Climate Resilience

How might we build resilience with kiwifruit growers in a changing environment?

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I wish to thank the Kellogg Rural Leadership Programme Investing Partners for their continued support.

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Executive Summary

The kiwifruit industry is New Zealand's largest horticultural exporter, responsible for 40% of all horticultural revenue (Aitken & Warrington, 2021) and in 2021, celebrated a record-breaking harvest exceeding $4 billion of global revenue (Burke, 2023). The impacts of climate change are being felt in the industry and will continue to have an impact on kiwifruit growing seasons into the future.

The purpose of this report is to collate scientific climate change data, analyse the likely impact this will have on key kiwifruit growing regions and summarise strategies to help kiwifruit growers build climate change resilience.

The aims of this report are to:

- Outline the likely impacts of climate change for New Zealand.
- Understand the current impacts of climate change on kiwifruit growers and where the greatest risks are for the future.
- Provide recommendations that will help build resilience and give growers confidence going forward.

The methodology for this report was based on the three-legged stool model. This included conducting a literature review, semi-structured interviews, and a thematic analysis to discover new knowledge to help build climate change resilience amongst kiwifruit growers.

The four main areas of climate change impact are:

1. Average temperatures are set to increase.
2. Minium temperatures are set to increase.
3. Average rainfall (precipitation) will be varied across the regions. The upper North Island is likely to become dryer.
4. Hot days (>25 ^{o}C) are likely to become more frequent with impacts posing a moderate risk.

These climate change impacts will have two major impacts on the kiwifruit industry. Firstly, there will be a decrease in winter chill hours, directly affecting the number of flower buds produced. Secondly, there may be a shift in suitable kiwifruit growing regions due to increasing temperatures. Regions that were formerly too cold and presented frost risk, may become more suitable than current regions.

The findings from semi-structured interviews and thematic analysis identified the following recommendations to help growers build climate change resilience:

1. Growers should work to become financially resilient by building reserves for responding to future climate change events.
2. Prior to purchasing a new orchard, due diligence should include climate change impacts.
3. Climate change is not a static problem. Adaptability is an essential attribute for growers to maintain their climate change resilience.
4. Collaboration will be key in responding to climate change. Growers, postharvest and Zespri all have their part to play.
5. Transparency of data from postharvest and Zespri is needed to give growers confidence in the longevity of the kiwifruit industry.

Acknowledgements

Firstly, I would like to thank the New Zealand Rural Leadership Trust team for providing an incredible opportunity through the Kellogg Rural Leadership Programme. Through your time, support, and energy you have facilitated an incredibly engaging course which has helped shape my leadership journey going forward.

I would like to acknowledge and thank Zespri International for their scholarship and my employer Seeka for supporting me throughout the course.

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The Kellogg Rural Leadership Programme has provided me with the next step on my personal leadership journey. I have taken away many new tools which will assist me in further developing my leadership skillset. The Rural Leadership Trust has an extensive network of New Zealand professionals and leaders which we were fortunate enough to learn from. Thank you to all the speakers on our programme for sharing your time, insights, and personal leadership experiences with us.

Cohort 50, what an incredible bunch of people. I have learned so much from each of you and look forward to our continued friendship beyond this programme.

This project wouldn't have been possible without the support from my friends and family.

1.0 Introduction

The kiwifruit industry is New Zealand's largest horticultural exporter, responsible for 40% of all horticultural revenue, with a 2020 harvest export value of $2.7 billion dollars (Aitken & Warrington, 2021). The industry went on to have a record-breaking 2021 harvest, exceeding $4 billion of global revenue (Burke, 2023). However, following these successful years, the past two kiwifruit seasons have been more challenging. In 2022, there were significant quality issues with the kiwifruit crop, resulting in a 40% drop in revenue (RNZ, 2023). The crop harvested in 2023 was of higher quality, however, yields have been significantly impacted throughout the growing season (Burke, 2023). During the 2023 growing season the kiwifruit industry experienced lower winter chill hours, hail, frost and cyclones (wind and flooding) which contributed to the reduced yields.

Climate change will continue to have an impact on kiwifruit growing seasons both now and into the future. Dealing with the weather is not new for growers. Throughout a kiwifruit season, growers must make many decisions based on the weather, and often based on their own experiences or weather predictions. However, growers are now not only experiencing seasonal fluctuations but also significant climate changes. These challenges are not unique to the kiwifruit industry in New Zealand but are also being faced by horticulturists globally. A study into rice production in South Korea concluded that the rice growing season would become shorter in the future and a reduction in rice yields is expected due to increased evapotranspiration directly affecting ponding in rice paddy fields (Bazrkar, et al., 2023). Furthermore, climate changes are expected to have an impact on pests and diseases. In 2011, it was reported that the coffee berry borer (*Hypothenemus hampei*) had increased its damage to coffee crops and its distribution range had increased across East Africa, as a direct result of hotter temperatures (Jaramillo, et al.).

The Ministry for Primary Industries (MPI) conducted a survey in 2018, following a baseline survey in 2009, to understand growers and farmers attitude towards, awareness of and understanding of climate changes. This was conducted through The Neilson Company, who collated responses from 707 interviews, representing dairy, livestock, arable, horticulture, viticulture, and other sectors. Key findings from the surveys are set out in Figure 1 and Figure 2 below.

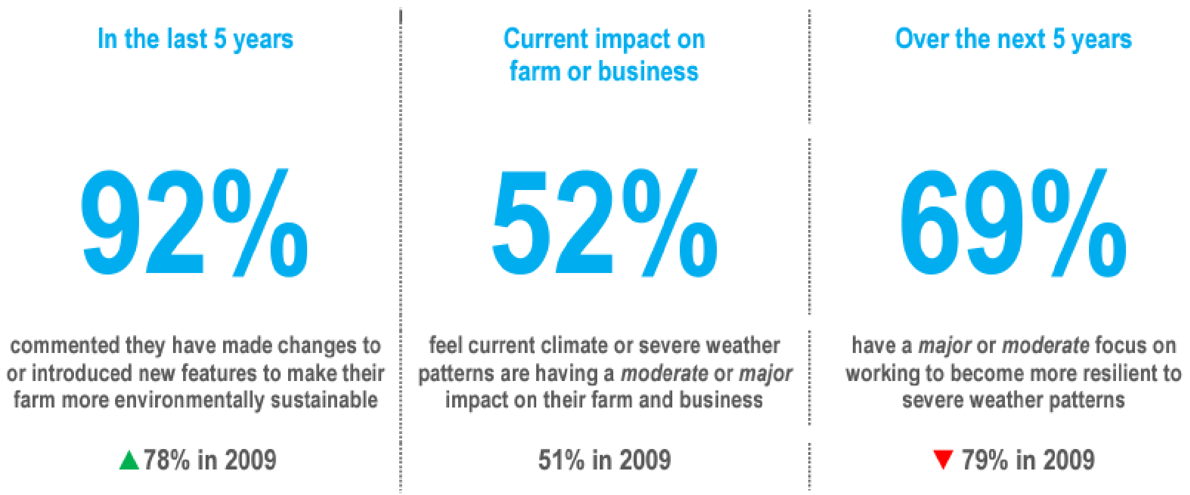

Figure 1: Key numbers from 707 New Zealand farmers surveyed (Ministry for Primary Industries, 2019).

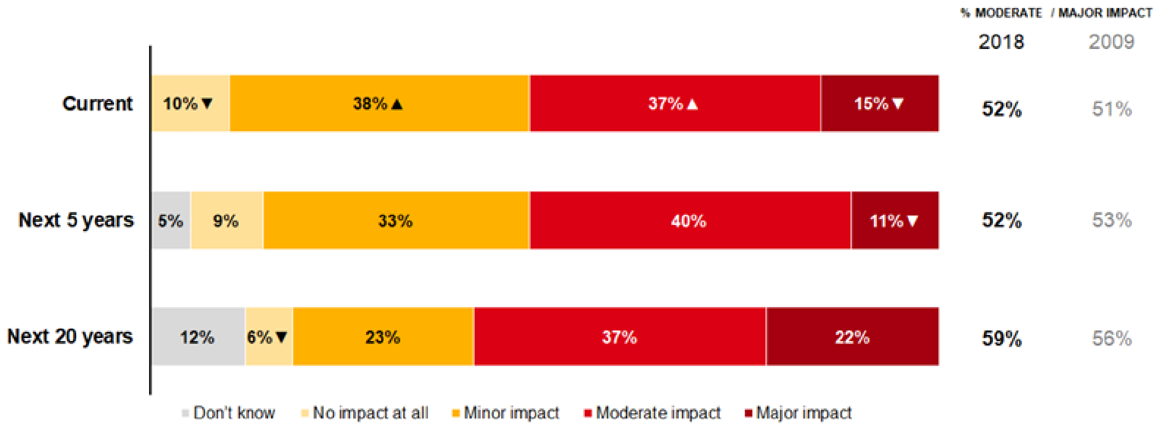

Figure 2: Perceived impact of climate change on own farm and business (Ministry for Primary Industries, 2019).

The key findings of the MPI surveys highlight the following:

- The majority of respondents (96%) believe they have responded on farm, implementing changes to improve their environmental sustainability.
- Around half of respondents feel there is currently a moderate of major impact from climate change on their farm or business. This has remained similar over the nine years between surveys.
- 69% of respondents have a major or moderate focus on becoming more resilient to severe weather patterns, a reduction of 10% from the 2009 survey.
- There is a range of 10% to 18% of respondents who either don't know or perceive there to be no impact of climate change on their farm or business over the next 20 years.

2.0 Purpose and Aims

The purpose of this report is to collate the latest scientific climate change modelling data, analyse the likely impact this will have on key kiwifruit growing regions and summarise strategies to help kiwifruit growers build climate change resilience.

The aims of this report are to:

- Outline the likely impacts of climate change for New Zealand, specifically in the North Island.
- Understand the current impacts of climate change on kiwifruit growers and where the greatest risks are for the future.
- Provide recommendations that will help build resilience and give growers confidence going forward.

This report will have delivered on these aims if kiwifruit growers can improve their understanding of the climate change impacts likely for New Zealand and strategies which can help improve their resilience into the future.

3.0 Methodology

The overall approach to this report was based on the three-legged stool model, adapted for this report, as shown in Figure 3. By conducting a literature review, semi-structured interviews and a thematic analysis the outcome will be the discovery of new knowledge to help build climate change resilience amongst kiwifruit growers.

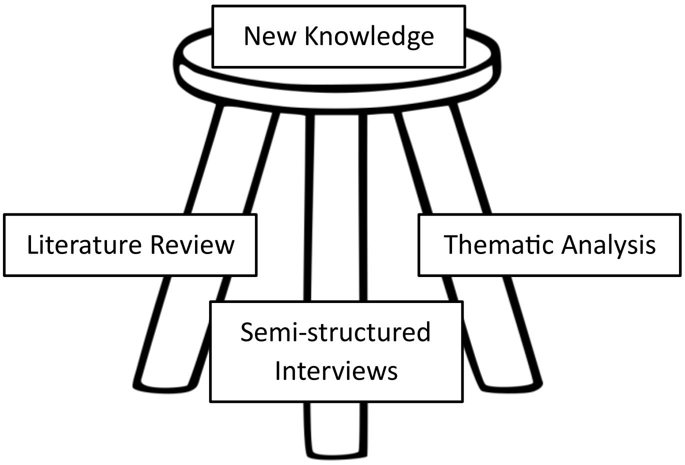

Figure 3: Three-Legged Stool (Wilson, 2018).

A literature review was undertaken to establish the context of climate change and how to define resilience. The aim was to define climate change, what its impacts are likely to be for New Zealand and what this means for kiwifruit growers and the kiwifruit industry.

Following the literature review, semi-structured interviews were conducted with ten orchardists across the Bay of Plenty and Gisborne regions. The purpose of these interviews was to analyse the following:

- What resilience means to growers.
- The current understanding of climate change from a grower point of view.
- Grower's experiences with climate change and severe weather events.
- What growers consider threats to kiwifruit production with regard to climate change.
- What support growers want from the rest of the kiwifruit industry to help build resilience.

Finally, a thematic analysis was conducted to compare and contrast the findings from the literature review and semi-structured interviews. Braun and Clarke (2006) described this process in six steps:

1) Becoming familiar with the data
2) Generating codes
3) Generating themes
4) Reviewing themes
5) Defining and naming themes
6) Locating exemplars.

Following further analysis of the thematic analysis, key findings were summarised by pulling together the literature review, semi-structured interviews, and the thematic analysis. From the key findings, conclusions and recommendations were able to be formed.

3.1 Limitations

The following limitations have been identified in this report:

- The Intergovernmental Panel on Climate Change (IPCC) is continually analysing and considering global climate change data. There is an incredible amount of data to consider and, as a result, there is significant time between each iteration of their Assessment report. Their Fourth Assessment Report (AR4) was published in 2007, Fifth Assessment Report (AR5) was published in 2014, and Sixth Assessment Report (AR6) was published in 2023.
- The National Institute of Water and Atmospheric Research (NIWA) and other industry bodies have based their reports AR5. They are yet to analyse and include the most up to date IPCC report in their own reporting.
- The focus on this report is on kiwifruit orchardists, with those interviewed in the Bay of Plenty or Gisborne regions. It is recognised there are other perspectives in the kiwifruit supply chain and other horticultural sectors, however these were outside of the scope of this report.
- Time constraints for this report meant ten growers were interviewed for the semi-structured interviews. Given more time, additional interviews would have been conducted to further enrich the interview data set.

It is important that these limitations are considered when using this report.

4.0 Literature Review

Climate change and resilience are extremely complex topics that can be difficult to understand. The purpose of this literature review is to summarise information about possible climate change impacts for New Zealand, what this means for kiwifruit growers, and the challenges of defining resilience in a horticultural context.

4.1 Climate Change Modelling

The World Bank Group defines climate change as:

> *"…the significant variation of average weather conditions becoming, for example, warmer, wetter, or drier—over several decades or longer. It is the longer-term trend that differentiates climate change from natural weather variability."*
> *– World Bank Group, 2021.*

To understand what these significant variations look like, climate change modelling has been developed, to project and analysis different scenarios at a global level. In 1988, the United Nations Environmental Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC), which was also endorsed by the UN General Assembly (IPCC, History of the IPCC, 2023). The role of the IPCC is to prepare regular and comprehensive scientific assessments on climate change knowledge. These assessment reports are made publicly available to enable access to current, scientifically backed knowledge.

Below, in Figure 4 is an example of the type of analysis the IPCC undertake in their assessment reports. A larger version of this figure is shown in Appendix A.

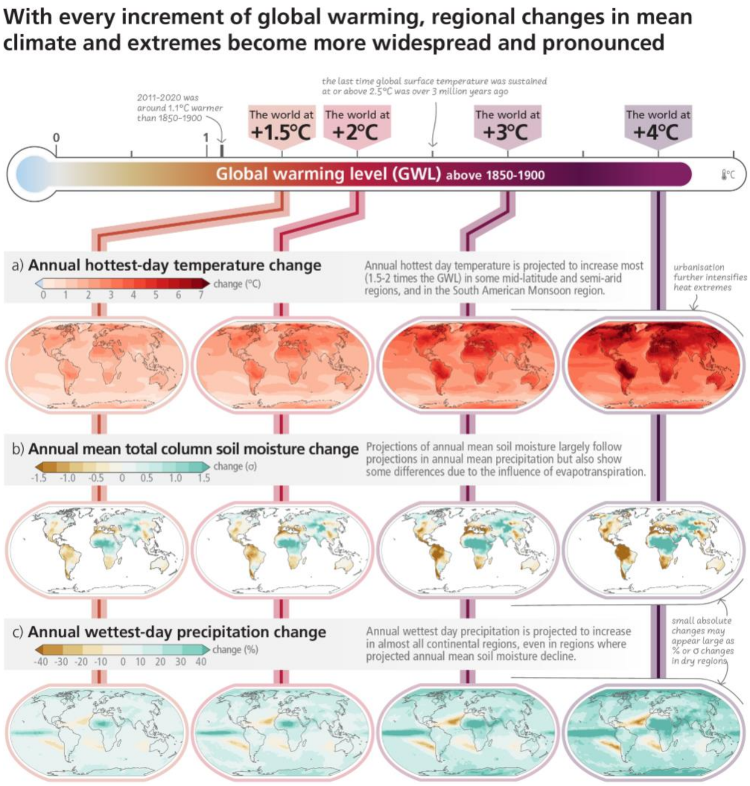

Figure 4: 2023 IPPC climate change scenarios (IPCC, 2023)

This year, the IPCC has released its Sixth Assessment Report (AR6). However, as this report was released this year, other organisations are yet to fully interpret this information and are therefore still basing their interpretations on the Fifth Assessment Report (AR5).

During an expert meeting in 2007, the IPCC stated:

"Scenarios of different rates and magnitudes of climate change provide a basis for assessing the risk of crossing identifiable thresholds in both physical change and impacts on biological and human systems."

- *The Intergovernmental Panel on Climate Change.*

Understanding the importance of modelling at different rates and magnitudes, the AR5 included Representative Concentration Pathways (RCPs), which have been used to help predict climate change impacts for various scenarios. Each pathway is grounded by different levels of Global CO_2 Emissions in the atmosphere (Wayne, 2013). Below, in Figure 5: Estimated CO_2 emissions beginning in 1980 compared to the four pathway (RCP) models (Peters, et al., 2013 updated 2019). 5, you can see the four identified pathways: RCP2.6 (blue), RCP4.5 (yellow), RCP6 (brown) and RCP8.5 (red). The baseline for these models is 1980, where they all begin from the same point. Historical data has been added over the model to show the actual level of emissions up to 2018.

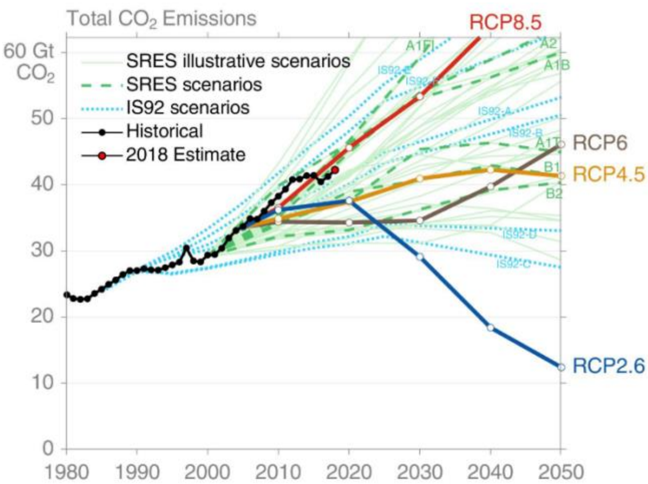

Figure 5: Estimated CO_2 emissions beginning in 1980 compared to the four pathway (RCP) models (Peters, et al., 2013 updated 2019).

Figure 5 estimated that, in 2012, Global CO_2 Emissions were tracking slightly above the RCP8.5 pathway, indicating that the world was on a worst-case scenario track at the time (Peters, et al., 2013 updated 2019). The revised estimates from 2019 found that emissions had dropped slightly below RCP8.5, still on the pathway for a worst-case scenario.

Graham Wayne (2013) created a guide to help understand and interpret these pathways, with a summary seen in Table 1 below. Wayne explains that in terms of climate change risk there is a rising pathway, two stabilisation pathways and one peak and decline pathway. These are then linked to global temperature increases and the relationship to greenhouse gas emissions.

Table 1: Representative Concentration Pathway (RCP) Primary Characteristics Summary (Wayne, 2013).

RCP	Pathway	Global Temperature Increase	Greenhouse Gas Emissions
RCP8.5	Rising	4.0°C	Increased emissions
RCP6	Stabilisation	2.5°C	Stabilise after 2100
RCP4.5	Stabilisation	2.0°C	Stabilise after 2100
RCP2.5	Peak and Decline	1.5°C	Substantially reduced over time

4.1.1 New Zealand Climate Modelling

Understanding global climate modelling is one part of the solution, and for the kiwifruit industry it is also important to understand this in a New Zealand context. The National Institute of Water and Atmospheric Research (NIWA) has used the IPCC's AR5 report as a basis for their interpretation for New Zealand. They have distilled the following four main conclusions from the report (Mullan, Sood, Stuart, & Carey-Smith, 2018):

- Scientific evidence confirms warming of the climate system with many unprecedented changes observed since the 1950s.
- Greenhouse gas emissions have reached levels in the atmosphere that are unprecedented based on at least the last 800,000 years.
- Human influence has been identified as a major cause of the changing climate.
- All RCPs are now likely to exceed an increase to global surface temperatures of 1.5°C by the end of 2100, compared to 1850-1900.

NIWA have used the RCPs for their New Zealand modelling and also reference RCPs in their scenario modelling. They have used three specific years and periods for reporting: "1995 – Baseline" (1986-2005), "2040" (2031-2050), and 2090 (2081-2100) (NIWA, n.d.).

Another clear distinction NIWA have made is the difference between weather and climate. Weather is thought of as the day-to-day weather features, such as when its sunny or cloudy, over the short term. While climate describes conditions for a specific area by considering these weather features over a long period, typically 30 years (NIWA, n.d.).

There are many climatic features that NIWA have analysed as part of their climate change modelling. A full summary of New Zealand climate changes projections has been appended (Mullan, Sood, Stuart, & Carey-Smith, 2018). The focus for this report will be several key features with the greatest impact on kiwifruit growing: mean temperature, precipitation, days above 25 degrees and days below 0 degrees. Figures 6-8 depict projected changes using the RCP8.5 pathway and 2090 period.

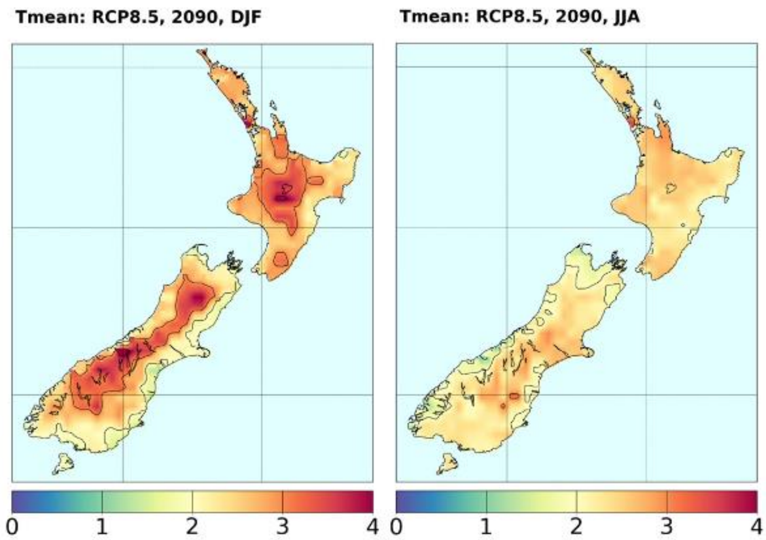

Figure 6: Projected changes in mean temperature (in °C) for summer (Dec-Jan-Feb) and winter (Jun-Jul-Aug) by the end of the 21st century, for the ensemble-mean of 6 climate models under the highest CO2 concentration scenario RCP8.5 from the IPCC 5th Assessment (NIWA, n.d.).

Figure 6, on the previous page, first shows the average mean temperature change for summer and then the average mean temperature change for winter. Everywhere in New Zealand is expected to see temperature increases, more significantly in summer and more notably in the North Island and at higher altitudes (Mullan, Sood, Stuart, & Carey-Smith, 2018).

Precipitation predictions vary based upon region, as shown in the figure below. In summer, there is likely to be little change across the country while in winter, the West Coast, Southland and parts of Canterbury are expected to see an increase in rainfall (Mullan, Sood, Stuart, & Carey-Smith, 2018). Three major kiwifruit growing regions are Northland, the Bay of Plenty and Gisborne. With predicted dryer seasons, growers will be faced with challenges trying to access water.

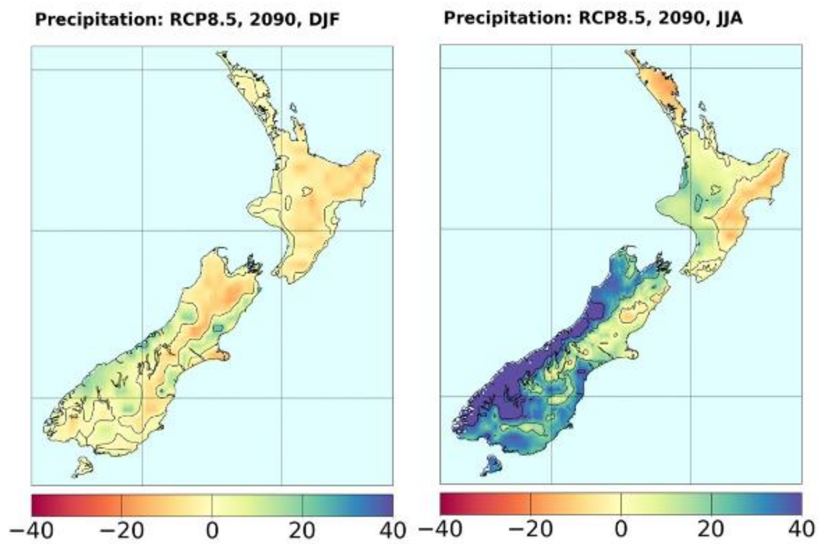

Figure 7: Projected changes in precipitation (in %) for summer (Dec-Jan-Feb) and winter (Jun-Jul-Aug) by the end of the 21st century, for the ensemble-mean of 6 climate models under the highest CO2 concentration scenario RCP8.5 from the IPCC 5th Assessment (NIWA, n.d.).

Another climatic area important for the kiwifruit industry is the area of extremes, such as hot days and frosts. New Zealand has a maritime climate, which acts as a buffer to some of the extreme high temperatures other parts of the world experience (NIWA, n.d.). A hot day is recorded when temperatures exceed 25 degrees and frost days are recorded when temperatures are below zero (Mullan, Sood, Stuart, & Carey-Smith, 2018). These thresholds were chosen due to their agricultural application and therefore relevance for New Zealand modelling.

As seen in Figure 8, hot days are likely to increase and will be in areas where temperatures are expected to increase too (higher elevation and north island). Frosts (cold nights) reduce in colder areas of the country, while already warmer, coastal areas won't see much change.

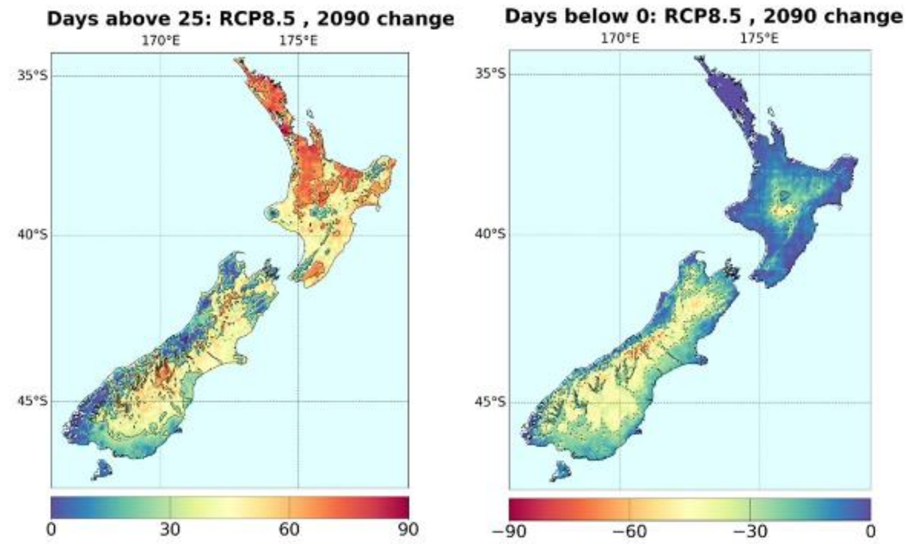

Figure 8: Projected changes in the annual number of hot days (maximum temperature 25°C or above) and cold nights (minimum temperature 0°C or below) by the end of the 21st century, for the ensemble-mean of 6 climate models under the highest CO2 concentration scenario RCP8.5 from the IPCC 5th Assessment (NIWA, n.d.).

4.2 Kiwifruit Industry

4.2.1 Overview

The New Zealand kiwifruit industry operates as a regulated industry, selling kiwifruit globally through a single organisation, Zespri International Limited.

> *"Based in Mount Maunganui, New Zealand, Zespri is 100 percent owned by current or past kiwifruit growers. Zespri exports and markets the world's leading portfolio of branded kiwifruit 12 months of the year, as well as implementing a world-leading kiwifruit research and development programme.*
> *Orchards and post-harvest facilities are independently owned and managed,"*
> *– Zespri (2022).*

As of 2022, New Zealand Kiwifruit Growers Incorporated (NZKGI) reported approximately 2,843 kiwifruit growers across 13,610 hectares of producing kiwifruit land (NZKGI, 2022). Over 80% of kiwifruit is grown in the Bay of Plenty, with Northland, Auckland, Waikato and Gisborne responsible for close to 15% collectively. Below, Table 2 and Figure 9 show the proportion and spread of kiwifruit production.

Table 2: Regional production hectares in the 2021/2022 season (NZKGI, 2022).

Region	Hectares in Production
Northland	533
Auckland	537
Bay of Plenty	11,053
Waikato	564
Gisborne	381
Hawke's Bay	212
Lower North Island	77
South Island	252

Figure 9: Regional production of kiwifruit in New Zealand, (NZKGI, 2022).

Not only is the majority of kiwifruit grown in the Bay of Plenty, but the Bay of Plenty grows predominantly kiwifruit. Figure 10 breaks down the horticultural production by crop for the Bay of Plenty region, with kiwifruit accounting for 80% of production (Tonkin & Taylor Ltd, 2023).

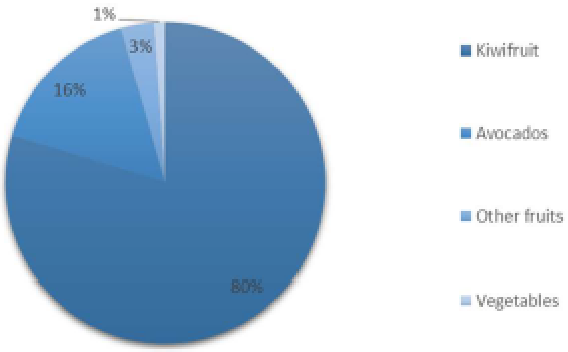

Figure 10: Planted land area (% ha) by horticultural activity (Tonkin & Taylor Ltd, 2023).

4.2.2 What does this mean?

By understanding how global climate change modelling happens at a global level, what this means for the climate in a New Zealand context, and an overview of the kiwifruit industry, there are some major risks identified:

- Kiwifruit is grown in areas likely to experience similar climate change impacts.
- 80% of the Bay of Plenty's horticultural production is in kiwifruit meaning is it exposed to far greater risk due to lack of diversity.
- Becoming resilient to the changing climate is essential for the kiwifruit industry.

Table 3 below summarises the risks to horticulture across a range of climatic areas, from temperature increase to coastal hazards (Tonkin & Taylor Ltd, 2023). The table uses a traffic light system for risk impact, where green is no impact through to red meaning major impact. Of the nine factors Tonkin and Taylor identified, only four are considered to be green and not currently a risk;

pests and diseases, fire weather, flooding and groundwater rise, and salinity rise. However, using the RCP4.5 and RCP8.5 pathway the risk levels for all nine factors are either yellow or orange by 2050 and either orange or red by 2100.

Table 3: Climate risk ratings for horticulture (Tonkin & Taylor Ltd, 2023).

Risks to horticulture					
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
	Now	2050	2050	2100	2100
Decreased winter chill	Yellow	Yellow	Yellow	Orange	Red
Temperature	Yellow	Yellow	Yellow	Orange	Red
Pests and disease	Green	Yellow	Orange	Orange	Red
Dryness and drought	Yellow	Orange	Orange	Orange	Red
Fire weather	Green	Yellow	Yellow	Orange	Orange
Extreme weather	Yellow	Orange	Orange	Orange	Red
Flooding	Green	Yellow	Yellow	Orange	Orange
Coastal hazards	Yellow	Orange	Orange	Red	Red
Groundwater rise and salinity stress	Green	Yellow	Yellow	Orange	Orange

The reason these climatic factors are considered risk factors is their impact on the yield of kiwifruit vines. Some of these factors are more significant than others. For example, it takes 950-1100 hours at temperature below 7.2 degrees (winter chill) for kiwifruit to set fruit and produce an adequate budburst (Cradock-Henry, 2017). With increasing temperatures, it is becoming more difficult to naturally achieve a good and uniform budbreak. Products such as Hydrogen Cyanamide (Hi-Cane) can help to improve a plants budbreak and increase the uniformity of flowering, meaning the fruit is less variable (EPA, 2023). However, chemical use in horticulture is constantly under review and therefore specific products cannot be relied upon long-term. Hi-Cane is currently under review from the Environmental Protection Authority (EPA), who have currently suggested a ten-year phase out of hydrogen cyanamide based product.

Table 4 outlines a range of climatic factors and their impact on yield, most of which are a reduction. This highlights the risk of climate change directly on kiwifruit yields.

Table 4: Climatic factor effects on kiwifruit yield, (Cradock-Henry, 2017).

Climatic Factor	Sub Factor	Impact on Yield
Decreased winter chill		Reduction
Temperature	Hot summer	Increase/Reduction
	Cold spring	Reduction
Pests and disease		Reduction
Dryness and drought		Reduction
Fire weather		Reduction
Extreme weather	Strong Winds	Reduction
	Hail	Reduction
	Frost	Reduction
Flooding		Reduction
Coastal hazard		Reduction
Groundwater rise and salinity stress		Reduction

Zespri has a strong relationship with Plant and Food Research who are involved in industry sceintific research. In 2021, Plant and Food Research worked with MPI on a research study assessing the suitability of different New Zealand regions under different climate change scenarios. Using the RCP2.6 and RCP8.5 pathways, Plant & Food Research identified the following climate change effects for kiwifruit growing regions, (Plant & Food Research, 2021):

- **RCP2.6 Pathway (low GHG scenario)**
  - Reduction in suitability for many parts of the upper North Island and East Cape, in particular Northland.
  - Improvements in suitability for the Central and Lower North Island along with the South Island.
- **RCP8.5 Pathway (high GHG scenario)**
  - More regions in the North Island will see a reduction in suitability.
  - The South Island and central North Island see improvements to suitability, similar to the low GHG scenario, but improvements are substantial in many locations.

Figure 13 below further details the impact of climate change in a kiwifruit context. As part of their 2022 Climate Change Adaption Plan, Zespri have analysed various climate variables, their potential impact, the projected change and what risk this is to the industry (Zespri, 2022). For example, the climate variables of the highest risk are average temperatures and minimum temperatures, both of which are projected to increase. With average temperatures increasing, between 0.9°C and 1.1 °C, there is risk of an increase in pests and pathogens becoming established. An increase in minimum temperatures, of between 1.0 °C and 1.25 °C, would see a variable budbreak and decrease in king flower production, resulting in reduced yield.

Figure 11 details the scenarios and key assumptions used in Zespri's 2022 Climate Change Adaptation Plan and Figure 12 details the risk ratings applied to New Zealand's climate related risks.

Scenario 1 Moderate (2°C) Emissions Scenario	Scenario 2 High (4°C) Emissions Scenario
· A moderate emissions scenario, in which aggressive action keeps global warming to within 2°C. · RCP 4.5	· A business-as-usual high emissions scenario, in which global warming continues unchecked. · RCP 8.5
· This scenario describes a world that has succeeded in implementing the Paris Agreement and is likely to keep total warming below a 2°C tipping-point.	· This scenario describes a world in which countries have failed to meet their emissions reduction pledges under the Paris Agreement.

Figure 11: The two scenarios applied to Zespri's climate risk analysis (Zespri, 2021).

Risk Ratings	
High	May require adaptive action in the short to medium term in order to minimise negative financial impacts.
Moderate	May require adaptive action, but uncertainties are high/timescales long. Keep a watching brief.
Low	Little clear evidence of risk requiring adaptive action. Revisit when fresh information becomes available.

Figure 12: Risk ratings applied in Figure 13 (Zespri, 2021).

Climate Variable	Potential Impact	Projected Change In NZ 2050		Risk Rating
		2°C Moderate Scenario	4°C High Scenario	
Average temperatures	Rising average temperatures may increase the risk of pests and pathogens becoming established in primary growing regions.	**~0.9°C**	**~1.1°C**	High
Minimum temperatures	A rise in minimum spring temperature may prevent consistent budbreak and king flower production in primary growing regions.	**~1°C**	**~1.25°C**	High
Maximum temperatures	A rise in summer maximum temperatures may increase energy costs in post-harvest sorting and distribution centres.	**~1°C**		Moderate
Number of hot days (>25°C)	An increase in the number of hot days in primary growing regions may increase the risk of heat stress among orchard workers.	**~75%** increase	**~95%** increase	Moderate
Average rainfall	Kiwifruit vine water demand may increase with rising temperatures, impeding fruit development in water-deprived areas.	Substantial regional and seasonal variation.		Moderate
Drought	An increase in the severity and frequency of droughts, especially in already dry areas, may impede fruit development.	**100mm** increase in Potential Evapotranspiration Deficit		Moderate
Number of dry days (<1mm / day rainfall)	An increase in the number of dry days may marginally alter the risk of drought and water stress in primary growing areas.	**0—5%** Increase in dry days		Low
Extreme rainfall events	An increase in extreme rainfall events may marginally alter the risk of harvest losses, soil erosion, flood damage and diminish soil productivity.	**0—5%** increase in the magnitude of a 99th percentile rainfall event		Low
Extreme wind speeds	An increase in extreme wind speeds may see more wind damaged fruit on the vine.	**0—2.5%** increase in the magnitude of a 99th percentile daily mean wind speed		Low

Figure 13: Zespri Physical Climate Risk Scenario Analyse and Risk Ratings for New Zealand Growing Regions (Zespri, 2022).

Therefore, it can be ascertained that the greatest climate change impacts expected for the kiwifruit industry are those considered high risk, as the impacts are expected in the short to medium term (Zespri, 2021). The high-risk impacts are outlined below, along with their current associated mitigation strategies and opportunities.

- As average temperatures increase, the suitability of current kiwifruit growing regions may decrease (Plant & Food Research, 2021). Warmer temperatures will increase pest and disease risk as the climate become better suited for pest establishment. Other areas may experience a reduction in frost risk and an increase in growing degree days, thus improving their suitability for kiwifruit production.
- If minimum temperatures increase there will be a reduction in winter chilling hours, reducing regional suitability to grow kiwifruit (Plant & Food Research, 2021). Having reduced winter chilling hours increases the risk of inconsistent budbreak, leading to variability, and a reduced number of king flowers.
    - Current mitigation strategies include developing more suitable cultivars and effective budbreak enhancers like Hi-Cane (Zespri, 2022).

4.3 Resilience: What Does This Mean?

The focus of this paper is not how GHG emissions can be reduced or climate change avoided, rather, it accepts that changes are going to happen, and kiwifruit growers must be resilient.

Resilience is about dealing with disturbances and shocks.
But resilience is a contested term.
Definitions matter, and there are tensions across definitions.
For example, some definitions emphasise the retention of the structure and function of an (economic) system, while others do not.
– Pells (2023).

The Ministry of Business, Innovation and Employment (MBIE) conducted a literature review on the definition of resilience in June 2023. They recognised that resilience was about dealing with shocks and disturbances, but a definition and concepts had not yet been agreed to. Through the MBIE literature view, four key elements were identified from various definitions (Pells, 2023):

- Bouncing back — Emphasises the speed and extend of recover after a shock
- Absorbing shocks — Stability of a system when faced with a shock
- Positive adaptability — ‘Bouncing forward’, adapted system as a result of shock
- System transformation — Significant changes or shifts to a system in response to shock

This highlights the need for a clear and concise definition of resilience to be formed, as currently it is a term that is often used flippantly.

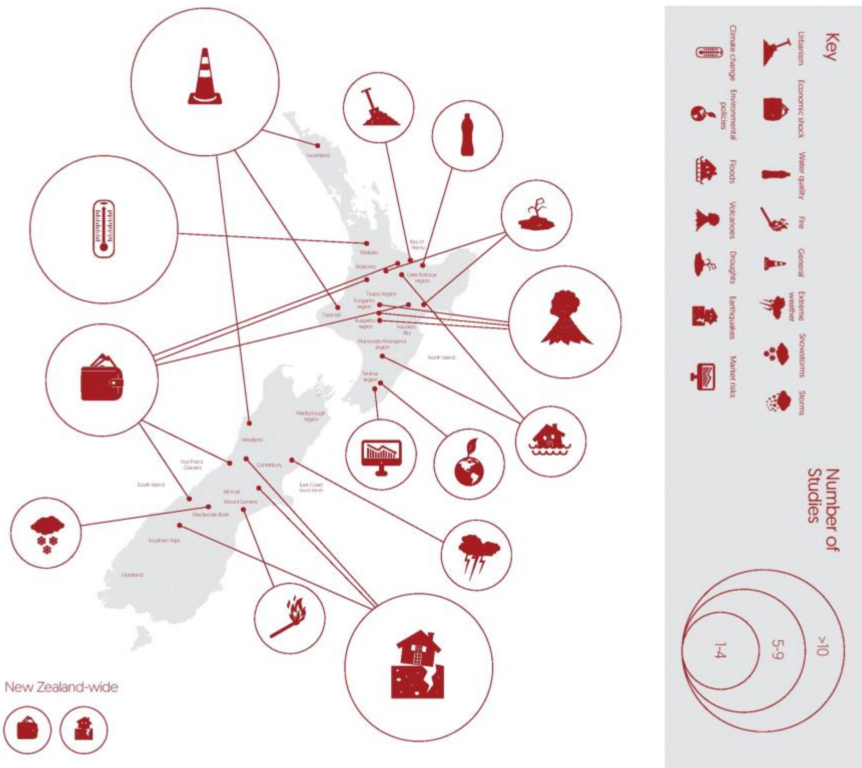

Figure 14: New Zealand resilience studies depicted by hazard and geographical location (Cradock-Henry, Beaven, & Orchiston, 2019).

Resilience is a term not exclusive to horticulture, or even primary production. It is used across many difference sectors and used in many different contexts. A recent systematic review set to review New Zealand studies focuses on rural resilience (Cradock-Henry, Beaven, & Orchiston, 2019). Seen in Figure 14, studies are often focused on a specific hazard in a specific region. This further reinforces the need to clearly define what resilience means for the New Zealand kiwifruit industry.

Climate change has been a relatively slow developing issue for the industry, with ample time to prepare. However, the number of opportunities to enable climate resilience is reducing as time goes forward (IPCC, Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 2023). The IPCC has projected and graphed opportunities to improve climate change resilience, seen in Figure 15. The IPCC projects that there will be more opportunities for resilience if early actions are taken now, to limit global warming to 1.5 degrees.

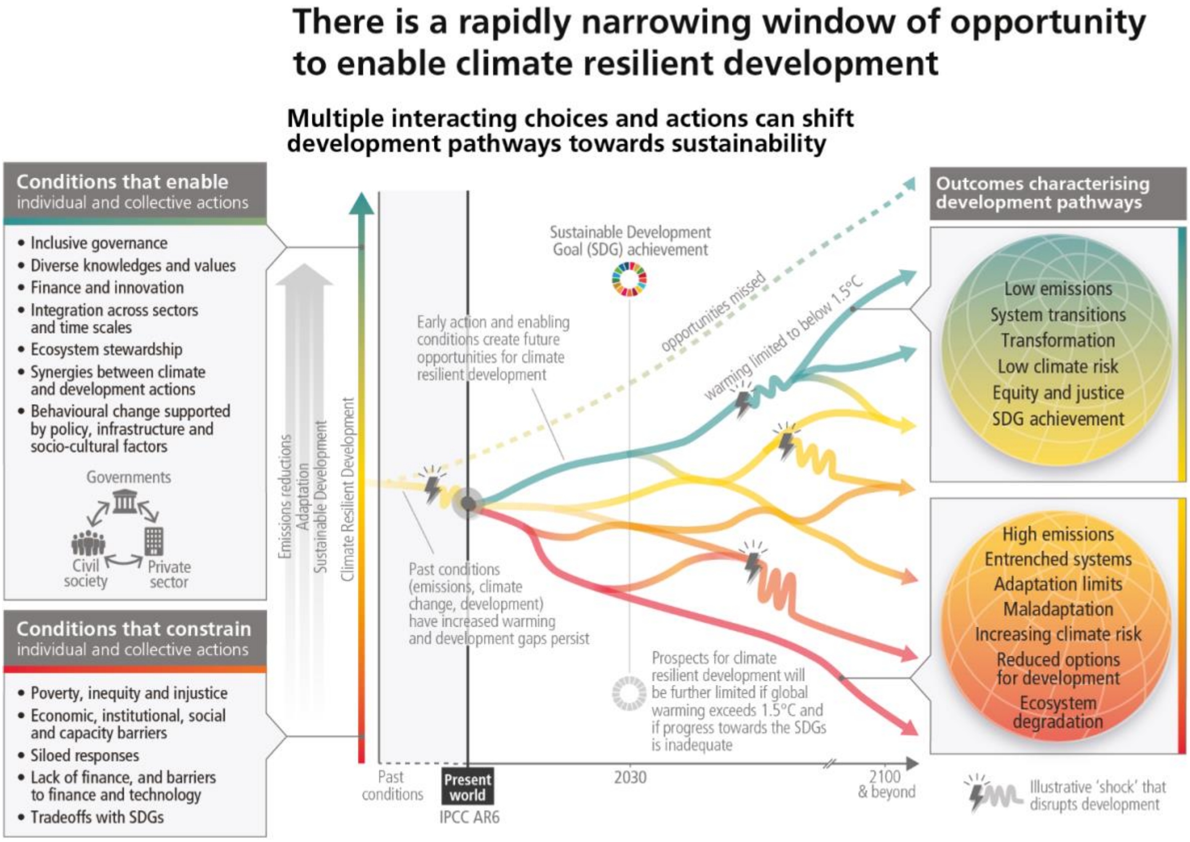

Figure 15: Climate change resilient development projected opportunity, (IPCC, 2023).

5.0 Analysis

As described in the methodology, semi-structured interviews were conducted with kiwifruit growers to understand their climate change experiences and how resilience might be built for the future. A thematic analysis was used to help understand the large qualitative data set gained from these interviews. Key words from the interviews have been coded and used to develop the following themes: climate change, climate change experiences, kiwifruit industry, resilience, postharvest and Zespri. The resulting mind map, created using Miro, can be seen below in Figure 16.

Figure 16: A mind map detailing themes of climate resilience, gained through semi-structured interviews and conducting a thematic analysis.

5.1 How Might We Build Resilience?

5.1.1 Climate Change

The interviewees were asked if they believe their orchard has been impacted by climate change. Nine out of the ten believe they have experienced the impacts of climate change, with discussions about extremes and variability in weather patterns. A Te Puke based grower reflected on their personal observations growing up:

> *"40 years ago, I remember walking down our driveway and a dip in the orchard would always pond and freeze.*
> *I remember racing down to break the ice.*
> *In the last 10 years this hasn't frozen once."*
> *– Te Puke based grower.*

A clear distinction arose between the gradual changes that were happening with climate change and the immediate impact of a weather event. Although a weather event has immediate impact when it occurs, growers can still prepare for this just like some of the slower changes such as increases in temperature.

All the growers interviewed had done something to help mitigate the impacts of climate change on their orchard, as summarised in Table 5 below. The strategies identified are a combination of current and future mitigation strategies. It should be noted that some of these strategies may be implemented by more of the growers interviewed but not discussed in the interview.

Table 5: Interviewee climate mitigation strategies discussed.

Mitigation Strategy	Climate Factor	# of Interviewees
Drainage	Rainfall, flooding	6
Irrigation	Drought	5
Tied in more winter buds	Temperature/winter chill*	3
New cultivars	More resistant	3
Rootstock (Bounty)	More resistant	3
Budbreak enhancers	Temperature/winter chill*	2
Planting of exposed ground	Erosion	1
Orchard/planting location	Temperature/winter chill*	1
Removal of hayward plants	Temperature/winter chill*	1
Shelter	Wind	1
Hail netting	Hail	1
Water storage	Drought	1
Biodiversity	Pests and Diseases*	1
Frost System	Frost	1
* Identified high risk in the Zespri Climate Adaptation Plan.		

The interviewees were then asked about regional climate change modelling and how they were using this information. All but one was aware that climate change modelling existed, however, most found that this was not useful. Microclimates, a distrust in forecasting, and seasonal variation impact were all discussed as reasons why climate modelling wasn't used at the grower level. The only grower to find it useful stated that what they had read for the Bay of Plenty region had actually happened. This was used in their due diligence when purchasing the orchard as they felt it modelled what to expect.

5.1.2 Climate Change Experiences

When discussing climate change, interviewees were specially asked what types of changes or events they had experienced. Figure 17 below is a word cloud summarising the responses from the interviewees. The larger the word in the word cloud diagram, the more frequently it was mentioned in responses.

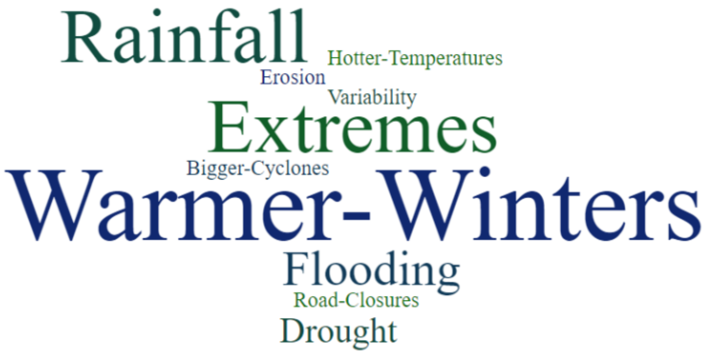

Figure 17: Word cloud summarising interviewees climate change experiences, specifically changes, and events.

The most talked about experience was warmer winters. As explained in this report, warmer winters result in less winter chilling hours, which has a direct impact on the kiwifruit yield. This is also one of the two greatest impacts of climate change identified by Plant and Food Research and Zespri. Kiwifruit Vine Health (KVH) tracks industry winter chill data and has reported a reduction at ten of their eleven monitoring sites across the Bay of Plenty and Gisborne, backing up the experience of those interviewed (Zespri, 2022). KVH recorded 410 winter chill hours in Te Teko in 2017, but only 230 hours in 2022.

5.1.3 Kiwifruit Industry

Interviewees were asked "What do you think the future impacts of climate change will mean for kiwifruit growers?". The purpose was to see if they were aware of what industry experts were expecting for the industry.

Many growers noted that they had already experienced a reduction in winter chilling hours, one of Zespri's identified greatest impacts of climate change. Zespri's second greatest impact would be a change to the growing regions. Both the low and high GHG emission modelling scenarios resulted in current kiwifruit growing regions becoming less suitable (most notably Northland) and other regions becoming more suitable (the South Island and central North Island).

Half of those interviewed discussed possible region changes. They noted that some regions would become extremely difficult to grow in. One grower viewed this through a positive lens as an opportunity for the industry, while the other four thought this would be a challenging shift for the industry, like the Gisborne grower quoted below.

> *"I read a report that some stupid little town on the east coast of the South Island will be the future of kiwifruit."*
> *– Gisborne based grower*

There was a lot of discussion around new cultivars of kiwifruit, like the recently released Zespri Ruby Red. This red kiwifruit requires less winter chilling hours than other varieties and was seen by the growers as one of the solutions to climate change. They felt there was the potential for new varieties to be more drought tolerant, require less fertiliser inputs and reduce the dependence on Hi-Cane or other budbreak enhancers. In 2021, Plant and Food Research and Zespri formed the joint venture The Kiwifruit Breeding Centre to help accelerate the development of new kiwifruit cultivars, formalising over 30 years of kiwifruit plant breeding (Kiwifruit Breeding Centre, 2022).

Other future concerns for the industry raised by interviewees included:

- Reduced yield and increased variability
    - One grower continued querying the impact this would have in market. Fluctuations in yield and quality would make it challenging for Zespri to achieve consistent, high returns for growers.
- Irrigation limitation as water sources and availability become restrictive.
- Changes to crop timings as the climate changes.
- One grower felt that environmental impact wasn't the greatest risk from climate change, rather the regulatory and social impacts were of greater concern.

The regulatory and consumer space is a big risk.
Often there is an enthusiastic change/response to environmental change but is this the best way?
– Ōpōtiki based grower.

5.1.4 Resilience

As explored in the literature review, the topic of resilience is complex, difficult to define and as many of the interviewees expressed, overused.

"Resilience.
A word much overused."
– Katikati based grower.

Nevertheless, interviewees were asked to define resilience. All of their definitions were centred on responding to events or adversity, or about moving forward. Half of the interviewees also define resilience as an 'ability' that you can have. Having reviewed all ten of the definitions the following summarised definition has been produced. All of the grower definitions can be seen in Table 6.

RESILIENCE: THE ABILITY TO ADAPT POSITIVELY TO EVENTS AND CONTINUE MOVING FORWARD.

Table 6: Interviewee definitions for resilience, key words identified.

Definition	Key Words
Building strategies to minimise risk.	Strategies, Minimise, Risk
Being able to adapt to change. Withstanding change means you're only doing one thing.	Adapt, Change
The ability to keep moving forward, or sideways, or backwards. Just don't stand still.	Ability, Moving, Forward
Being able to muck through it.	Able, Muck Through
The need to be self-sufficient and be prepared for events.	Self-sufficient, Prepared, Events
Just working through it as best you can.	Working, Through, Best
Your ability to adapt to any given challenge in a way that allows you to continue to operate.	Ability, Adapt, Challenge, Continue
Is being able to believe that the future is better than the now, and strive positively forward, rather than get pessimistically stuck. Ability to be able to stay strong in the face of adversity	Positively, Forward, Ability, Adversity.
Ability to get thrown down, get back up again and keep going.	Ability, Keep Going
A word much overused. Ability to respond positively to events.	Ability, Respond, Positively, Events

Another aspect of grower resilience explored was how resilient they felt. A scale of one to ten was used where one was not resilient and ten was fully resilient. They were asked to give themselves a score for their current state of resilience, and a score for where they want to be. Their results have been graphed below in Figure 18.

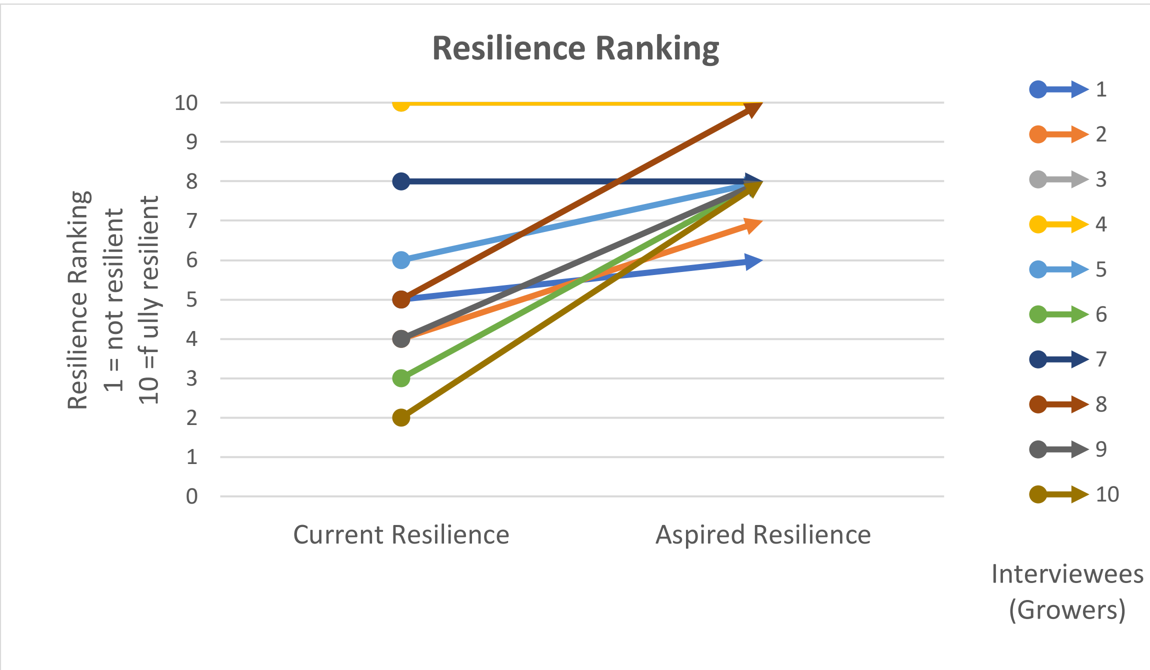

Figure 18: Current grower resilience and aspired grower resilience.

Overall, there was a greater spread of current resilience (2 – 10) with an average rating of 5.7. Three of the growers wanted to maintain their Current Resilience score, while all others wished to improve their current score. The spread of growers' Aspired Resilience scores (6 – 10) reduced, with an average score of 8.3. Some growers found it difficult to represent resilience on this scale. However, regardless of this scale, the majority of growers felt that they wanted to increase their own resilience into the future.

70% of growers felt resilience was something you could not score a 10 in. There is always going to be an element of vulnerability as you cannot completely protect against every aspect of climate change.

"I don't think resilience can be a 10, it's not feasible.
Orcharding is about getting 80% of the job done.
It is good enough."
– Gisborne based grower.

The growers were then asked to identify specific areas that contributed to their resilience scores. Firstly, they were asked what areas they felt most resilient in, as seen in Figure 19. Irrigation and financial were the top areas making growers feel resilient followed by an elevated site location.

Having irrigation allows the grower to apply water to supplement short comings in rainfall. Irrigation can be critical through key growing periods such as fruit set. With a lot of discussion about this season's El Niño growing conditions, expected to bring a warm dry summer, it is not surprising that irrigation makes grower's feel more resilient.

Financial resilience and elevated site location are two areas identified that are separate from on orchard practices. Having an elevated site can help minimise the impacts from flooding. Several of the growers talked about their due diligence before purchasing their orchards. One interviewee talked about losing part of their orchard in the next five years. They weren't concerned about this though, as they knew this was a possibility before purchasing the orchard and have been prepared for it. Other growers with challenging sites also talked about knowing the orchard challenges prior to purchase. Therefore, they already had a plan going in of the orchard limitations and how they might make improvements. The conversations were closely linked to financial resilience. Those who have a healthy balance sheet felt they were in a positive potion to handle any climate change impacts.

Figure 19: Word cloud summarising areas interviewees felt most resilient, on left, and areas that would help growers feel fully resilient, on right.

The interviewees were also asked what areas would help them to feel more resilient, as seen on the right side of Figure 19. New cultivars was one of the top areas discussed, with a couple of growers talking about the marginal growing condiitons in Kerikeri for Hayward (green) kiwifruit. They would feel more resilient with new cultivars which were better resistant to the projected climate change impacts. Another popular area of discussion was fully covering their orchard. This practice involves fully covering the orchard with cloths, helping reduce the impacts of wind and hail events. While some growers felt resilsient due to their finanaical position, some felt that a better financial position would help improve their feeling of resilience.

5.1.3 Postharvest

The postharvest sector within the kiwifruit industry supply chain is responsible for the packing and storing of kiwifruit, before being shipped to market by Zespri, seen in Figure 20 below.

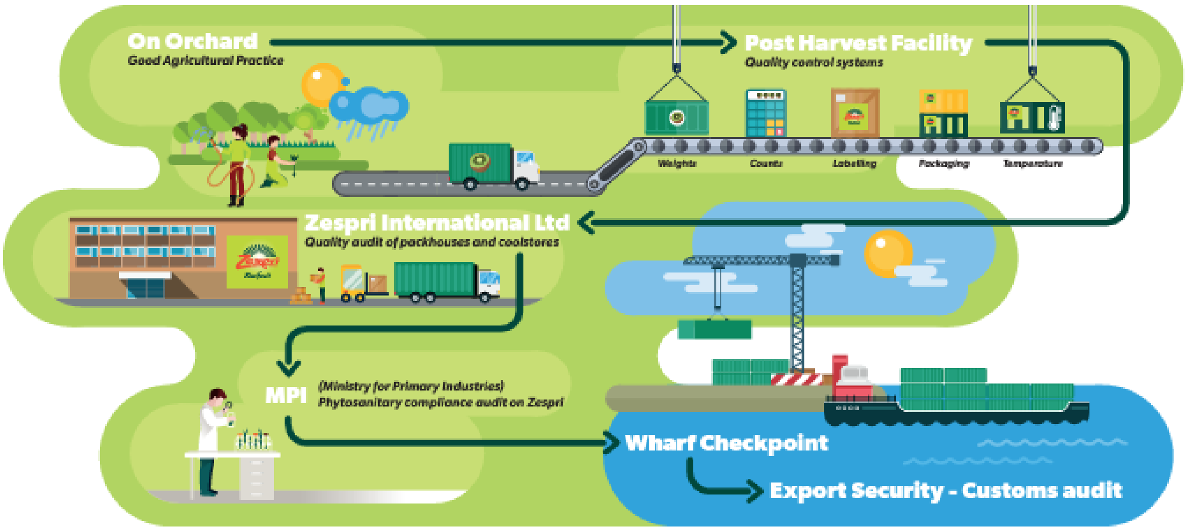

Figure 20: A simplified overview of the kiwifruit supply chain, (NZKGI, 2022).

Many of the postharvest providers offer growers services such as technical field days, orchard management services and all year-round support. Because of this level of interaction with growers it was important to understand the role of postharvest and what could be done to help with grower resilience. The interviewees were therefore asked what postharvest facilities could to do help them feel fully resilient. The main points raised were:

- Capacity to take the fruit when it is ready.
    - Making investments in infrastructure to ensure this is possible.
- Technical support and on orchard strategies.
- Postharvest gets see more fruit so have a better understanding of what's happening.
- Improved collaboration within the industry.
- Postharvest have bigger budgets and skilled people, better placed to get information out to growers.
- Share how postharvest plan to be sustainable through seasons with lower yields and less returns.
- Communication must be timely and reach growers.
- Foster a symbiotic relationship with growers.
    - Growers should be the primary driver of their own resilience.

One of the growers emphasised the need for industry collaboration. They felt, particularly in the postharvest space, a lot of resource and time was spent on competing.

"We are in the same waka.
We have finite resources and energy.
It is okay to have different views, but we are a small fish in a big, big sea.
We can't be eating each other."
– Gisborne based grower.

Several growers did make comments about the need for growers to self-drive their own resilience. They felt there was risk if a grower was too dependent on their postharvest facility.

"Too many growers are reliant on their postharvest facility.
Unless you are fully managed by your packhouse, you should be able to be the one driving resilience, not your packhouse.
Post harvest should be symbiotic, not relied upon."
– Ōpōtiki based grower.

5.1.4 Zespri

Similar to the previous question, interviewees were also asked what Zespri could be doing to help them feel fully resilient. There was a clear distinction from postharvest, which was still focused on the orchard. The focus of Zespri was around markets, returns and new cultivars. The main points raised were:

- Transparency of fruit data, particular offshore performance.
- Continued investment in science, even when returns are down.
- Build confidence in the future and longevity of the kiwifruit industry.
- Focus on supply chain and market resilience.
- Relay consumer feedback from the market.
- Communication must be timely and reach growers.
- Technology and innovation.
- Lobbying government, ensuring growers can continue to grow.
- Improve timeliness of responses to events.
- Be assertive and say what is needed with confidence.
- Have a whole industry focus, not just Te Puke.
- What is the plan for the future? Tell growers how you plan to maintain high returns for them.
- New cultivars.
- Retain Hi-Cane (budbreak enhancer).
- High level climate change focus, rather than on orchard.

Zespri are also involved in international growing regions, to help provide them with fruit for a twelve-month supply. One of the growers interviewed raised this point. Being involved in international growing regions, Zespri may be exposed to more climate change impacts and various extremes. They could be sharing lessons from these regions with their New Zealand growers to help educate them.

"Zespri is exposed to a lot more growing areas, even international growers.
They have a lot more exposure and experience to share.
Share these experiences in the various extremes.
Share more global case studies."
– Ōpōtiki based grower.

5.1.4 Industry Response

Interviewees were also asked to reflect on any previous climate change events and how they felt these events were handled by the wider industry. Most notably, the industry has dealt with two significant cyclones in 2023, cyclones Hale and Gabrielle. The growers interviewed from Gisborne were able to share their recent experiences with a climate response.

Reponses were divided amongst the interviewees. Some felt like the response had been handled well, while others felt it was handled poorly.

Those who thought it was handled poorly noted:

- Lack of preparation.
- Response was good for those most devasted and in the media, but there are plenty of other growers still impacted struggling to get support.
- "No silt, no help."
- Lack of visibility after the event.
- Feeling of isolation.
- Response needs to be timelier.

One of the growers from Gisborne talked specifically about the industry response to cyclone Gabrielle.

"The response was poor.
They flew in on helicopter and didn't say anything.
Lack of preparation was evident."
– Gisborne based grower.

6.0 Key Findings

The key findings section provides a summary of the climate change factors which will be most significant for kiwifruit growers followed by a summary from the semi structured interviews, identifying key areas which might help kiwifruit growers build resilience to climate change impacts.

The literature review began by collating global climate change data and modelling which was then explained in a New Zealand context and a kiwifruit industry context. Below is a summary of the most significant impacts expected for the industry within the next 50 years and the associated risk level in accordance with Zespri's 2022 Climate Adaptation Plan (Zespri, 2022):

- Average temperatures are set to increase. Modelling using the RCP4.5 scenario the increase is expected to be 0.9°C and using the RCP8.5 scenario is expected to be 1.1°C.
    - This is of high risk, meaning action may be required in the short to medium term.
    - New pests and diseases becoming established in key grower regions with warmer temperatures.
- Minium temperatures are set to increase. Modelling using the RCP4.5 scenario the increase is expected to be 1.0°C and 1.25°C using the RCP8.5 scenario.
    - There is a high risk of impact to budbreak, creating variability and a reduction in king flower production.
    - Cold nights, or frost, may reduce. This opens up the potential of new growing regions in the central North Island or South Island to establish.
- Average rainfall (precipitation) will be varied across the regions. The upper North Island is likely to become dryer.
    - There is a moderate risk, meaning action may be required, but the timeframe is uncertain.
    - An increased reliance from growers on water supplies and irrigation systems.
    - Restricted water may impede fruit development, resulting in smaller fruit.
    - Drought risk increasing, with the severity and frequency likely to increase also.
- Hot days (>25 °C) are likely to become more frequent with impacts posing a moderate risk.
    - Heat stress for plants will again put pressure on water supplies and irrigation systems.
    - Heat stress becomes a greater concern for orchard workers.

Although this report has focused on the impact of these climatic features and the risks they bring to the industry, the impacts of climate change can offer some opportunities as well. Opportunities include development of new cultivars of kiwifruit, development of new growing regions within New Zealand, and improvements to on orchard practices to become more efficient as an industry.

Semi-structured interviews were conducted to gather qualitative data from a grower perspective. A thematic analysis was then conducted to further analyse this data set and understand what support growers might need to become more resilient.

Overall, the interviews demonstrated that most growers have a good grasp on the high-level implication of climate change. Although it was not to a high level of detail, it was enough to encourage implementation of action on orchard already, will all interviewees already having implemented some response to climate change. They also understood how these climate change impacts were likely to impact the kiwifruit industry. Summarised below are some of the key points mentioned by interviewees, which might help kiwifruit grower build climate change resilience:

- Resilience is a term often overused without a clear definition for the context in which it is used.
    - The following resilience definition was developed to summaries the key aspects of definitions provided by interviewees: the ability to adapt positively to events and continue moving forward.
- Although the kiwifruit industry offers support in many areas, growers should still be the ones driving their own climate change resilience strategies.
- Climate change resilience is not static and requires constant maintenance to remain resilient.
- Industry response times to significant weather events are important to growers.
- Postharvest providers should act symbiotically with growers.
    - Postharvest facilities are exposed to many growers and see more fruit than individual growers. Sharing of information will aid individual growers to be more informed.
    - This sector of the kiwifruit supply chain is highly competitive. Growers feel that more collaboration will lead to positive outcomes as everyone utilises the resources within the kiwifruit industry.
    - Increased transparency will lead to more confidence with growers.
- Zespri plays an important role connecting kiwifruit growers to the market.
    - Transparency is also important for Zespri, giving grower confidence in the longevity of the kiwifruit industry.
    - Technology and innovation, in particular new kiwifruit cultivars and new budbreak enhancers, are seen as the best mitigation tools for the projected climate change impacts.
    - Zespri has access to international kiwifruit growers, who may have been exposed to a wide range of climate change impacts across the globe. It is important to share these experiences and learnings with New Zealand kiwifruit growers.

7.0 Conclusions

The purpose of this report was to collate scientific climate change data, analyse the likely impact this will have on key kiwifruit growing regions and summarise strategies to help kiwifruit growers build climate change resilience.

Climate change is a complex and slowly developing issue around the world. Trying to distil this down to the level of an individual grower has many challenges. Often, mitigation tools and strategies require large capital input, without an immediate obvious return.

The IPCC is the global body that assesses scientific climate change data in a global context. NIWA and other organisations then uses IPCC assessment reports to form and update their climate change modelling for New Zealand. The findings of this climate change modelling can then be utilised for research specific to the kiwifruit industry, for example by Zespri and Plant and Food Research.

The orchardists interviewed were not necessarily aware of the climate change modelling data available, but they were aware of the impacts of climate change. All ten growers had commented on changes or significant events they had experienced, as well as steps they had already implemented to reduce future impacts of climate change.

Currently growers have reported experiencing warmer winters, heavier rainfall events and more significant extremes, like stronger cyclones. They also identified future impacts are likely to include, significant changes in growing regions suitable for kiwifruit production and the need for development of more resistant rootstocks, like Bounty, and new resistance kiwifruit varieties.

Although discussions about the impacts of climate change in horticulture often tend to be negatively focused, some of the discussions with interviewees were also positive and focused on the opportunities. There will be significant opportunities for the kiwifruit industry to develop new kiwifruit cultivars which are more resistant to the effects of drought or require less winter chilling hours to achieve a successful budbreak. Hi-Cane is the most effective and widely used budbreak enhancer, but the industry is facing a future where its use will be prohibited. An opportunity to develop a new budbreak enhancer exists and will help continue the success of current kiwifruit varieties. As climate change factors, such as average temperature increase, are more widely felt, New Zealand's current growing regions may reduce in suitability for kiwifruit production. A future opportunity for new regions opens, with regions such as the central North Island and South Island likely increasing in suitability for growing kiwifruit.

Overall, kiwifruit growers have a good baseline understanding of climate change and what impacts to expect. Growers interviewed acknowledged that there are likely significant challenges ahead for the kiwifruit industry but also identified opportunities and strategies for mitigation. Climate change is a constantly moving target which will require continual adjustments and ongoing collaboration across the industry to remain resilient to climate change impacts in the future.

8.0 Recommendations

The following recommendations are made to the kiwifruit industry for helping to build climate change resilience with kiwifruit growers:

1. Growers should work to become financially resilient. It was identified as one of the major factors that lead to growers feeling more resilient. Having financial reserves available to respond to a climate change events meant growers felt more confident, rather than fearing what might happen.

2. Prior to purchasing a new orchard, due diligence is essential. Growers should be assessing any new orchard purchases with climate change impacts in mind. Factors to be considered include site elevation, exposure to wind, access to water and drainage status.

3. Climate change is not a static problem. Adaptability is an essential attribute for growers to maintain their climate change resilience. Growers should be encouraged to stay up to date with reliable and current information to ensure they are well informed and prepared to adapt as needed.

4. Collaboration will be key in responding to climate change. Being a regulated industry, the kiwifruit industry has a unique advantage. There is already a high level of collaboration and sharing of information. Expanding on this collaboration and sharing of experiences will help future-proof the industry.

5. Transparency of data is needed to give growers confidence in the longevity of the kiwifruit industry. More detailed data from kiwifruit performance onshore and offshore will help growers identify any climate change impacts they may be able to mitigate going forward.

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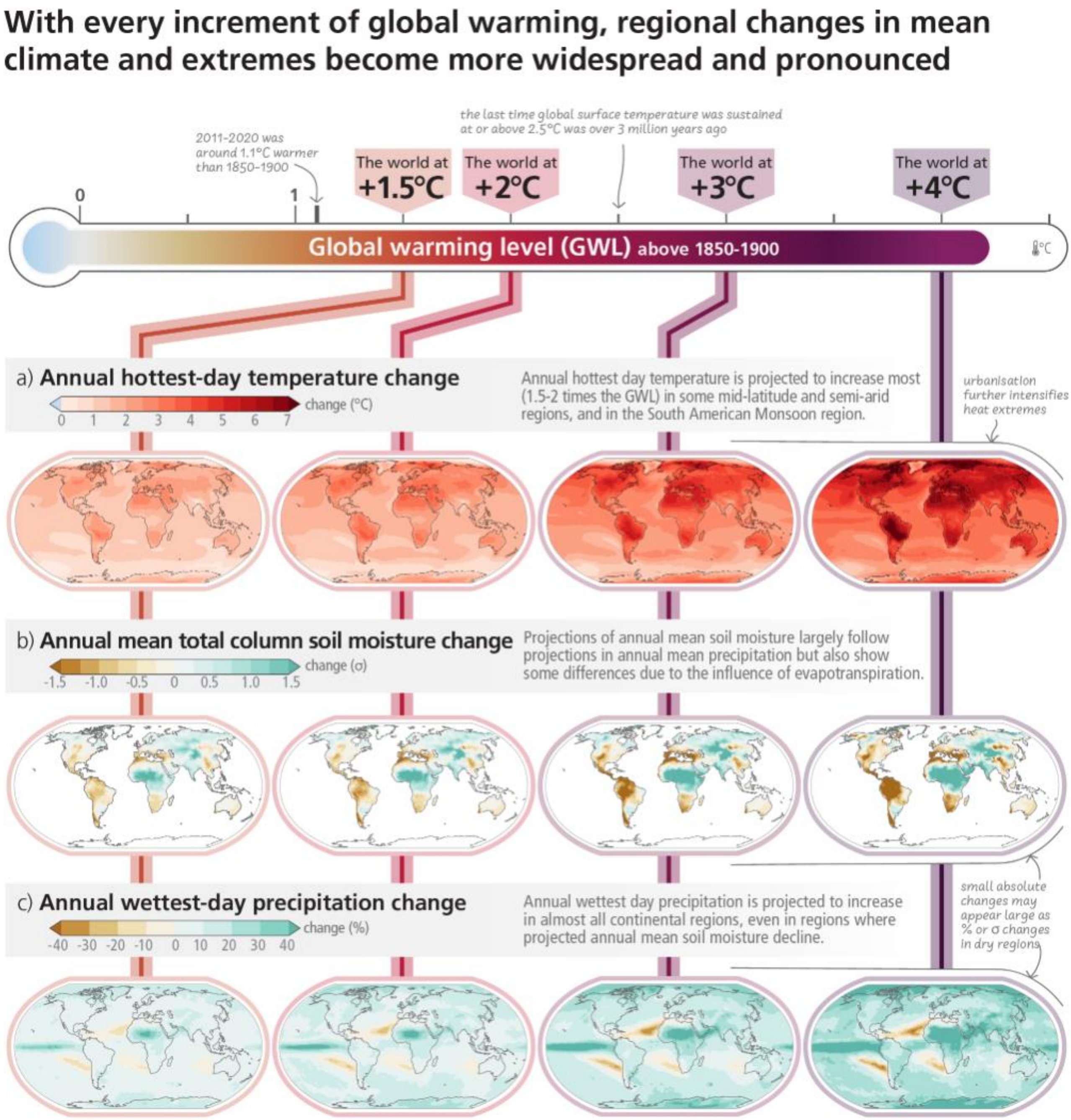
Appendices

Appendix A: Larger Version of Figure 21: 2023 IPPC climate change scenarios, (IPCC, 2023).



Appendix B: Main features of New Zealand climate change projections, (Mullan, Sood, Stuart, & Carey-Smith, 2018).

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation
Mean temperature	Progressive increase with concentration. Only for RCP2.6 does warming trend peak and then decline.	By 2040, from +0.7°C [RCP2.6] to +1.0°C [RCP8.5]. By 2090, +0.7°C to +3.0°C. By 2110, +0.7°C to +3.7°C.	Warming greatest at higher elevations. Warming greatest summer/autumn and least winter/spring.
Minimum and maximum temperatures	As mean temperature.	Maximum increases faster than minimum. Diurnal range increases by up to 2°C by 2090 (RCP8.5).	Higher elevation warming particularly marked for maximum temperature.
Daily temperature extremes: frosts	Decrease in cold nights (minimum temperature of 0°C or lower).	By 2040, a 30% [2.6] to 50% [8.5] decrease. By 2090, 30% [2.6] to 90% [8.5] decrease.	Percentage changes similar in different locations, but number of days of frost decrease (hot day increase) greatest in the coldest (hottest) regions.
Daily temperature extremes: hot days	Increase in hot days (maximum temperature of 25°C or higher).	By 2040, a 40% [2.6] to 100% [8.5] increase. By 2090, a 40% [2.6] to 300% [8.5] increase.	
Mean precipitation	Varies around the country and with season. Annual pattern of increases in west and south of New Zealand, and decreases in north and east.	Substantial variation around the country (see section 3.6.1), increasing in magnitude with increasing emissions.	Winter decreases: Gisborne, Hawke's Bay and Canterbury. Winter increases: Nelson, West Coast, Otago and Southland. Spring decreases: Auckland, Northland and Bay of Plenty.
Daily precipitation extremes: dry days	More dry days throughout North Island, and in inland South Island.	By 2090 [8.5], up to 10 or more dry days per year (~5% increase).	Increased dry days most marked in north and east of North Island, in winter and spring.
Daily precipitation extremes: very wet days	Increased moderately extreme daily rainfalls, especially where mean rainfall increases.	More than 20% increase in 99th percentile of daily rainfall by 2090 [8.5] in South West of South Island. A few percentage decrease in north and east of North Island.	Increase in western regions, and in south of South Island. Decrease in extremes in parts of north and east of North Island.
Very extreme precipitation events: greater than 2-year average recurrence interval	Increase.	Percentage increases *per degree of warming* range from 5% for 5-day duration events to 14% for 1-hour duration events.	Little robust regional variability. Possibly larger increases in the very north and very south of the country.
Snow	Decrease.	Snow days per year reduce by 30 days or more by 2090 under RCP8.5.	Large decreases confined to high altitude or southern regions of the South Island.
Drought	Increase in severity and frequency.	By 2090 [8.5], up to 50mm or more increase per year, on average, in July–June PED.	Increases most marked in already dry areas.

Climate variable	Direction of change	Magnitude of change	Spatial and seasonal variation
Circulation	Varies with season.	Generally, the changes are only a few hectopascals, but the spatial pattern matters.	More northeast airflow in summer. Strengthened westerlies in winter.
Extreme wind speeds	Increase.	Up to 10% or more in parts of the country.	Most robust increases occur in southern half of North Island, and throughout the South Island.
Storms	Likely poleward shift of mid-latitude cyclones and possibly also a small reduction in frequency.	More analysis needed.	See section 3.7.
Solar radiation	Varies around the country and with season.	Seasonal changes generally lie between -5% and +5%. (See section 3.9.1.)	By 2090 [8.5], West Coast shows the largest changes: summer increase (~5%) and winter decrease (5%).
Relative humidity	Decrease.	Up to 5% or more by 2090 [8.5], especially in the South Island. (See section 3.9.1.)	Largest decreases in South Island in spring and summer.

Appendix C: Semi-Structured Interview Questions

I am currently a scholar on the Kellogg Rural Leadership programme, and as part of this course, it involves a research project through post graduate study at Lincoln University. The topic I've chosen to look at is: ***"Climate Resilience: How might we build resilience for kiwifruit growers in a changing environment?"***

I would like to interview you to get an understanding of what a broad range of kiwifruit growers think about resilience, climate change and preparedness for climate related changes. There are no right or wrong answers, but I'm interested in your honest opinion given your background. The interview should take about 30 minutes. This will be kept anonymous, with no names/roles or other specific personal details being mentioned in the report. I would like to identify common themes and the scope of these themes. I also think it is important to mention that your responses here are in no way reflective of Zespri or your affiliated packhouse, but rather as an individual working within the kiwifruit industry. If you feel uncomfortable with any question, or do not wish to answer, you can say so and we can either move on or end the interview there.

Background Information (please note this is anonymous)

1. Name.
2. What region are you based in?
3. What is your total orchard(s) area in hectares?
4. What varieties of kiwifruit do you grow?
5. How long have you been in the kiwifruit industry (years)?

Climate Change

6. How do you believe that climate change has impacted your orchard?
7. What type of changes or events have you experienced?
8. What things did you do to mitigate the impact of these changes or events?
9. Where do you expect support to come from after an event?
10. How do you feel the responses to these changes or events have been handled?
11. What future things are you planning to do in response to a changing climate?
12. Are you aware of any climate modelling for your region, and if so, how useful have you found this information?

Resilience

13. How do you define resilience?
14. How resilient to climate change do you currently feel on a scale of 1 - 10? 1 being not at all and 10 being fully resilient.
15. What areas do you feel most resilient in?
16. On the same scale, where do you aspire to be? i.e. do you want to become more resilient than you currently are?
17. What areas do you feel need more work to become fully resilient?

Future Actions

18. What do you think the future impacts of climate change will mean for kiwifruit growers.
19. What things could your post-harvest facility be doing with you to help build your resilience?
20. What things could Zespri be doing with you to help build your resilience?