land use diversification has improved long term environmental and

financial sustainability of the business and enhanced the resilience of the farm. They believe the there were limited downfalls to land use diversification however, complexity was the main downfall. Through engagement with specialists, daily decision making based on science and best practice and through putting systems in place to manage the complexity it can be overcome. Other downfalls were increased risk due to the reliance on contractors and requiring more employees and reduced aesthetics of the farm.

Michael Read

Michael Read and his family traditionally owned a 500 ha mixed arable farm, which grew small seed (for seed multiplication), grain and finished winter lambs. Michaels parents diversified the farm system by planting 180ha of blackcurrants in 1978. After the Ribena factory closed many of the blackcurrants were removed. They now have 30 ha of blackcurrants with the aim of growing this area to 100 ha. Michael has planted a 15 ha apple orchard, 6 ha were planted initially, the following year another 6 ha were planted followed by a remaining 3 ha of apples. The aim is to grow the apple orchard to 20 ha (this creates one business unit). Michael is now trailing cherries as another potential investment opportunity. The remaining farm is still in arable land, growing grain, small seed, ryegrass for multiplication, hemp and finishing winter lambs.

Planning

Michael wanted to maximise the opportunity of having good soils, this led him to diversification. He mentioned that land use planning all started on the back on an envelope, where he compared a large range of land use options. He did research on the different land use options and spent time investigating the market opportunity of different crops. He utilised advisors and the bank, to understand profitability and risk etc. When it came to the planning for apples her found that there were limited advisors in Canterbury, so he visited a range of orchards in the North Island to understand the more about the crop. They already had climate data on the property from the blackcurrants, this helped to understand which crop best suited the property. When investigating future land use options, he looks for integration with other land uses along with improved cashflow. The sharing of infrastructure and labour is of benefit to the farm because it creates a more efficient system.

Outcomes of diversification

Michael found that that land use diversification was very rewarding, he is producing a great product for market. He enjoys learning new things and finds establishing and growing new crops very challenging and exciting. He mentioned that according to the budget apples will improve profitability and cashflow of the farm system, however it is too early to see the true financial outcomes. Long term diversification has made succession easier; his brother runs the arable side of the business, and he runs the horticulture. Both have full control of their own systems; this brings clarity and ownership and reduces the opportunity for argument. Another advantage was environmental enhancement, he mentioned that the modelled nitrogen leaching is lower the surrounding farm systems. The downsides to diversification are reduced cashflow and increased risks during development and in the early stages of production. Climate, market and financial risks are the key risks they face when growing a new crop, “it’s like taking a big punt” he said. Complexity is another downfall to land use diversification, he mentioned that higher value crops come with more detail when compared to traditional farming. This requires more crop checks, more labour and more record keeping. He mentioned that complexity can be overcome by putting systems in place to manage it.

5.3 Opportunities and benefits to land use diversification

There is limited research data on land use change in New Zealand, research is particularly limited when investigating land use change from pastoral systems to horticultural systems. There is some data on land use change towards forestry. However, most of the land use change data is modelled data rather than on farm evidence. The interviewees demonstrated the outcomes they have seen on farm however some of the data was hard to quantify and is therefore subjective data. I have themed the on-farm benefits into six key benefits.

Improved farm business resilience

Improved farm resilience was a key theme which was identified during the interviews as a major benefit to land use diversification. The main factors which improved farm resilience was the ability to spread risk and improved financial performance. The interviewees found that land use diversification led to the spreading of cashflow and spreading the financial risk across multiple markets this was reinforced by (Campbell, White, & Black, 2002; Medhurst & Segrave, 2007). This reduced the risk of price volatility affecting their financial situation and allowed them to ride through the waves of downturns in specific markets more easily. One of my interviewees grew a large area of blackcurrants and overnight the market was pulled from beneath them with the closing of the Ribena factory, he has leant from this "not to throw too many eggs in one basket" and is conscious not to plant too much land in one specific crop. They now have a system which includes mixed cropping, winter lambs, an apple orchard, blackcurrants and now they are trialing cherries.

Land use diversification enhanced farm business resilience to climate risks too. We are likely to see climate change impacts in the coming years, which is predicted to increase temperatures throughout New Zealand and increase the likelihood of more regular extreme weather events (Ausseil, et al., 2019). Having multiple crops on farm is likely to reduce the risk of damage to the environment plus it spreads the risk of crop damage leading to reduced financial burdens from extreme weather events.

Improved financial performance

Almost all the interviewees mentioned that long term financial sustainability and improved profit was a key benefit to land use change. One interviewee mentioned that the diversification to horticulture lead to a 'transformative cashflow'. The only farmer who didn't mention improved financial performance, was in the early stages of development, they were relying on modelling to prove the financial benefit as it was too early to see the real financial outcomes of land use change. This was reinforced by (Campbell, White, & Black, 2002), who did case studies of many farms who had diversified in Australia. Many of these case studies showed that in the early stages of land use diversification, there was a large cash outlay, however once development was complete, and the crops had matured there was significantly improved financial performance from the farm system along with improved cashflow. Improved cashflow and profit creates options and opportunity for the landowners or for the farm business, it reduces risk, improves farm resilience and helps to future proof the farm system.

Succession

Succession was a key benefit seen from land use diversification on sheep and beef farms. The improved financial performance led to more options for family members in succession (Campbell, White, & Black, 2002; Renwick, et al., 2019), more options for retirement and more options for off farm investment. This made it much easier for landowners to support off farm family members, plus it created opportunities for more families to make a living on the farm. Land use diversification

creates different business units within the farm system, allowing family members to run a business unit each. This creates clear boundaries of roles and responsibilities when multiple family members are on farm. Two of the farmers I interviewed mentioned that prior to land use change the farm could financially sustain one family, now up to three families are living off one farm. However, to ensure this is successful a strategic business plan and systems should be put in place so that each person in their business knows their roles responsibilities and there are adequate reporting systems.

Environmental enhancement

There are many ways in which the environment can be enhanced through land use diversification. Studies show improved water quality through reduced sediment runoff, reduced phosphate loss and reduced nitrate leaching (Dodd, Quinn, Thorrold, Parminter, & Wedderburn, 2008; Dorner, et al., 2018; Agfirst Waikato, 2020; Journeaux, et al., 2017), this was highlighted in Table 1. In many cases this occurred through the fencing of waterways, the planting of riparian buffers, agroforestry where livestock is incorporated into the system and where trees were planted (for either carbon or production forestry). However, modelling has shown the many horticultural crops and specialized arable crops have lower phosphate and sediment losses when compared to sheep and beef farming and similar nitrate losses to waterways. Some of the farmers interviewed mentioned improved water quality, however they had no proof. Erosion can be reduced through the planting of trees or reversion to natives or using spaced poplars where livestock can graze the farmland too (Jordon, Willis, Harvey, Petrokofky, & Petrokofky, 2020; Norton & Reid, 2013). This has played a significant role in regenerating landscapes in areas like the Hawkes Bay. The Dawkins family found that removing livestock and planting *P. radiata* healed some of the erosion scarring over time, and now on occasion that block can be grazed again.

Many studies show that GHG emissions were reduced through land use change from sheep and beef farming to either forestry, horticulture, viticulture or arable crops. Table 2 shows the GHG emissions from the differing land uses and highlights that both dairy and sheep and beef farms have the greatest emissions. This is because livestock are large emitters of methane. None of my interviewees could prove whether land use change reduced they're on farm GHG emissions, this is likely because it is only recently that we have started calculating on farm emissions, and farmers wouldn't have calculated their number prior to changing land use. Given that farmers in New Zealand will have to start paying for GHG emissions from 2025, I believe that this alone could be a major driver of land use change, particularly on the steep and lower productive hill country (LUC classes 5-8).

In recent years we have seen increasing emphasis on the importance of biodiversity in our farm systems. Land use diversification increases the biodiversity within the farm systems which provides a range of other benefits towards the ecosystem and the whole farm system (Norton & Reid, 2013; Dominati, Maseyk, Makay, & Renel, 2019; Dodd, Quinn, Thorrold, Parminter, & Wedderburn, 2008). Biodiversity is enhanced the most within the farm system through the reversion to natives and through riparian plantings and through the exclusion of livestock (Dodd, Quinn, Thorrold, Parminter, & Wedderburn, 2008).

Two of the farmers I interviewed mentioned that they had improved soils as a result of land use change. Both mentioned that the amount of topsoil increased over time since land use change. One of the land uses where topsoil increased was in viticulture and the other was in pasture, with a tree block on the boundary of the paddock, another study showed that in some agroforestry systems, the soil carbon increased (Jordon, Willis, Harvey, Petrokofky, & Petrokofky, 2020). This proves that no matter the land use if the natural capital is utilized within its limits, then improved sustainability and enhanced environmental outcomes can be seen.

Integration with existing systems

A key benefit which of land use change was the opportunity integrate the existing farm system with the new land use for added benefits. This was highlighted through all my interviews with landowners, even though they all had very different farm systems. The Dawkins family mentioned that the planting of 142ha of trees (on steeper and erosion prone hill country) has been beneficial to the livestock production on farm. They believe that the planting of trees leads to an increase in productivity of the farm due to improved subdivision when forestry blocks were fenced. The trees have provided shelter for livestock, and the pastures, this has enhanced pasture production and ultimately livestock production on farm.

The sharing of resources between different land use systems was highlighted by farmers, both properties which had vineyards and the property which had blackcurrants grazed sheep through the horticultural blocks at certain times of the year. This saved time on the tractor either mowing or spraying with herbicides, plus it took the pressure of the sheep and beef feed demand at crucial times of the year. Michael Reid mentioned the sharing of labour units was very beneficial to his farm system, he spread the labour units between two different varieties of apples, blackcurrants and the existing arable and sheep wintering business. He mentioned that when he looks into other diversification systems, he looks for crops which are harvested outside the timeframe of harvesting his existing crops, this enables him to share the labour units between the existing system, plus it improves cashflow. Another way in which the new land use can be integrated with the existing system is though using cashflow or cash surplus from the new land use to enhance the existing sheep and beef farm. This can be used for improving infrastructure or environmental stewardship in the existing farm system, or it can be for improved efficiency or meeting regulation requirement. Without the alternative land use many sheep and beef farms don't have the cash surplus to make major improvements. Figure 4 below highlights the improvements and integration that happen within a farm system with the planting of production trees, riparian planting, and the regeneration of indigenous species.

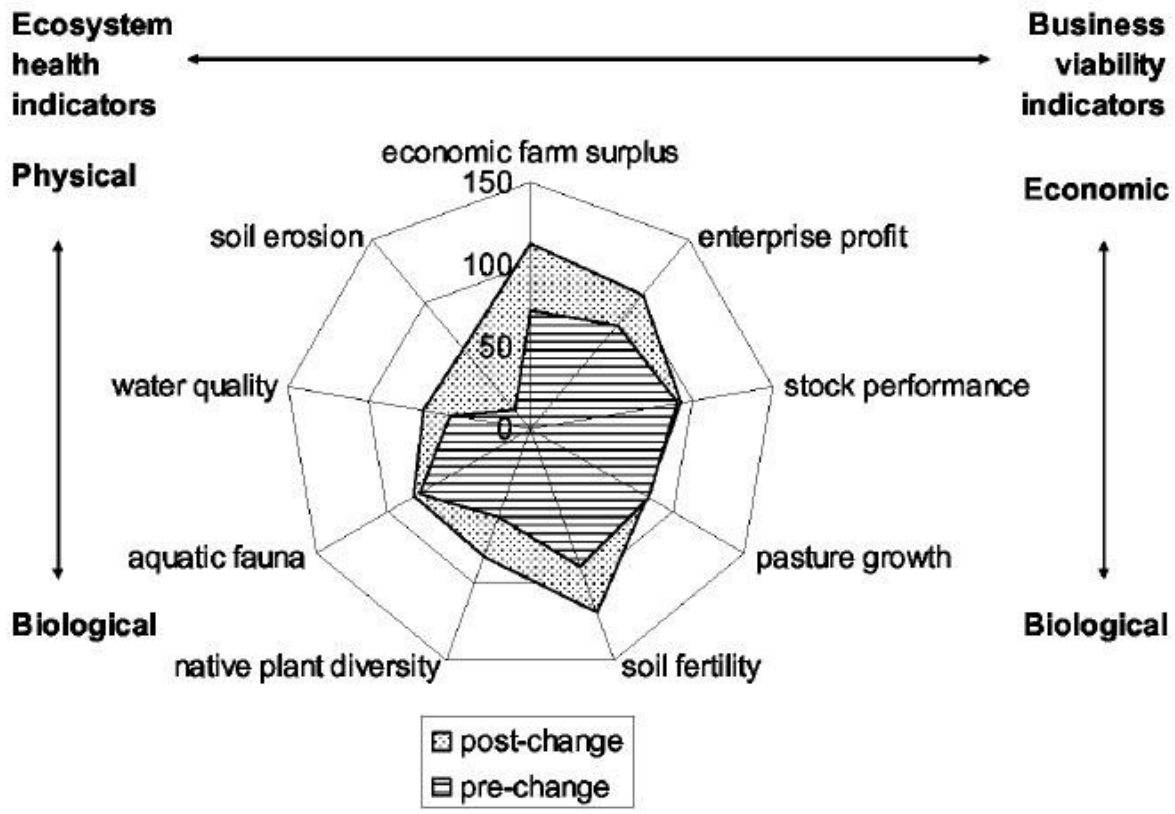

Figure 4: Benchmarked aggregate indicators (%) for economic and environmental performance of the Mangaotoa catchment farm before and after land use changes (Dodd, Quinn, Thorrold, Parminter, & Wedderburn, 2008).

Other benefits outlined in farmer interviews included enhanced aesthetic value, personal benefits such as enjoyable, challenging and rewarding, not to mention increase knowledge and skill.

Farmers replanting sensitive land for soil conservation or biodiversity reasons create the opportunity to increase returns on the better parts of the farm and explore other revenue streams for underperforming parts of the farm.

5.4 Downfalls to land use diversification

Studies investigating land use diversification on pastoral farms show very few downfalls, the major limitations to diversification were increased complexity of the business, lack of technical expertise and access to capital (Campbell, White, & Black, 2002) (Medhurst & Segrave, 2007), the interviews reinforced this. Throughout my interviews the two most common downfalls to land use change were increased complexity of the business and increased risk.

Adding another business unit to any business is likely to increase the complexity. Diversifying land use in agricultural systems creates a whole new level of complexity, in most situations landowners have diversified to a land use that they have no experience in. This requires upskilling, research and bringing in expertise. During and post development there is increased workload, likely increased labour units (particularly in horticultural and viticultural systems). Michael Reid suggested “that higher value crops come with more detail and monitoring compared to traditional farming systems, farmers considering land use change need to understand this and realize that it brings extra workload and labour”. This creates distractions to the existing farm enterprise which in some instances can create production losses and takes time away from family and holidays. Some of the

farmers I interviewed had overcome the complexity by having systems and strategy in place to manage the complexity. Interviewees looking into expansion of their diversification were investing in technology which aids in removing complexity and labour units.

Risk was another major downfall highlighted in the interviews was increased risk. Land use diversification from sheep and beef farming to horticulture, forestry or viticulture can be very expensive and it can take many years until breakeven on the investment (Campbell, White, & Black, 2002). In many cases farmers are investing in a land use which that have no experience with, the lack of knowledge alone creates both financial and market risk and climatic risk. However, everyone that was interviewed mentioned that this risk can be reduced through thorough research, careful planning, bringing in expertise, market analysis and modelling. One of the interviewees mentioned that it's important to have 95% confidence in the new land use type another stated that more information leads to good decision making.

5.5 Planning for land use change

Decision-making framework for land use change demonstrated by (van Zoonneveld, Turmel, & Hellin, 2020; Agfirst Waikato, 2020; Campbell, White, & Black, 2002) all gave great insight to key considerations when it comes to decision making and planning of land use change. I believe that adapting this framework could lead to improved decision making and planning processes when considering land use diversification on sheep and beef farms in New Zealand. It has already been highlighted the key to success in any attempt to diversify an existing farming business is good planning. I have summarized some important steps to take when considering land use diversification.

Step 1: Farmer and farm business goals

When deciding how to diversify the farm it is important to understand the farmers goals and their goals and vision for the business. (Campbell, White, & Black, 2002) suggested that "to run any business successfully you need to have a clear goal and vision of how to achieve that goal, but most importantly you must have the commitment to achieve it". Another key consideration is that many farms in New Zealand are small family businesses, many of which aim to pass the farm onto the next generation. Land use change or land use diversification is often a multi generation decision, so it is important to recognize all stakeholders in the decision-making process (Agfirst Waikato, 2020).

As part of understanding farmer and farm business goals, vision and values it is important to consider the following:

Age and stage of farmer

The age and stage of the farmer will affect the investment they are wanting to make into the farm business. It is important to understand their long- and short-term personal goals, this will help to identify what's best for the farming family in the short and medium term.

Long term goals of each family member

It is important to get the whole family around the table to discuss a plan, this will help to identify family goals and ensure that everyone is on the same page when it comes to intergenerational business planning. An example of some questions asked should be does the next generation want to option to take over the farm? Does the next generation need financial support from the farm? Do we need to diversify to aid in succession?

Key drivers for diversification

When it comes to land use change it is important to consider the drivers for land use diversification, i.e., financial, wanting a challenge, to provide for the next generation, environmental reasons. If farm succession is the driver for diversification, then the process of succession planning may need to take place as part of the process (Agfirst Waikato, 2020). One of the farmers interviewed mentioned that part of the decision for land use change was to help set up the children for the future. This will likely be beneficial come succession; however, the added complexity of the business has resulted with less family time while they are young, therefore compromises need to be made.

Strategic plan and structure of the business

The family (all involved in the farm) should make sure they have a strategic plan for the business. All involved should understand the vision, values, objectives, and goals for the farm business and seek advice to create a business structure. If the farming family understand their own long-term goals and the goals of the family business, then they can use it as a guide to ensure they make the best decisions for the business. The Read family has found added benefit though setting us a business structure, it has led to improved reporting on the different business units, and a more trusted relationship with banks and advisors.

Step 2: Land and resource evaluation

Understanding the biophysical resources of the farm is very important for making both management decisions and land use decisions, it aids farmers in creating a more sustainable and resilient farm system long term. When considering land use diversification on farm I suggest evaluating the on-farm resources and splitting the farm into land management units. Once the farm is split into different land management units it is beneficial to calculate the livestock performance and profitability of each individual unit. This can aid farms to compare profitability with other land uses and it can help to realise opportunities for diversification on farm.

Land use capability mapping

For complex sheep and beef farms with a wide range of soils, slope and climatic conditions I would recommend LUC mapping. This will help to identify the physical limitations of the land under sustained production and potential land use options which will best match the capability of the land. Lachie suggested that LUC mapping is a great tool for identifying different land behavioral patterns and it helps to make decisions based on science. Another situation where LUC mapping can be useful on farm is when a new farm is purchased, and the farm owner doesn't understand the natural and biophysical limitations to the farm. In this situation LUC mapping can lead to well informed management and land use decisions. Lachie reinforced this when he mentioned that LUC mapping negates experience.

Mapping out land management units

For less complex sheep and beef farms with minimal changes in slope and soil type and topography. Farmers can identify land management units of the farm themselves (or with the help of an advisor). This would likely be sufficient for making good land use decisions. However, it is important to recognize the key biophysical factors and limitations to each land management unit.

Step 3: Create a farm plan

The farm business plan should represent the overall farm system, it should clearly identify the risks to the farm (environmental, social, cultural and economic) and it should create a plan on how to manage or mitigate these risks. All these things are likely to be included in the integrated farm planning system going forward (Integrated farm planning Work programme, 2022). Completing this process will ensure that the new land use is suited to the capability of the natural resources within

the farm, this will likely enhance environmental outcomes and sustainability of the whole farm system.

This farm plan should include:

- Vision and goals for the farm business
- A map of land management units of the farm
- Identify the risks of each land management unit
- SWOT analysis (strengths, weaknesses, opportunities, threats)
- A plan to measure and monitor change
- A plan to manage and mitigate risks on farm
- Prioritization of which risks are most important to resolve.

Step 4: Assessment of enabling and disabling factors

This step is important for understanding whether land use change to a different form of land use is possible with the resources available. Here are some factors to consider then looking into land use change.

Biophysical resources

Understanding the biophysical resources for the farm (e.g., soils, slope, topography, climate) and knowing the limitations of these resources will allow a better match of land use to its surrounding environment. Studies have shown it is also beneficial to understand other resources within the environment particularly biodiversity and ecosystem benefits, managing these areas wisely can result in the enhancement of overall farm systems and reduced environmental consequences. Some questions worth asking are:

- Do these biophysical resources have the capability of long production for the specific crop (or land use) without having degrading effects on the environment?
- If a land use isn't environmentally sustainable, then what other land use options do I have for this area of land?

Access to water

In recent decades water for irrigation has been seen as an enabler of land use change because it broadens the opportunities for landowners. Water is seen as financially attractive because it increases the certainty of profit and reliability of return on certain crops. In the past increased water availability through irrigation has been a driver the expansion of dairying and horticulture (Renwick, et al., 2019). With increased demand for horticultural crops in New Zealand and with the incoming impacts of climate change looming water security and storage is becoming more important to landowners. Therefore, when considering land use change, it is important to understand whether there is access to water for irrigation on farm, and the reliability of this water. This is a major factor that may influence land use type.

Financial

Having cash or financial backing to cover the costs of initial setup of the new land use is crucial for land use change. Consider the cost of development, the time to breakeven, and the time until you start to see cashflow after development. Those with a lower level of investment generally were paid off more quickly (Campbell, White, & Black, 2002). It is important to get banks and financial advisors involved in the planning process, this helps to plan financially and ensures a trusting relationship with the banks throughout the process.

Markets

The location of the farm may affect access to the market, if there are physical barriers affecting access to market then this may be a large limitation to land use change. Scale of the farm may also affect the market, if there is only a small area of the farm where land use change can occur, then it may be hard to find a market for a small quantity. In the Central Plains Irrigation scheme a number of those who developed alternative enterprises noted that they did not have enough scale (in terms of land availability to go to the next level such as supplying supermarkets and export markets despite there being high demand for products (Renwick, et al., 2019).

Personal characteristics of the farmer

The farmer who is considering land use change needs to be passionate about what they are doing, they need to be open to learning, and risk adverse. Land use change often requires learning a new set of skills, landowner needs to be willing to learn new skills. The Dawkins family stated "if you're not passionate about the land use then don't do I".

Access to labour

In many cases changes in land use change means that there will likely be a change in labour requirements of the farm. Labour is cited as a primary industry constraint (Agfirst Waikato, 2020), therefore there needs to be careful consideration around labour requirements of the new farm system, particularly if land use is moving towards horticulture which has a high labour requirement.

Regulation

Regulation to land use could be a limitation to land use change in the future, however if farmers are committed to environmental enhancement and sustainability of their farm production this should not be an issue. Regulations in some regions limit land use change options, it is important to understand the local regulations and consents required prior to committing to land use .

Step 5: Selection of on farm diversification options

Identify land use options which align with farmer goals and values, match the land use resources, fit within the farm planning outcomes and meet the enabling factors of the farm system. If there are any disabling factors that become a barrier, then other land use options may better suit the farm system.

Step 6: Farm system modelling

This is an important step to ensure that farmers understand how the land use will affect the remaining farm system. There are three key steps to this modelling:

Modelling whole farm system

It is important to understand how land use change on one area of the farm will affect the remaining farm system. Land use change will likely lead to adjustments to management and/or livestock systems on the remainder of the farm. Whole farm system modelling tools would be beneficial at this stage to ensure that there are no unintended consequences.

- Understand how the new land use can benefit the remaining farm system
- Downfalls to the remaining system or unintended consequences
- Understand management changes that need to occur
- Ensure that the overall farm business will have improved long-term sustainability and improved environmental outcomes
- Ensure that the overall farm business meets it financial goals

Modelling for future climate production risks

Ensure that the climate is going to match the land use in years to come, this may require doing some climate projections and modelling to understand how climate change may affect the crop production. Long term modelling to understand how the new land use may affect the receiving environment and to ensure long term sustainability, financial modelling will be important to ensure financial viability. Do research to ensure future regulations will not affect how the crop is managed down the track can be beneficial too.

Financial modelling

Financial modelling is important for understanding profitability and cashflow of the new enterprise. This enables farmers to work with their financial advisors to create a plan to reduce risk and ensure the improved long term financial performance and enhanced business resilience.

Step 7: Learning and Evaluation

Leaning and evaluation are especially important steps to ensuring that farmers know what they are getting themselves into. It provides the opportunity to learn about the crop in which you are considering growing. Many of my interviewees mentioned that it is important to do your research on the crop. Understand climate and growing conditions, seasonality, labour required and do your research on market availability for that crop. Get experts in and utilize their knowledge as much as possible. Evaluate different varieties and cultivars to identify which might be the best options for your farm system. This is also a fantastic opportunity to understand the detail and management factors involved in growing the crop. Take your time on this stage, because the more you arm yourself with information the more likely you are to succeed.

Step 8: Trial and experiment

Do small trials, to ensure it works in the climate prior development, this will reduce the risks of diversification. A study highlighted that the expansion of the diversified business should occur gradually over time, in line with the ability of the business to generate cash flow to support expansion (Campbell, White, & Black, 2002). This will likely reduce the risk of the investment. The Trotter family did trials in their vegetable garden prior to planting 1.5ha of strawberries. When the Read family diversified into apples they started with 6 ha, with the aim of growing the area to 20ha. They are now trialing a series of cherry varieties as another diversification option but will not invest into them until they can prove that they will be successful in the environment.

5.6 Collaboration

It was highlighted throughout my interviews that there is real potential for farmers to collaborate with likeminded farmers or with catchment collectives when considering land use change. This would lead to the formation of more cooperative models throughout the agricultural industry. It will allow farmers to share resources, knowledge and infrastructure and it would increase scale of the business which in turn can create better access to markets. There is potential for catchments to work together and achieve a common goal, this would be especially useful for the sharing of labour and expertise. It was suggested through two interviews that growing apples in Canterbury could be a great opportunity for collaboration. Apples is a fairly new crop to Canterbury, and more scale is needed in the region. There is currently limited expertise on apples in Canterbury so it would allow farmers to share the expertise and potentially a share a manager to run the operation for all the farms. Doing this would allow the sheep and beef farms to focus their time on their remaining sheep and beef farm systems. (Renwick, et al., 2019) suggested that farmers expressed a willingness to collaborate to develop new markets or to get access to more land.

However, there are downsides to collaboration, it has been suggested that when cooperatives get too large it can become more difficult. Another interview suggested that when there are multi stakeholders are involved the messaging and direction gets too far from the original scope, this leads to inefficiencies. Managing the different people within the cooperative was also a downside. Interviews highlighted that it is important that you work with likeminded people with similar goals. Figure 5 below suggests that there are eight principles of collaborative governance, these are required for successful collaboration. If farmers are considering a collaborative approach, a careful consideration is required when deciding who you will collaborate with. A common purpose, trust and transparency and having shared values is essential for long term success of the relationship (Circle Forward, 2020). Followed by planning, shared or equitable power, leadership and the sharing of knowledge.

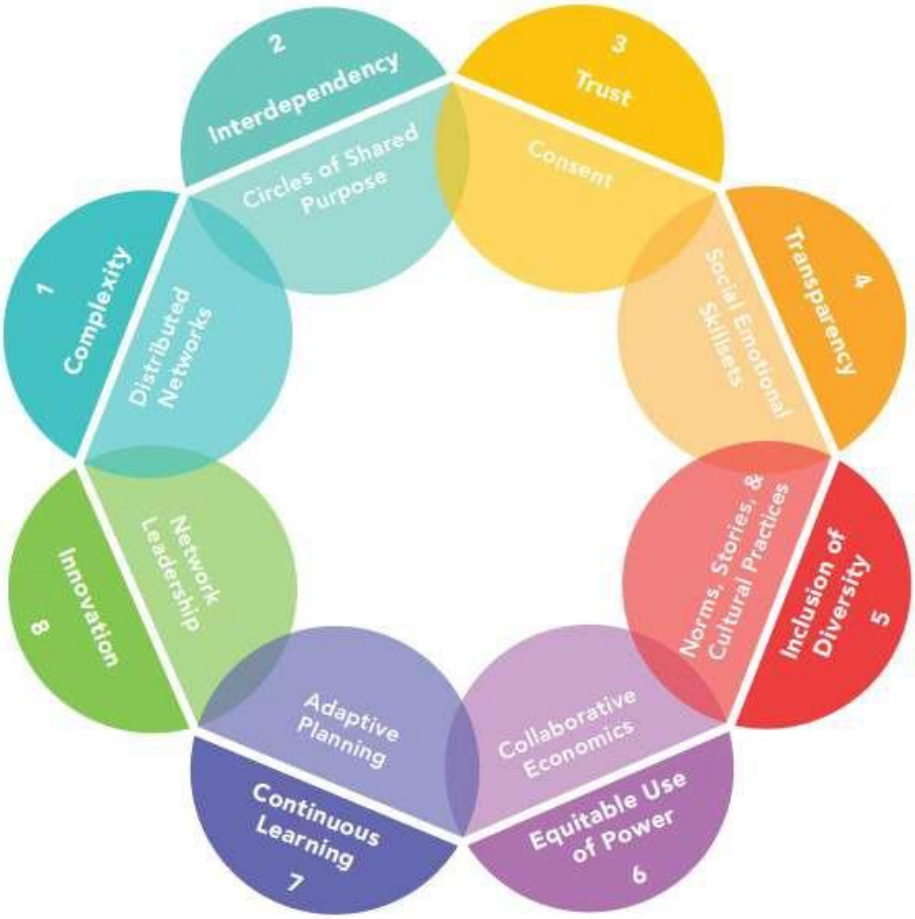

Figure 5: The 8 principles of collaborative governance and the assumptions and values aligned to these principles (Circle Forward, 2020).

When considering cooperative and collaborative models as an option for farmers in land use change there is plenty of potential, however there is also a lot of grey areas. More research needs to be done on the potential for cooperatives to aid the transition of land use throughout New Zealand and more research is needed on the process of establishing these cooperative models for successful outcomes.

5.7 What do we need from the agricultural sector to aid land use transition?

There is a need for more research on land use options throughout the country. More specific research on the suitability of different horticultural crops in each region would be helpful to farmers considering land use change along with more research into new and alternative crops or markets. This would help to de-risk the process of land use change for farmers. Bayne & Renwick (2021) mentioned that the government could play a role in facilitating the development of alternative land uses by investing in research and development and creating an environment in which innovation can thrive (Bayne & Renwick, 2021). This has been done very well in the Taranaki, where a report has been created identifying different land use diversification options for farmers. It studied a range of different crops along with the soils, land and climate in the region and it suggested viable land use options for farmers. To aid farmers in the transition of land use change, it would be great to have regional reports like this available to farmers nationwide.

It has been suggested that incentivizing alternative land uses may help to drive farmers towards land use change. This was reinforced by (Renwick, et al., 2019) who mentioned that incentivizing alternative land configurations could enable faster transition while remaining competitive.

There is a need for specialist consultants and expertise who are easily accessible to farmers and can guide farmers through the transition of land use change. To achieve this there will likely be a requirement for upskilling within the industry to create more advisors and to create better advice. Furthermore, it has been suggested that the banks need to have a better understanding of different land use options, so that they are confident to financially support farmers through the development process.

Sharing the success stories is another way to encourage farmers to consider land use diversification. Farmers learn from farmers, so once diversification has proven to be a successful model other farmers are likely to follow suit. The use of case studies to highlight outcomes plus the challenges and barriers that farmers face through land use diversification will aid farmers through the transition process.

6.0 Conclusions

This study proved that partial land use diversification is a real option which sheep and beef farmers should consider for overcoming social, environmental, regulatory and financial pressures. To de-risk the process of land use diversification, research and planning are crucial. Matching the land use to the capability of the biophysical resources is important for ensuring that there are no negative consequences to the environment. If land use change is well planned and researched it will likely transform farm systems through improved long term financial performance, improved environmental outcomes and increased farm business resilience. There is potential to collaborate with other likeminded farmers and create cooperative models for the sharing of infrastructure, resources, and expertise, however more research needs to be done on this. Overall land use diversification is very important for the agricultural sector in New Zealand.

7.0 Recommendations

- ☐ Landowners should assess their farm as if it is a blank canvas, identify production and profitability and limitations of different land management units. This will aid in realizing the opportunities and inefficiencies within the farm system. Plus, it might help the farmer to realize that land use diversification is a real opportunity.

- ☐ Research the different land use options you are considering, understand the requirements of the crop and the biophysical resources of your land to ensure you match the land use to the capability of the land. Plan for diversification thoroughly.
- ☐ Develop tools which outline land use options which suit the local climate. These could be developed and maintained by regional councils with the use of local climate data and research into land use options. The tools should be accessible to farmers, this would likely de-risk the process of land use change for farmers and provide them with a starting point when considering land use change.
- ☐ Collaboration could be considered with likeminded farmers to build scale and share resources when changes are made to land use. If they decide to do this investigation and planning into corporate governance models is recommended.
- ☐ Case studies should be produced on farmers who have been through the process if land use diversification, these could be done by the regional councils to aid farmers in making the change.

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Appendices

Appendix 1: Definitions and examples of alternative land use configurations (Bayne & Renwick, 2021)

Approach	Characteristics	Examples
Mixed farming	Mixed farming involves a system of farming which involves the growing of crops as well as the raising of livestock. According to the FAO, 'mixed farming is probably the most benign agricultural production system from an environmental perspective because it is, at least partially, a closed system. The waste products of one enterprise (crop residues), which would otherwise be loaded on to the natural resource base, are used by the other enterprise, which returns its own waste products (manure) back to the first enterprise. As it provides many opportunities for recycling and organic farming and for a varied, more attractive landscape, mixed farming is the favourite system of many agriculturalists and environmentalists.' [30], (p. 1 of Chapter 3).	Although numbers are reducing due to specialization, mixed farming systems are found in many regions of NZ. For example, a number of farms still have sheep and/or beef enterprises as well as crop enterprises [31]. However, there are challenges with viability across these systems.
Diversification	Diversification relates to farmers taking a portfolio approach, producing alternative species or products to protect against market downturn. Often, but by no means always, this takes the form of a small proportion of land being dedicated to niche production, while the main production continues under an intensified management regime.	An early diversification in livestock production was the farming of deer [32]. Another example of an industry niche sector expansion through diversification is the wine sector, now an established regime within New Zealand's primary industry.
Infrastructural sharing	Taking lessons from the growth of the 'sharing economy', farm equipment and infrastructure could be either jointly owned in a co-operative between farm units; or each farm unit could invest in only certain items, and rent or lease infrastructure and equipment from others as required. Farm units would then not require as much capital investment, particularly for items that only have seasonal or occasional use. As many investments in equipment and production require scale, this supports a more consolidated and intensive regional farming model. This is linked to land-use because individual farms could grow a greater range of more specialized crops.	Machinery rings, which are common in a number of countries are an example of such an approach [33]. In New Zealand, a 50/50 sharemilking arrangement between farmers and DairyNZ for stock and land management is in place. (See Sharemilker model)
Diversified Specialisation	Diverse specialization sees instead of joint ownership or lease of equipment, that farmers might become 'specialised land managers'- providing a service to a variety of land owners choosing to invest in certain land uses. In this way, the whole of a farm unit could still be intensively managed, but by a number of different farm managers who are contracted to provide the specialized management service. Land tracts become more diversified, but individual farmers do not need to become experts across multiple farm enterprises. Farmers may own similar size units, but only manage a portion of their own land, while also managing on contract portions of neighbouring properties that are being farmed in their specialist land use.	This model exists for production of root crops (such as carrots and potatoes) [34] where due to need for rotations and specialist equipment, growers often rent land across a number of farms to grow the crops. Flying flocks/herds exist where owners move their animals across a number of farms.
Intensified Diversification	Intensified diversification relates to 'producing more diversified products off the same parcel of land', preferably with minimal additional inputs into production. Examples usually include either finding markets for wastes or byproducts; or growing a diversified crop alongside the main production unit.	Some examples from New Zealand include: Baby doll sheep in Yealands vineyards. The sheep primarily keep the grass down between rows of grapes, but also provide another diversified farm product; Recreational and ecotourism services from forests; Deer co-products such as tails, pizzles and sinews [35].
Land Sparing	Land sparing refers to the concept of sparing land for biodiversity conservation and was introduced by [36] to characterize zoning policies that set aside land from agricultural production for maintaining local biodiversity. This idea is sometimes referred to as "the Borlaug hypothesis", after Norman Borlaug, father of the Green Revolution, who considered agricultural intensification good for the environment as it concentrated production on limited land [37]. Within a regional area, it would mean that some land would be retired from farming whilst intensification occurs on the remaining land.	Set-aside within the EU and also the Conservation Reserve Programme in the US are examples of this type of policy in the farmed landscape. QE2 covenants may be seen as an example of this in NZ.
Land Sharing	In contrast to land sparing, this approach promotes agricultural practices with lower ecosystem impacts and aims to increase within-field biodiversity (so-called wildlife-friendly farming). Organic and regenerative farming fit into this category biodiversity credit	Again, looking to the EU we can see that this approach has been widely adopted through environmental programmes aimed at reducing the intensity of input use for example [38].
Patchwork	Under this approach land becomes a patchwork quilt of a variety of uses, through the establishment of maximum land footprints for any one land use activity. The original rationale for promoting a patchwork scale approach was to mitigate losses that could emerge due to large tracts of one type of production being destroyed due, for example, to a natural disaster. However, it can also be seen as a way to encourage diversity more generally in the landscape. Policy measures would be required to restrict the size of individual land use blocks, which would also have the benefit of reducing the risk of disease outbreak or natural disaster to each industry.	Such anti-consolidation policies have been employed in the past in New Zealand to restrict individual farm unit size [39], but not on a land usage basis.
Industrial/Land- use Symbiosis	The underlying aim of industrial symbiosis is small scale circularity to reduce waste in production. In effect, the idea is that two or more industries are associated and co-located together, such that the wastes from one industry become the feedstocks for another's production unit. At the larger scale, industrial symbiosis engages separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or byproducts. Waste by-products from one industry are used by another in a co-dependent economic relationship for mutual benefit. Land can play an important part in this process.	The models have been used extensively in Europe (e.g., Kalundborg, Denmark) [40]. In a NZ example, the principle has been adopted between local wood processors, geothermal energy production, government, R&D, indigenous and logistics and service agencies in the Kawerau region. At the individual level, some forms of agriculture do practice a 'whole-systems' approach, typically biodynamic and organic ventures, often at a small scale, although increasingly sectors are adopting such practices.

Appendix 2: Risk assessment of models of land use (Bayne & Renwick, 2021)

Approach	Main Impacts on Sustainability	Complexity	Resilience	Role of Market	Possible Policy Interventions	Degree of departure from Current System	Scalability
Land Sparing	Environmental Gain.	Medium at regional level as could require trading of production rights on land	Increase resilience by introducing buffer into landscape	Requirement for fallow areas could be part of supply contracts	Regulation to take land out of production. Could introduce trading. Possible financial incentives	Relatively small if simply retiring parts of farm. Stays in Qi	Can easily be applied at regional level
Land Sharing	Environmental Gain	Medium at regional level if trying to maximise environmental gain	Lower intensity may reduce disease pressures but may increase financial pressures	Premium for credence attributes could encourage change. Supply contracts could demand changes	Regulation of intensity. Incentives for extensification	Large if move to low intensity systems from high intensity ones. Can move to Qii/Qiii	Depends on viability of lower intensity systems
Intensified Diversification	Economic Gain	Low as relates to individual land owner. Niche development can add complexity to system	Economically more resilient but landscape may not change	Market will provide opportunities for alternative products	R&D to support development of new products	Relatively small as producing new products from similar system. Stays in Qi	Need for markets/supply chain infrastructure to achieve scale
Diversification	Environmental Gain	Low based on individual land owner. Niche development can add complexity	Diversified landscape will be more resilient	New profitable enterprises can drive change	R&D support to develop new enterprises. Market development	Depends on nature of diversification but may be large and may move to Qii or Qiii	Need for markets supply chain infrastructure to achieve scale
Infrastructural sharing	Economic Gain	Medium requires co-ordination across land managers to achieve scale	Diversified landscape will be more resilient	New profitable enterprises can drive change	R&D support to develop new enterprises. Market development	Depends on nature of diversification but may be large as will be new enterprise. May move to Qii or Qiii if integrating say livestock with crops	Sharing can help with scale issue but need for markets for products
Diversified Specialisation	Economic Gain	Medium requires co-ordination across land-managers to achieve scale	Diversified landscape will be more resilient	New profitable enterprises can drive change	R&D support to develop new enterprises. Market development	Depends on nature of diversification but may be small if just involves making land available. However, may move to Qii or Qiii if integrating say livestock with crops	Need for markets supply chain infrastructure to achieve scale
Patchwork	Environmental Gain	Medium/High depending on specification (extensive and intensive margins)	Regionally area will be more diversified	Low driven by policy not markets	Regulation to enforce patchwork. Could introduce trading scheme	Potentially large at regional scale. May force farms to be more integrated (Qii or Qiii) or may end up like land sparing	High but may incur significant economic costs on farms in region
Industrial Symbiosis	Environmental and Economic Gain	High as likely to require co-ordination across land managers and possibly other industrial sectors and range of stakeholders	More circular/closed system will increase resilience	Cost savings and increased profitability could support change	Support industry development. R&D support	Large change due to re-thinking of systems. Possible move to Qiii or Qiv	Easier to achieve at smaller scale as larger scale with more players will become increasingly complex

Appendix 3: Interviewees

Farmers:

Richard and Chris Dawkins, Sheep and beef farming, diversified into viticulture and forestry
Trotter Family, Techno beef system diversified into strawberries
Michael Read, Arable and lamb finishing diversified into blackcurrants and apples
Scott Berry, small scale sheep and beef diversified into viticulture and marketing of wine

Industry Professionals:

Mark Cox, Operations Director Craigmore Farming Fund, and farmer
Erika Van Reenan, Agribusiness consultant, environmental consultant, director at Agfirst
Lachie Grant, Director of Land Vision Ltd.
Dave Janet, owner of Forest Management Ltd

Appendix 4: Interview Questions

Interview questions for Farmers:

Farm history

1. Describe your farm system and how it has changed overtime?

2. What are you doing on farm already to overcome environmental outcomes?

Planning

3. What are your reasons for diversifying your farm system?
4. What was the planning process and timeframe from first thought, conversion of land use?
    - Where on farm?
    - What land use?
    - Planning and modelling, land evaluation
    - Are there other factors you should have considered in hindsight?

Benefits and implications

5. How has partial diversification impacted the remaining production of you farm?
6. What are the benefits of partial land use change?
    - Environment and farm system, financial, sector, biodiversity etc.
7. If you were to go through the process again, would you change anything? What would you change?
8. Are there any downsides to the land use change? How have you managed them?
9. How has partial land use change has improved overall long-term sustainability of the farm business? Both sustainability and financially

Sector challenges

10. If many farmers decided to diversify their farm, what advice would you give them?
11. If many farmers were interested in land use change, what implications do you think it would have on the sector?
12. Is there anything we could do as a sector to help farmers through the process of land use change?

Interview questions for Industry professionals

Farm system and planning

1. If you were advising a sheep and beef farmer now, what would are the top three recommendations you would give them to ensure they have an environmentally and financially sustainable farm business to pass on to the next generation?
2. Which key factors should farmers consider if thinking of converting a proportion of their farm into a different land use?
    - Within farm
    - Outside the farm gate
3. What do we need to know about your industry, to aid farmers in their decision making when considering land use change?
4. What other recommendations would you give farmers who are considering partial land use change?
5. What planning process would you encourage farmers to use to ensure we improve environmental sustainability and farm profitability?

Benefits and implications

6. What benefits and implications do you think we will see as an industry if many sheep and beef farmers look to make small scale diversification on farm?

- Benefits
- Implications

7. What benefits and implications do expect to see from a farm system if farmers diversified the land use on a small proportion of their farm?
   - Benefits
   - Implications
8. How do you think partial land use change on sheep and beef farms could affect the wider communities?

Sector challenges/responsibilities

9. If multiple farms changed the land use on a small area of their farm towards your industry, how do you think it would affect your industry and the wider agricultural sector?
   - What factors do your industry and the wider agricultural sector need to consider now to prepare for land use change?
10. What can the agricultural sector and surrounding communities do to help support farmers through partial land use change?
    - Agricultural sector
    - Your industry
    - Surrounding community
11. What strategies do you think we need to put in place to ensure both environmentally sustainable, financially sustainable, and more resilient farm systems?
12. Could there be any benefit or downfalls to collaboration between farmers to help manage on farm development and management of land once its converted?