Climate Adaptation: how might Manawatū-Rangitīkei sheep and beef farmers futureproof their land?

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Executive Summary

Farmers adapt to the weather as part of their everyday decision-making on farm. Evidence suggests that, for New Zealand, the climate will change more significantly in the years between 2040 and 2090. How might Manawatū-Rangitīkei sheep and beef farmers adapt to the changing climate and futureproof their land?

The purpose of this report is to translate scientific climate modelling into practical contexts for Manawatū-Rangitīkei sheep and beef farmers and consultants.

This report aims to provide knowledge of:

1. Climate change predictions within the century.
2. What risks and opportunities are associated with climate change predictions.
3. What practical short to long-term actions could be considered that might future-proof farming businesses?

The methodology involved a literature review, followed by semi-structured interviews which formed qualitative research into futureproofing solutions.

The key findings are four climatic attribute changes to be aware of:

1. The frequency and intensity of drought.
    a. By mid-century, a rainfall deficit of 50mm – 75mm per year.
2. The number of ‘hot days’ over 25^{o}C.
    a. By mid-century an increase of ‘hot days’ over 25^{o}C, between 40% and 100% per year.
3. The frequency and intensity of adverse and compounding weather events.
    a. El Niño and La Niña natural weather cycles exacerbated by climatic changes globally.
    b. More severe adverse weather events, their frequency requiring more research.
4. An increase in temperature.
    a. By the end of the century, an increase of 0.7^{o}C - 3.1^{o}C under the Representative Concentration Pathway’s (RCP) 2.6 and 8.5.

Recommendations to Manawatū-Rangitīkei sheep and beef farmers and consultants:

1. Use credible, trusted, and up-to-date sources of information to inform opinions about the changing climate.
2. Learn from advisors who collaborate closely with the scientific community and can translate data into meaningful, practical contexts.
3. Assess the current farming system concerning the top four climatic attribute changes and identify relevant, attainable, short to long-term actions, that may futureproof the business.
4. Build financial resiliency to be able to absorb hits and invest in futureproofing mitigation solutions.
5. Identify primary land use resources and their potential alternate use, if the existing system needs to change in the future.

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1.0 Introduction

Agriculture is the largest industry contributor in the Manawatū-Rangitīkei districts with an economic contribution of $475m in 2022, accounting for approximately 21% of the district's gross domestic product (GDP) (Infometrics, 2022). The sector is fundamental to the district economy, therefore futureproofing for the effects of climate change is crucial.

Farmers are required to be more informed than ever before with much to adapt to – and the changing climate is no different. Farmers adapt to the weather every day by making decisions on farms based on weather predictions and experience. However, evidence suggests that the climate is changing, with predictions of hotter days and drought conditions occurring more significantly in the years 2040 and 2090 (Ministry for the Environment, 2018). The frequency and severity of adverse weather events are also of concern.

"For farmers, it is not a question of whether to adapt or not, but rather what to adapt to and how" (Fitzgerald, 2022). This report addresses high-level future predictions of what the climate might look like in the Manawatū-Rangitīkei within the century and provides practical solutions on how farmers might adapt by futureproofing their land.

2.0 Purpose and Aims

The purpose of this report is to translate scientific climate modelling into practical contexts for Manawatū-Rangitīkei sheep and beef farmers and consultants.

This report aims to provide knowledge of:

1. Climate change predictions within the century.
2. The risks and opportunities associated with climate change predictions.
3. The practical short to long-term actions that could be considered to futureproof farming businesses.

These aims will be achieved if farmers gain an improved knowledge of the long-term effects of climate change in their district, and the actions they might take to futureproof their land.

3.0 Methodology

The methodology used to answer the research questions include:

1. Literature review to:
    a. Explore New Zealand climate modelling data and climate change predictions for the Manawatū-Rangitīkei districts.
    b. Form knowledge of how climate change predictions might affect sheep and beef farmers of the Manawatū-Rangitīkei.
    c. Form knowledge of solutions that could futureproof land from the effects of climate change.

The literature review phase primarily involved finding the most up-to-date and relevant information and providing initial sets of ideas that aligned with the research questions.

2. Following the literature review, qualitative research was conducted through six semi-structured interviews with farmers, industry experts, a climate scientist and industry peers to seek:
    a. Their understanding of climate change.
    b. Their experiences and learnings from adverse weather events.
    c. Insights into futureproofing solutions.
    d. Which trusted sources of information on climate change they refer to.

As described by Braun and Clark (2006), the data from the interviews were investigated through latent thematic analysis which followed a deductive 'top down' approach where research delved deeper into initial ideas. This analysis started by transcribing the interviews from recordings, where ideas were coded through a list of keywords, which were then mapped into themes using a mind map.

Interviews were conducted face to face, and each of the interviewees were from different backgrounds, enabling comprehension into unique lived experiences. Generation 'Baby Boomers' (aged 59-77), 'X' (aged 43-58), and 'Millennials' (aged 27-42) (Pew Research Center, 2019) were each represented in the interviews.

3.1 Limitations

This report has been produced through literature reviews of the most up-to-date and available information. At the time of writing, the Intergovernmental Panel on Climate Change (IPCC) released its Sixth Assessment Report which had not yet been interpreted by the Ministry for the Environment (MfE) in New Zealand, thus findings have been made using the IPCC's Fifth Assessment Report.

This report should be used for high-level insights into climate change effects for the Manawatū-Rangitīkei district. There are data and modelling limitations for more granular and regional information.

Currently, there is limited data on the effects of heat stress on beef cattle in New Zealand.

Currently, there are gaps in knowledge of how rural environments influence mental health and wellbeing (Philip, et al., 2022).

The 'Silent Generation' (aged 78–95) and 'Generation Z' (aged 11-26) were not represented through interviews in this report. However, a recent survey conducted by the Pew Research Center found that both 'Millennials' and 'Gen Z' are more highly engaged and likely to act on climate change than their older counterparts (Pew Research Center, 2021).

4.0 Literature Review

4.1 Climate Change: Evolving over Time

Over time, the concept, acceptance, and research into climate change has evolved. A high-level timeline below indicates how the concept first evolved through to 2023.

- **1859:** Climate change was predicted by John Tyndall who found “methane, water vapour and CO_2” in the atmosphere were causing greenhouse effects (personal communication, April 24, 2023).
- **1896**: 37 years later, Svante Arrhenius predicted that fluctuations in CO_2 levels could change the earth’s surface temperature (National Aeronautics and Space Administration (NASA), 2023).
- **1970s:** Climate change action catches widespread attention with the first “Earth Day” held in 1970 (American Institute of Physics, 2023).
- **1988**: The Intergovernmental Panel on Climate Change (IPCC) was established to provide insights to policymakers by evaluating the science associated with climate change based on current knowledge. The World Meteorological Organisation (WMO) and the United Nations Environment Programme (UNEP) formed the organisation. The IPCC has had six assessment series and produced six Assessment Reports. These reports are the most detailed scientific bodies of work on climate change produced in the world (Intergovernmental Panel on Climate Change (IPCC), 2023).
- **1990:** The first IPCC Assessment Report was released, urging international collaboration.
- **1992:** Countries signed up to the United Nations Framework Convention on Climate Change, launching negotiations to respond to climate change (United Nations Climate Change, n.d.).
- **1997:** Kyoto Protocol was introduced and entered into force in February **2005** with its first commitment period starting in 2008 (United Nations Climate Change, n.d.).
- **2004:** Ministry for the Environment (MfE) releases its first edition of the Climate Change Guidance Manual for Local Government.
- **2006:** Former United States vice president Al Gore released the documentary “An Inconvenient Truth” explaining the detrimental impact humans were having on the planet.
- **2007:** The IPCC releases its Fourth Assessment Report. (Intergovernmental Panel on Climate Change (IPCC), 2023).
- **2008:** MfE releases its second edition of the Climate Change Guidance Manual for Local Government from findings in the IPCC Fourth Assessment Report.
- **2013, 2014:** The IPCC Fifth Assessment Report was finalised and supported discussions into the Paris Agreement (Intergovernmental Panel on Climate Change (IPCC), 2023).
- **2015:** The Paris Agreement was adopted, entering into force in November **2016** (United Nations Climate Change, n.d.).

- **2016:** MfE releases its first edition Climate Change Projections Report from findings in the IPCC Fifth Assessment Report (Ministry for the Environment, 2018).
- **2018:** MfE releases its second edition Climate Change Projections Report to update information on extreme rainfall (Ministry for the Environment, 2018). The Ministry for Primary Industry (MPI) conducted a farmer survey which indicated that 63% of New Zealand farmers believe in climate change, and that "global human activity is contributing to climate change beyond natural weather cycles" (Ministry for Primary Industries, 2019).
- **2023:** The IPCC's Sixth Assessment Report is released.

Climate change thinking over this time can be described through E.M. Rogers's Diffusion of Innovation (DOI) theory where the 'adoption' of a new idea has occurred gradually through a social process and is dependent upon the different characteristics of people in society (Boston University School of Public Health, 2022).

The depth of understanding and acceptance, however, continues to evolve as new and more robust data becomes available and in relevant contexts.

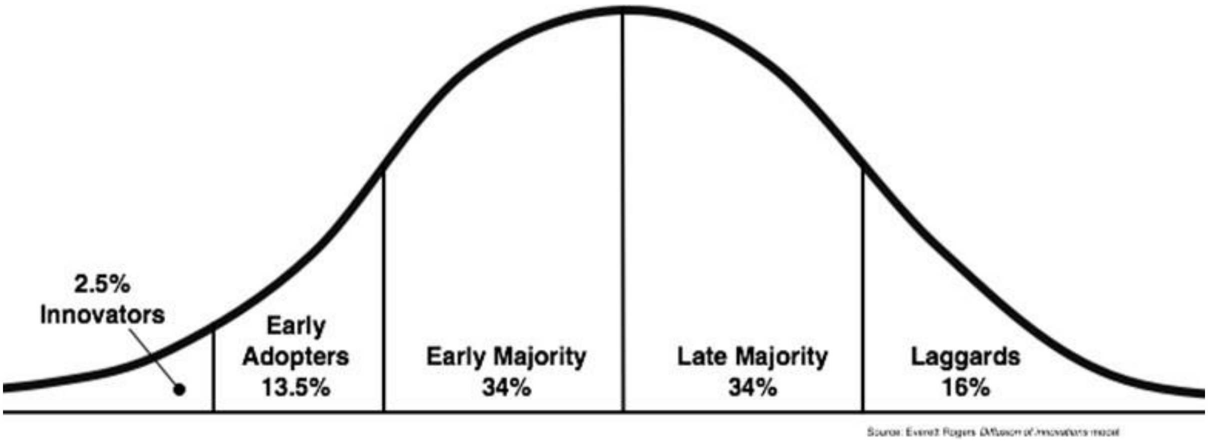

Figure 1 The five established adopter categories, represented as a bell curve illustrating the adoption of ideas over time *(From Boston University School of Public Health, 2022, p.1).*

4.2 Climate Model Simulations

Climate change modelling is complex. Its associated data can be difficult to communicate effectively. The IPCC reports using specific climate model simulations run by an independent research community (Graham Wayne, 2013). To understand climate projections in New Zealand, the National Institute of Water and Atmospheric Research (NIWA) interprets the IPCC reports using regional climate modelling through a supercomputer (Ministry for the Environment, 2018).

The Ministry for the Environment (2018) report predictions of changes are presented for years 2040 (2031-2050), 2090 (2081-2100) and 2110 (2101-2120), all comparative to the IPCC current climate 'baseline' of 1986-2005.

The IPCC Fifth Assessment Report refers to four scenarios distinguished as 'Representative Concentration Pathways' (RCPs) which are important to understand at a high level and are referred to in this Kellogg report. Each pathway represents a projection based on the atmospheric concentration of greenhouse gas emissions (GHG) (Graham Wayne, 2013).

Table 1 Representative Concentration Pathways referred to in the IPCC Fifth Assessment Report and their interpretation.

Representative Concentration Pathway (RCP)		
RCP2.6	Mitigation pathway	Suggests some diminishing of CO_2 in the atmosphere (aligned with the Paris Agreement goals).
RCP4.5	Stabilisation pathway	Stabilisation of CO_2 concentrations without overshoot (close to the median range)
RCP6.0	Stabilisation pathway	Stabilisation of CO_2 concentrations without overshoot (close to the median range)
RCP8.5	Worst case pathway	High GHG emissions and is considered the 'worst-case scenario'.

It is difficult to ascertain exactly which pathway the current global trajectory is on; however, recent estimates suggest the CO_2 levels are tracking slightly below the RCP8.5 pathway as illustrated in Figure 2. Compared to previous estimates in 2012, where CO_2 emissions were tracking higher than RCP8.5 (Peters, et al., 2013, updated 2019).

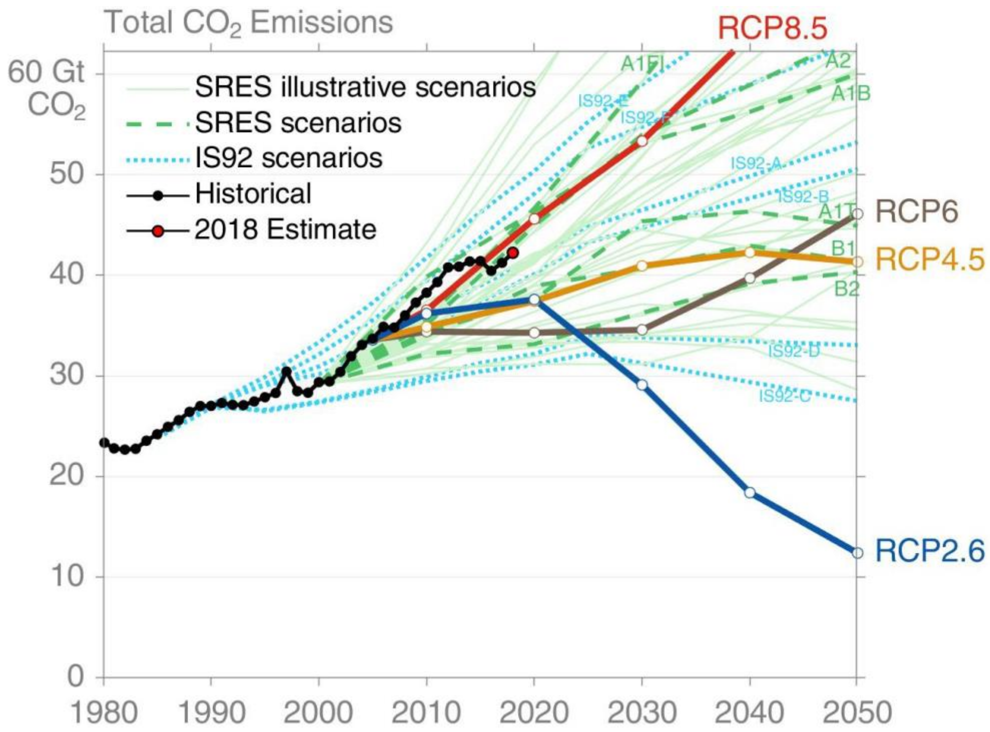

Figure 2: Estimated CO_2 emissions compared with previous climate models and the current four pathway (RCP) modelling. All scenarios appear as though they are on track in previous years as they are set to the same base year *(From Peters, et al., 2019, p.5).*

4.3 Horizons Regional Council: an overview

The Horizons Region consists of seven districts, one of which is the Manawatū-Rangitīkei. The region includes 2.2 million hectares of land from Ruapehu to Horowhenua, representing 8% of New Zealand's total land area which includes one of the largest areas of highly erodible land in New Zealand (Horizons Regional Council, 2023). There are 35,000 kilometres (km) of waterways and three major rivers dissecting the landscape: Whanganui (290km), Manawatu (182km), and Rangitikei (241km) (Horizons Regional Council, 2021). These characteristics have a high susceptibility to erosion and sediment loss.

The Horizons Regional Council One Plan is a planning report for the region on how resources will be managed by the council, districts, and the community. One Plan addresses four challenges, with climate change being an overall theme:

1. Surface water quality degradation.
2. Increasing water demand.
3. Unsustainable hill country land use.
4. Threatened indigenous biological diversity.

Within the 21st century, Horizons Regional Council, (2014) reports that it expects climate change will have the following effects on the region:

- **A maximum 50cm rise in sea level.**
- **A 3°C increase in temperature.**
- **An increase in precipitation.**
- **An increase in westerly winds.**
- **Frequent extreme weather events.**

The One Plan references MfE's first edition of the Climate Change Guidance Manual for Local Government written in 2004.

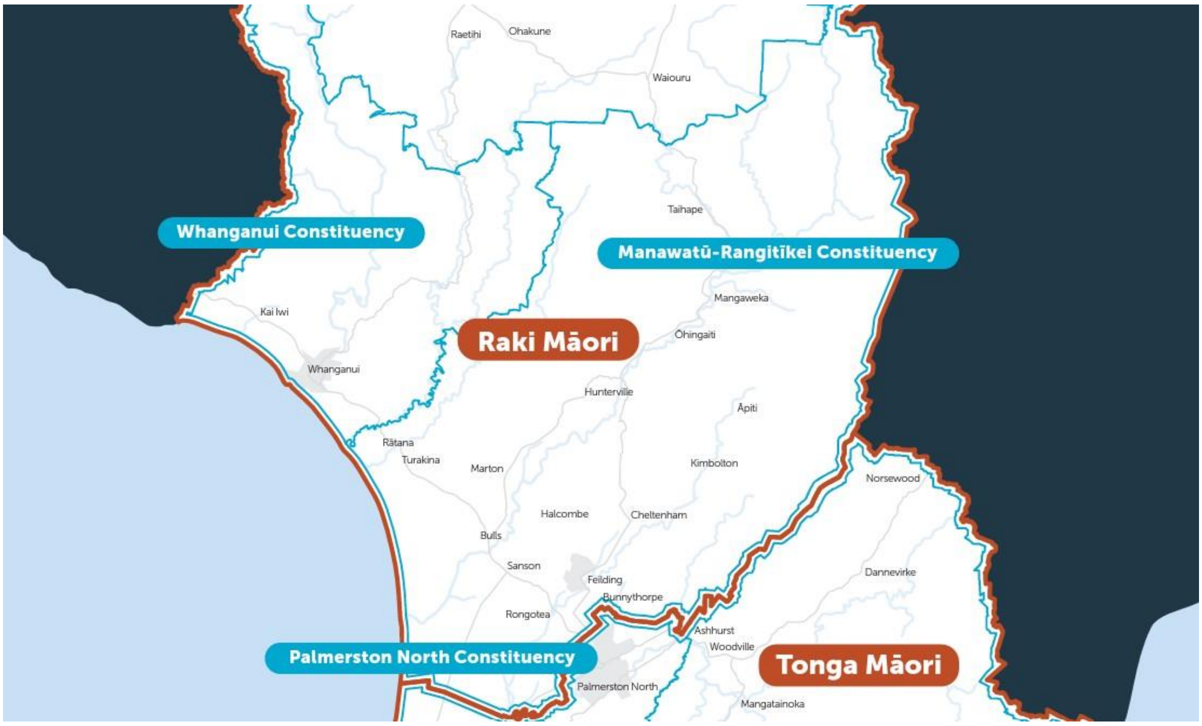

Figure 3 **Horizons Regional Council constituency map illustrating the Manawatū-Rangitīkei boundary** *(From Horizons Regional Council, n.d.).*

4.4 Manawatū-Rangitīkei: an overview

The Manawatū-Rangitīkei district comprises varying topography from flat to mountainous land classes which include the Ruahine forest park. The climate is temperate, with a prevailing westerly wind, and annual rainfall of between 800mm to 1,800mm. Valleys within the district can, due to their topography, create micro-climates (Basher et al., 2020).

Land use in the Manawatū-Rangitīkei is predominantly sheep and beef (45%), followed by native cover (33%), dairy (8%), forestry (5%) and other (9%) (Horizons Regional Council, 2021).

Land use capability (LUC) classification is a system that categorises land in New Zealand which considers the topography and capacity for long-term production (Lilburne et al., 2016). There are eight classes (LUC class 1 to LUC class 8).

The LUC class in the district varies, with minimal LUC class 1, being the most highly productive land with pockets in Kiwitea, Kimbolton, Cheltenham and Tangimoana, whilst the majority of the district (nearly half) comprises LUC 6-7 defined as non-cultivatable with moderate-severe limitations to pastoral use. (Landcare Research, 2023). On average, 7.6% of the land in this district is highly erodible land that is not protected (not covered by woody vegetation) (Landcare Research, 2006).

Increasing limitations to use ↓

LUC Class	Arable cropping suitability†	Pastoral grazing suitability	Production forestry suitability	General suitability
1	High	High	High	Multiple use land
2	↓	↓	↓	
3				
4	Low			
5	Unsuitable			Pastoral or forestry land
6				
7		Low	Low	
8		Unsuitable	Unsuitable	Conservation land

Decreasing versatility of use ↓

Figure 4: Land use capability class 1 to 8, increasing limitations and decreasing versatility *(From Lynn et al., 2009, p. 9)***.**

A large part of the region was once under ocean waters and began to uplift in the late Tertiary period (the period between 66 million years ago and 2.6 million years ago). This left behind substantial mud, sand, shell, and gravel deposits, which later formed papa, sandstone and shell limestone characterising the soils and their erosion susceptibility today (Cowie & Campbell, 1965).

The district has good conditions for growing pasture but has experienced extremes in previous years where summers can bring prolonged dry conditions and flooding – as can be evidenced by the February 2004 floods which devastated parts of the district. This was a compound event that cost between $160-180m (Sutton, 2004). Of which, $66m equated to losses in the sheep and beef sector.

What is clear in the regional and district council plans is that future planning for the effects of climate change focuses on erosion and flooding due to the topography and rivers within the district. It has been identified in Rangitikei's State of Environment report the need to research further into indicative flood mapping for areas in Bulls and Marton (Rangitikei District Council, 2019).

4.5 Climate Adaptation: the 'What'

The climate is changing. What does this mean for Manawatū-Rangitīkei sheep and beef farmers?

When it comes to understanding climate change effects within the 21st century, farmers have a pessimistic perception of climate change and extreme weather events in the long term. This research shows that farmers' focus on being more resilient to the effects of extreme weather patterns is as important today, as it will be in the future (Ministry for Primary Industries, 2019).

Evidence suggests that the years between 2040 and 2090 will be when New Zealand experiences the projections of climate change occurring more significantly (Ministry for the Environment, 2018). From year to year, the climate will vary in addition due to natural weather cycles such as El Niño and La Niña, possibly exacerbated over time due to changes in the climate, as seen by the recent Cyclone Gabrielle (personal communication, April 24, 2023).

The projections of climate change for the Manawatū-Rangitīkei district are explained below and summarised at the end of this section.

4.5.1 'Hot Days' ≥ 25^{o}C and Cold Nights ≤ 0^{o}C

One of the more significant changes for the district is the number of 'hot days' over 25^{o}C. Akin to the current Hawkes Bay climate where the average number of 'hot days' is 27.5, it is predicted, under RCP8.5 (worst-case), an average of 31.3 'hot days' per year by mid-century can be expected. This is an increase of 12.7 days over 25^{o}C to the present day (Ministry for the Environment, 2018).

This increases significantly out to the year 2100 with 47 additional 'hot days' comparable to the present day (Ministry for the Environment, 2018). An increase in 'hot days' could lead to more frequent drought conditions, livestock heat stress and water insufficiencies. This could also lead to more severe compounding events where, after a period of drought, sudden rain can cause flash flooding and slips caused by land cracking.

Table 2 **Average number of 'hot days' per year (maximum temperature ≥ 25°C) for the present day and for future periods under each pathway. Averages are modelled for below 500-meter altitudes** *(Modified from Ministry for the Environment, 2018, p. 68).*

Present	2031 – 2050 period				2081 – 2100 period			
	RCP2.6	RCP4.5	RCP6.0	RCP8.5	RCP2.6	RCP4.5	RCP6.0	RCP8.5
18.6	26.9	29.0	28.8	31.3	25.7	36.7	44.2	65.5

Table 3 **Average number of 'cold nights' per year (minimum temperature ≤ 0°C) for the present day and for future periods under each pathway. Averages are modelled for below 500-meter altitudes** *(Modified from Ministry for the Environment, 2018, p. 69).*

Present	2031 – 2050 period				2081 – 2100 period			
	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
18.2	12.0	10.6	11.3	9.4	12.4	7.2	5.5	1.7

A sheep is most comfortable in environment temperatures between 5 and 25°C. A sheep will begin to experience moderate heat stress at a temperature of 22°C with a relative humidity of 80% (Schütz , 2022). Heat stress can affect a sheep's reproductive process and ability to fight threats to the immune system, hindering growth, milk, wool, and meat production (Sejian et al., 2017).

Increases in temperatures and 'hot days' will create more conditions for internal parasites such as barbers pole and external parasites such as flies. Footrot and facial eczema also become more prevalent during hot, humid temperatures (Schütz , 2022).

Animals will naturally seek shade to reduce their exposure to heat stress. On 'hot days' >26°C, sheep can alter their behaviour such as minimising travel to troughs (Schütz , 2022).

Hotter, drier conditions may trigger on-farm decisions to shift lambing dates earlier, which can impact the overall farming system and access to markets (Fitzgerald, 2022).

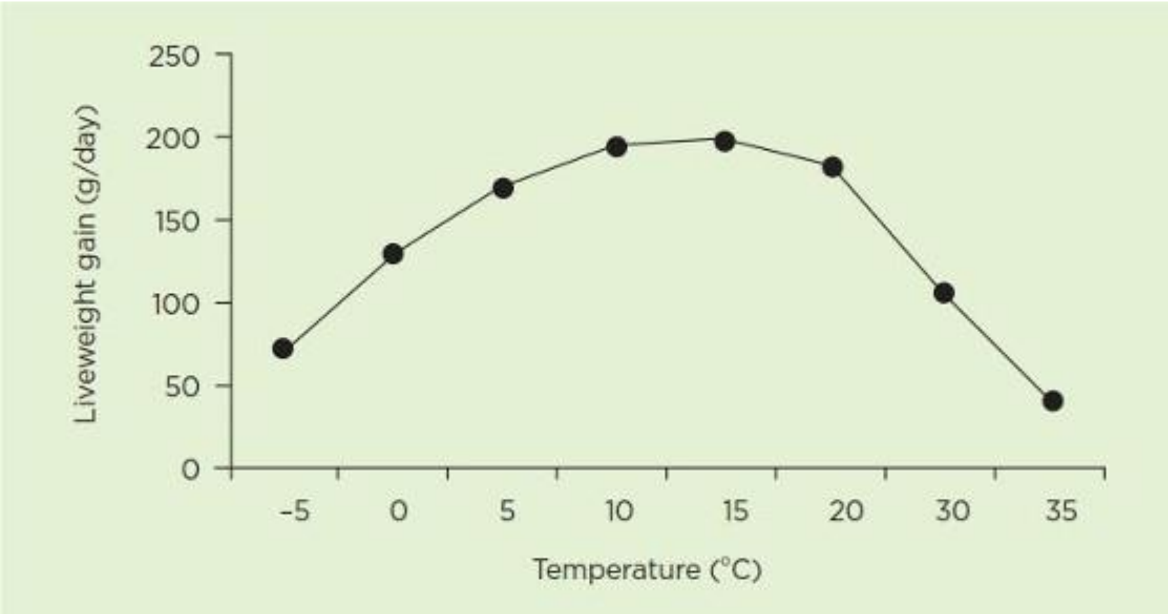

Figure 5 **Temperature effects on lamb growth rates** *(From Ames & Brink, 1997, p. 138).*

Cattle prefer temperatures between 4 – 20°C. This is because they are ruminant animals and produce significant amounts of heat through energy digesting food and producing (DairyNZ, 2023). Like sheep, heat stress affects reproductive performance and growth rates. Symptoms of heat stress in cattle include an increased breathing rate through panting and sweating. They will also eat and ruminate less, thus decreasing production (DairyNZ, 2023). For optimum comfort, cattle require 4-9m^2 of shade per cow (DairyNZ, n.d.).

Table 4 Table of recommended sites and species for planting trees for shade *(Modified from DairyNZ, n.d., p. 1).*

Site for shade planting	Shade species and planting design
Paddock boundaries	Single-row spaced poplars (one tree every 10-15m) or a dual-purpose shade/shelter belt (one tree every 2-5m).
Irregular and sharp paddock corners or riparian strips	A few large-stature natives (totara, kahikatea, rimu) interspersed with smaller natives (flax, cabbage trees, pittosporums).
Hard-to-farm, ungrazed dry/steep sidings and embankments	Ground-durable eucalypts or other high-value fast-growing timber species.
Steep grazed areas ("too steep for the fert truck")	Wide-spaced poplars and willows (50-150 trees/ha).
In paddocks near homesteads or paddock edges beside the farm and public roads	Large specimen trees (chestnuts, oaks, elms, lime, cedar) and fruit or nut trees (preferably deciduous to encourage grass growth and cover year-round).

Semi-permeable plantings like poplar or eucalypt can reach heights of 5 meters within five years and can quickly offer protection from the elements (B+LNZ, 2019).

4.5.2 Drought, Evapotranspiration, and Temperature

Since 1909, the average temperature in New Zealand has risen by 1°C (Hendy et al., 2018). Comparative to the baseline (1986-2005), projections in the report by the Ministry for the Environment (2018) indicate that temperatures will increase by a further 0.7°C - 1.1°C under the two pathways (RCP2.6 and RCP8.5).

By 2090, under RCP2.6 and RCP8.5, the temperature is expected to increase by 0.7°C and 3.1°C. Interestingly, under the mitigation pathway RCP2.6, there is no change expected between 2040 and 2090.

Projected temperature increases by the year 2110 are more difficult to ascertain due to the reliability of modelling, however, for all pathways except RCP2.6, temperatures are expected to increase relative to the 2090 changes (Ministry for the Environment, 2018).

As an example, an interviewee in the Rangitīkei has recorded temperature extremes between -4°C and 34°C. Under the two pathways (RCP2.6 and RCP8.5), the extreme temperature would then be between -3.3°C and 36°C using a mean temperature change of 2°C under RCP8.5 by 2090. An additional 2°C in extremely hot temperatures is a threat to livestock, particularly those who finish young animals susceptible to heat stress. An overall increase in temperature means animals will also drink more, seek shade, and grow more slowly.

Potential evapotranspiration deficit (PED)* for the district under the worst-case pathway (RCP8.5) by mid-century could be between 50-75mm/year deficit (Ministry for the Environment, 2018). This will impact the pasture growth curve and may result in reduced grass growth. Farms in the northwest area around Taihape and on the east coast in the Tararua district are more likely to be affected (Horizons Regional Council, 2021).

Invasive weed species can thrive in the pasture sward under drought conditions, resulting in less productive pasture and can therefore require management which will be costly (Horizons Regional Council, 2021).

*PED: The amount of water that would need to be added by rainfall (or irrigation) to retain pasture growth rates.

Table 5: Predicted changes in seasonal and annual average temperatures per RCP in °C for the Manawatū-Whanganui region (Horizons Regional Council area) between the periods from 1986-2005 and 2031-2050 *(Modified from Ministry for the Environment, 2018, p. 38).*

RCP	Summer	Autumn	Winter	Spring	Annual
RCP2.6 (Mitigation)	0.7	0.8	0.7	0.6	0.7
RCP4.5 (Stabilisation)	0.9	0.9	0.9	0.8	0.9
RCP6.0 (Stabilisation)	0.9	0.9	0.8	0.7	0.8
RCP8.5 (Worst-case)	1.1	1.1	1.1	0.9	1.1

Table 6 As Table 5, but for changes between the periods from 1986-2005 and 2081-2100 *(Modified from Ministry for the Environment, 2018, p. 40).*

RCP	Summer	Autumn	Winter	Spring	Annual
RCP2.6 (Mitigation)	0.7	0.7	0.7	0.6	0.7
RCP4.5 (Stabilisation)	1.5	1.5	1.5	1.3	1.4
RCP6.0 (Stabilisation)	1.9	1.9	1.9	1.6	1.8
RCP8.5 (Worst-case)	3.3	3.2	3.2	2.7	3.1

4.5.3 Adverse and Compounding Weather Events

The most significant short-term threats from climate change are adverse weather events, as experienced in recent times with Cyclone Gabrielle. From research conducted by New Zealand's climate scientists, evidence suggests more severe weather events (personal communication, April 24, 2023).

Compounding events may also be more common through periods of prolonged drought followed by extreme rainfall resulting in flash flooding.

River channels are formed by natural processes because of connections between sediment, water flow and vegetation. The force of water flow during a flood can undermine and erode riverbanks, particularly where a bend in the river channel occurs (Charlton, 2008), as demonstrated in Figure 6. One way of reducing the effects of sudden influxes of water is implementing a groyne (Horizons Regional Council, 2010).

Figure 6 **Arrows pointing to bends in the river channel susceptible to erosion caused by flooding. These are beneficial areas for groyne construction to avoid further erosion, productive land loss and to protect fragile infrastructure close by** (Modified from Google Maps, 2023).

A groyne is a modification to the river channel by implementing structures that protrude from the banks to slow the water flow thus resulting in protecting the adjacent riverbanks from erosion (Horizons Regional Council, 2010).

Adverse events, drought and flooding have negative effects on the health and well-being of people. Rural communities can become isolated physically and socially, and farmers' ability to make sound decisions for their businesses can be compromised. "Farms that are more resilient to these threats [drought, climate change] might be more productive during harsh periods, leading to less impact on the well-being of farmers" (Philip et al., 2022).

Transport of consumer goods and animals in and out of the district is exposed to flooding and extreme weather events with state highways 1, 3 and 57 exposed to adverse events causing disruptions to the supply chain and timely on-farm decisions (Horizons Regional Council, 2021).

Native species take longer to recover and re-establish after a flooding event. Invasive weed species and pests can flourish under these conditions, such as blackberry, and possums.

4.5.4 Erosion

The land use capability classes suggest significant erosion threats to the district and are an area of particular concern. The unpredictable frequency of heavy rainfall and the severity of adverse weather events will have further detrimental effects on land that is fragile and immature. Sediment and productivity losses through landslides over time can be significant and difficult to recover from. Thin topsoil can take decades to return to previous productivity (Neverman et al., 2023).

In February 2004, the district lost 100 million cubic meters of soil due to the erosion of hill country across 120,000 hectares (Horizons Regional Council, 2021). The Horizons One Plan addresses priority management zones for the Sustainable Land Use Initiative (SLUI). The defining element of the SLUI initiative is the development of Whole Farm Plans, which is a voluntary initiative aimed at reducing erosion (Horizons Regional Council, n.d.).

Table 7 Manawatū-Whanganui annual sediment load* lost to the coast. % change to baseline mid-late century prediction under representative pathways *(Modified from Neverman et al., 2023, p. 11).*

Present baseline load	2040 (%) load change				2090 (%) load change			
	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
12	33	45	44	59	29	55	83	127

* Sediment load is the amount of sediment that is transported through a body of water annually and is expected to increase across the country, having direct impacts to land productivity and waterways.

4.5.5 Precipitation

Annual rainfall changes are minimal in most parts of the country, due to our temperate, maritime climate. However, cyclical weather patterns can result in significant rainfall over a short period. The frequency at which precipitation extremes occur requires further analysis for the district (Horizons Regional Council, 2021).

Table 8 **Predicted changes in seasonal and annual rainfall between the periods from 1986-2005 and 2031-2050 for the Manawatū-Whanganui region using an ensemble average*** *(Modified from Ministry for the Environment, 2018, p. 77).*

RCP	Summer	Autumn	Winter	Spring	Annual
RCP2.6 (Mitigation)	0%	0%	3%	1%	1%
RCP4.5 (Stabilisation)	0%	-1%	5%	1%	1%
RCP6.0 (Stabilisation)	-1%	0%	6%	0%	1%
RCP8.5 (Worst case)	0%	-1%	5%	0%	1%

Table 9 **As Table 8, however for changes between the periods 1986-2005 and 2081-2100** *(Modified from Ministry for the Environment, 2018, p. 80).*

RCP	Summer	Autumn	Winter	Spring	Annual
RCP2.6 (Mitigation)	3%	2%	6%	3%	3%
RCP4.5 (Stabilisation)	2%	0%	6%	1%	2%
RCP6.0 (Stabilisation)	2%	0%	11%	3%	4%
RCP8.5 (Worst case)	0%	-5%	10%	-1%	1%

*****An ensemble average is taking results from multiple models to obtain more accurate and reliable estimates.

4.5.6 Wildfires

Under the stabilisation pathway RCP6.0, the district can expect that low-level wildfire weather is more likely to occur in the 21st century. It is projected to expect between rank 1-2 for most of the district. Rank 1-2 is classified as a smouldering, low-vigour surface fire (Government of British Colombia, n.d.).

Risk areas to consider are where forestry leaf litter is common. If sheep and beef farmers diversify their farming systems by planting trees, the risk of wildfire should be considered and any mitigation measures put in place such as water sourcing, fire belts, and management of forest canopy.

Moderate and vigorous surface fires, classified as rank 3 are expected for Palmerston North (Ministry for the Environment, 2018). For comparison, the Canterbury, Marlborough, and Otago regions are at higher risk with extreme and aggressive fires under rank 6 projected.

The increased number of 'hot days' expected increases the probability of wildfires. As can be attributed to the 2015 fires which spread through Tangimoana destroying 40 hectares of farmland and infrastructure (Heaton & Galloway, 2015).

4.5.7 Summary of the scale of projected climatic changes and associated risks and opportunities

Table 10 **Summary of projected climatic changes and associated key risks and opportunities in the Manawatū-Rangitīkei District, ascending by relevance and significance.** *(Modified from Ministry for the Environment, 2018, pp. 32-123) and (Modified from Horizons Regional Council, 2021, pp. 10-137)*.

Climatic Attribute	Scale of change [RCP2.6 – RCP8.5] Mitigation - Worst Case	Key Risks and Opportunities	Additional Comment
Number of ''hot days'' (Maximum of ≥ 25°C)	2040: 40% to 100% increase. 2090: 40% to 300% increase.	**Risks** Heat stress in livestock. Evapotranspiration. Human health and wellbeing. Facial eczema, barbers pole exposure. Wildfires. Weeds and pests. **Opportunities** Specialty crops such as durum, hemp and quinoa. Plant-based milk crops such as oat and hemp. Increase arable yields.	Comparable to the current Hawkes Bay climate with 27.5 'hot days' by mid-century. Fewer colder nights ≤ 0°C expected.
Drought	2040: 0mm to 75mm 2090: 0mm to 150mm increase/year potential evapotranspiration deficit (PED)*.	**Risks** Crop loss and quality. Economic loss. Heat stress in livestock. Water access. River and pond flows.	Increase in significance and regularity. Most relevant in areas already experiencing drought. Further research is required to enhance confidence. *PED = the amount of water needed to be replaced by rainfall to retain pasture

		Human health and wellbeing. **Opportunities** Drought-resistant crops such as lucerne.	growth rates not constrained by water shortage.
Temperature	2040: +0.7°C to +1.1°C. 2090: +0.7°C to +3.1°C. 2110: +0.7°C to +3.8°C.	**Risks** As above. **Opportunities** As above.	RCP8.5 (worst case) suggests a significant temperature increase within the century.
Extreme rainfall events: >2-year average repetition period	Range from 5% for 5-day period events to 14% for 1-hour period events. Increases vary per degree of warming.	**Risks** Flooding. Sediment runoff. Erosion. Biodiversity threat. Human health and wellbeing.	Increases more so in the far north and south of the country. Further regional analysis is unavailable. Flooding effects are worse after a prolonged dry period. Climate modelling does not simulate cyclones.
Storms	Likely change in the distribution of cyclones. Cyclonic systems will likely be stronger. Thunderstorms are more likely to occur.	**Risks** Flooding. Erosion. Human health and wellbeing. Livestock injury.	More analysis is required to assess the magnitude of occurrences. Region-specific projections are poor. Climate modelling does not simulate cyclones.
Precipitation / Rainfall	2040: +1% across all pathways 2090: +4% to +1% Annual rainfall		No significant changes for the Horizons region by mid-century.
Extreme wind speeds	Increase expected up to 10%+ in the southern half of North Island.	**Risks** Cyclone environments.	Sea level pressure is expected to increase over the North Island in summer (high-pressure cyclone environment exposure). Increase in westerly winds

			during winter, and north-easterly during summer.
Sea level rise	2040: 0.3m rise under RCP8.5 2100: 0.8m under RCP8.5	**Risks** Loss of productive land. Economic loss.	
Frosts	2040: 30% to 50% decrease. 2090: 30% to 90% decrease.		Overall, percentage changes are similar across New Zealand, however, the number of frosts decreases over time more significantly in the coldest regions.
Humidity	Minimal decrease.		The largest decreases are expected in South Island in Spring-Summer.

5.0 Analysis

This section analyses rich data from the semi-structured interviews into how Manawatū-Rangitīkei sheep and beef farmers might futureproof their land from the predicted changes in the climate within the century. In keeping with the aims of this report, this section addresses practical short to long-term actions that could be considered to futureproof farming businesses. Some of the interviewee's sentiments are supported by evidence through further research into their initial ideas.

From the thematic analysis described in the methodology, a mind map was developed to produce themes from keywords coded from the interviews (Figure 7).

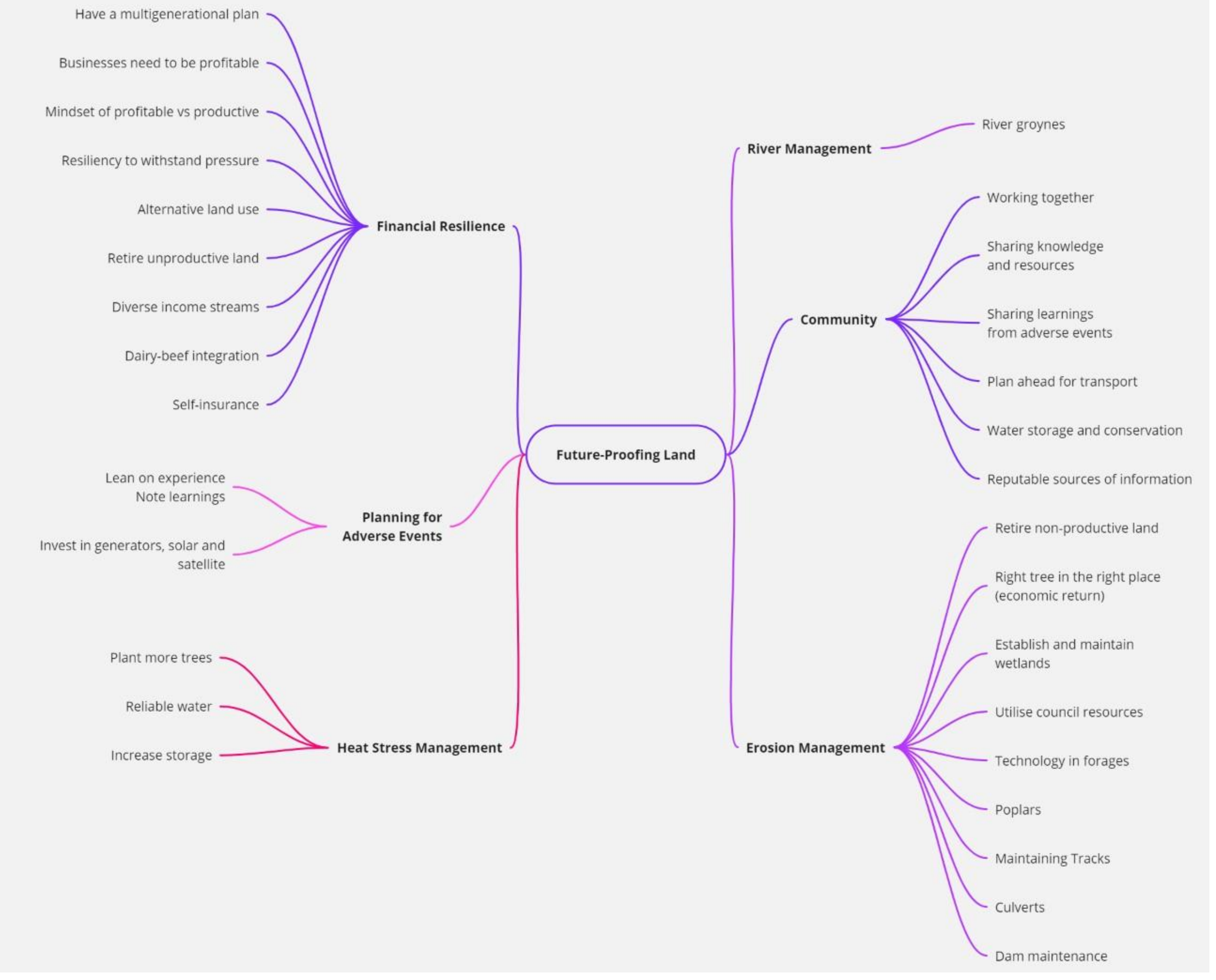

Figure 7 A mind map showing futureproofing mitigation solution themes from interview responses through thematic analysis as described by Braun and Clarke (2006).

5.1 Climate Adaptation: the ‘How’

5.1.1 Futureproofing Land

How might Manawatū-Rangitīkei sheep and beef farmers use this information to make business decisions?

The interviewees were asked to describe what futureproofing land for the effects of climate change might look like, translated into a word cloud in Figure 8.

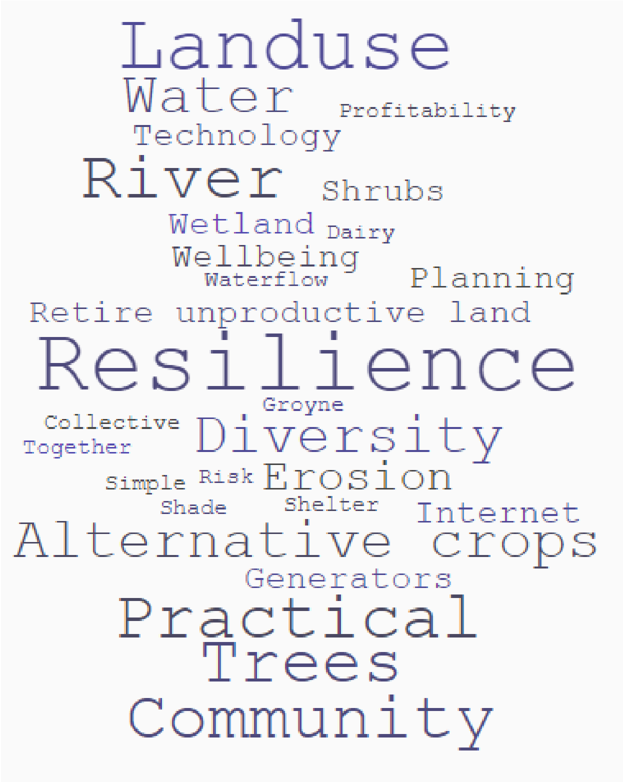

Figure 8: Word cloud from interviewees when asked "How might farmers futureproof land for the effects of climate change"?

Interviewees had some high-level prior assumptions and knowledge of how the climate might change in their district. They were particularly concerned about the frequency and severity of adverse events. Over half of the interviewees had either implemented futureproofing mechanisms or were aware of other potential mechanisms.

5.1.2 People, Community, and Wellbeing

All the interviewees, speaking of their own experiences mentioned that one of the most important measures in adapting to climate change and managing adverse events is *“rural communities working together”.*

“Farmers are suffering stress [from February 2004 floods], *but the community effort to assist the worst affected farmers has helped to stem a severe drop in farmer morale”* (Sutton, 2004).

“Thank goodness we weren’t doing that alone” [reflecting on the 2015 floods]. *“Think about things, not as the individual, but as the collective”.*

Speaking of experience and knowledge, from the interviews, futureproofing through people, community, and well-being might look like this:

1. Sharing resources (and making them known to neighbours) – generators, satellite internet, labour, tools, and machinery.
2. Sharing knowledge of learnings and understanding of climate change and engaging in farmer-to-farmer support - *"Consider joining catchment groups".*
3. If isolation and access risk is high because of an adverse event, *"consider leaving a vehicle with a neighbour"* or use alternative transport such as a push bike, motorbike and horseback to get places.
4. *"Consider water storage and conservation",* availability for livestock and human consumption.
5. Utilising reputable sources to inform opinion and knowledge about climate change. *"Social media is incredibly hard"* and is rife with *"misinformation and disinformation*".*

*Misinformation is the use of false information that unintentionally hurts others, whereas disinformation is the deliberate use of false information to deceive the public (The Disinformation Project, 2021).

5.1.3 Financial Resilience

The interviews indicated that a medium-long-term strategic plan in place for multigenerational businesses is highly recommended. Farming businesses need to be profitable and agile to respond to financial pressures. Two farmers suggested that their businesses have been able to withstand the financial hits that resulted from the flooding events of 2004, and Cyclone Gabrielle, 19 years later. If weather events become more frequent or severe, however, the more resilient a business needs to be.

The mind shift from 'being productive' to 'being profitable' was suggested as a necessary and important cultural change in farming if businesses are to be financially resilient in the future.

The interviews suggested that futureproofing through financial resilience might look like this:

1. Building a medium-long-term strategic plan that addresses *"20, 50, and 100 years"* if the business is multigenerational that considers the changing climate.
2. Increasing awareness of what options are available to *"pivot primary land uses if the existing farming systems need to change".* For example:
    a. *"Flat finishing land could be used for more arable".*
    b. *"Could irrigation be an option in the future?"*
    c. *"Retire underproductive land back into native shrubs".*
    d. With more days over 25°C, maize yields could prosper, or alternative specialist crops such as rape seed, durum, oats, hemp and quinoa could bring opportunities.
3. Identifying diverse income streams that will contribute to the bottom line and complement the existing system. For example:

    a. Trees for carbon sequestration or timber.
    b. Introduce more arable into the system.
    c. *“Could biofuel crops on marginal land be an option?”*
    d. Identify opportunities within the *“dairy-beef industry”.*
4. From a risk and insurance perspective, *“expect premiums for farming infrastructure to increase”.* Consider how might the business self-insure for items such as fencing and build an understanding of what processes there are to apply for any applicable funding through an adverse event. Farmers tend to insure houses, whereas infrastructure is insured with minimal cover for natural disasters (Sutton, 2004).

5.1.4 Planning Well for Adverse and Compounding Weather Events

Whilst no two weather patterns are the same, interviewees suggested that being well prepared for adverse or compounding weather events is crucial. The interview results indicated that futureproofing through being well-prepared might look like this:

1. For farmers who experience an adverse event, *“take notes of the decisions and learnings for next time”.*
2. *“Investing in a generator to keep the business and rural community going”,* as can be seen in Northland in response to Cyclone Hail, where farmers are organising shared generators to ensure business continuity.
3. *“Solar panels to retain electricity, especially for fencing to keep animals retained, or to keep freezers cold”.*
4. Investing in satellite internet to enable communication and connectivity. This was essential in Tairāwhiti during Cyclone Gabrielle, where 31 Starlink satellites went into the Gisborne to Hawkes Bay region, re-establishing communications in an area completely isolated (Radio New Zealand, 2023).

5.1.5 Heat Stress Mitigation in Livestock

Two interviewees were aware that the district might expect hotter temperatures in the future. *“This is going to be a particular concern to lamb-fattening operations which are susceptible to heat stress”.*

In response to futureproofing for heat stress, the interviews suggested:

1. Ensuring livestock can seek shelter and have access to reliable, palatable water. Consider travel distances between shelter and water sources and adjust if needed.
2. *“Plant more trees”* if needed.
3. *“Increase water storage capacity by building dams and fencing off”.*

5.1.6 River Management

Three interviewees had experienced flooding during an adverse event and had lost stock, productive land, native vegetation, and infrastructure. One interviewee was currently implementing a groyne after the recent floodwaters from Cyclone Gabrielle.

From this interview, a futureproofing mitigation strategy to reduce the impacts of flooding could be to implement river management mechanisms such as a groyne.

Figure 9 This creek flooded during Cyclone Gabrielle, causing erosion to the riverbank and threatening close-by infrastructure. As can be shown in the two boxes and arrow, a groyne is under construction to mitigate future loss on this property.

"…used wire from elevators, wrapped around large logs and stumps which is tied to a log buried into the riverbank like a fencing foot on a strainer post", as illustrated in Figure 9.

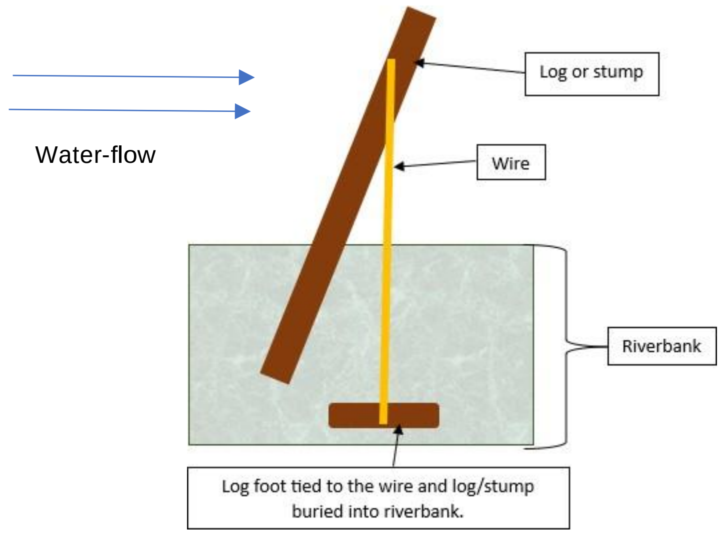

Figure 10 **Aerial diagram of the river groyne under construction referred to above**.

5.1.7 Erosion Mitigation

Considerations for erosion mitigation from the interviews included suggestions for futureproofing below:

1. Consider the *"retirement* [of erosion-prone], *non-productive land by enabling indigenous shrubs to re-establish"*. *"Manuka is well suited to holding water in its foliage and binding soil particles"*.
2. *"Plant the right tree in the right place"* – strategically, in addition, this possibility could contribute economically through carbon sequestration or timber.
3. Use and manage Poplar trees by:
    a. *"Space planting poplars at the base of steep hills"* and *'pair-planting' of poplars on gullies".*
    b. Removing *"sails of poplars as they grow"* to manage their growth.
4. *"Establish or maintain wetlands to act as a water catchment from hill country".* Wetlands stabilise the water flow and mitigate sediment loss from hill country into waterways and rivers, whilst also improving water quality.
5. Expect *"changes to forages grown in hill country…there could be substantial improvements to pasture quality".*
6. *"Manage water sources mid-way up steep gullies rather than at the base".*
7. *"Build and maintain spillways for dams to prevent wall collapse"* in high rainfall events.
8. Avoid pugging by managing grazing and pasture cover well during wet weather.
9. Maintain tracks on hill country by:
    a. Managing the water tables on tracks by *"increasing the number and size of culverts and adding wing-walls to culverts"*.
    b. Constructing and maintaining tracks to shed water *"with a suitable incline, width and crown"*.

5.1.8 Wildfires

Considerations for futureproofing for wildfires from the interviews included suggestions for futureproofing below:

1. *"Have an evacuation plan"* – everyone on the farm knows what to do in an emergency if a fire was to break out.
2. Implement fire breaks in forestry so fires cannot jump.
3. *"Identify the closest water source"* to ensure emergency services can access quickly.
4. Manage the canopy appropriately.

6.0 Key Findings

The key findings summarise the more significant climatic attribute changes to be expected for Manawatū-Rangitīkei sheep and beef farmers to be aware of. This section will also summarise key insights from the semi-structured interviews.

The literature review provided scientific insight into the projected climatic changes expected within the century in the Manawatū-Rangitīkei, summarised below:

1. The frequency and intensity of drought.
    a. By mid-century, a rainfall deficit of 50mm – 75mm per year.
2. The number of 'hot days' over 25°C.
    a. By mid-century an increase of 'hot days' over 25°C, between 40% and 100% per year.
3. The frequency and intensity of adverse and compounding weather events.
    a. El Niño and La Niña natural weather cycles exacerbated by climatic changes globally.
    b. More severe adverse weather events, their frequency requiring more research.
4. An increase in temperature.
    a. By the end of the century, an increase of 0.7°C - 3.1°C under the Representative Concentration Pathway's (RCP) 2.6 and 8.5.

These climatic attributes each propose both risks and opportunities for the district, which include biological, economic, and environmental factors.

From the qualitative research conducted through interviews, and thematic analysis, findings are that farmers are already acting to futureproof their farming businesses and that adverse weather events are of more concern in the short term.

Futureproofing mitigation strategies found from the semi-structured interviews can be summarised below:

1. Tackling challenges together in rural communities.
2. Informing opinion from reputable and credible sources.
3. Having a plan in place to ensure business financial resilience. This includes identifying diverse income streams and opportunities for alternate land uses.
4. Lean on previous experience and set up a simple system for business continuity such as investing in generators or satellite internet.
5. Manage heat stress by ensuring there is adequate shelter and water storage capacity.
6. Implementing flood mitigation techniques such as groynes to slow the movement of water and reduce the loss of productive land and infrastructure.
7. Retire non-productive land, maintain wetlands, manage water tables and plant more trees to mitigate erosion.

7.0 Conclusions

The purpose of this research was to translate scientific climate modelling into practical contexts for Manawatū-Rangitīkei sheep and beef farmers and consultants.

What is known about the changing climate in New Zealand on a national and regional scale continues to evolve. More granular and regional modelling is required so farmers can run scenario models for their farms based on how the climate might change.

Any preparation for the effects of climate change is gradual in nature. Farmers adapt to their climate every day and are already futureproofing land in response to experience, whether through protecting their land and assets from adverse weather events or by diversifying their farming portfolio to attract multiple income streams. Adapting to how the climate may change within the century, however, requires knowledge of 'what' and 'how' to enable proactive action.

The relevance of emissions scenarios needs to be frequently assessed and reported on in New Zealand by climate scientists for government bodies. Council long-term plans need to be amended as and when new climate information becomes available to ensure plans and advice do not rely on outdated data.

The relevant scientific data and reporting are poorly translated in practical terms for the rural community. There is a lot of information and reports available on climate adaptability in New Zealand, however, farmers are too time-poor to find and translate this into information that is relevant to them. Conversely, farmers have practical knowledge of their climatic environments, and some have lived experiences of adverse weather events. There is a gap and an opportunity for 'agents of change' to be conduits between the scientific and rural communities to tackle climate change together.

Overall, New Zealand has a responsibility under the Paris Accord and the common good to act on its commitments to climate change. As a small, exporting nation, New Zealand packs a punch on the world stage; it is a necessity to act to protect market access. Not only this, but incremental actions and investment today, will help, not hinder the future generations to prosper.

8.0 Recommendations

1. Use credible, trusted, and up-to-date sources of information to inform opinions about the changing climate.
2. Learn from advisors who collaborate closely with the scientific community and can translate data into meaningful, practical contexts.
3. Assess the current farming system concerning the top four climatic attribute changes and identify relevant, attainable, short to long-term actions, that may futureproof the business.
4. Build financial resiliency to be able to absorb hits and invest in futureproofing mitigation solutions.
5. Identify primary land use resources and their potential alternate use, if the existing system needs to change in the future.

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10.0 Appendices

10.1 Manawatū-Rangitīkei Land Use Class