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Taihoro Nukurangi

Regional climate change summary tables and associated risks and opportunities for the primary sector

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Prepared by:
Paula Blackett
Ashley Broadbent
Nick Cradock-Henry (MWLCR)

For any information regarding this report please contact:

Paula Blackett
Environmental Social Scientist
Social Science and Economics
+64 7 859 1864
Paula.Blackett@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 11115
Hamilton 3251

Phone +64 7 856 7026

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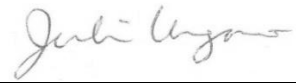	Reviewed by:	Juli Ungaro
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1 Introduction

The primary sector in Aotearoa-New Zealand faces significant adaption challenges in the face of climate change. The first step toward adaptation for primary producers is understanding the range of possible climate futures that may occur and the implications of those climate changes for primary industries at different locations (Cradock-Henry et. al 2019). This report summarises existing climate change information, drawing on previous research and presents preliminary information regarding risks and opportunities. The aim is to enhance understanding of future climate impacts and implications and raise awareness regarding potential adaptation options.

More specifically in this report we have:

1) Collated (from existing sources) a set of key climate change variables, as relevant to the Aotearoa-New Zealand (A-NZ) primary sector by subnational climate zone. Presented as six sub-national regional tables, this information details key climate changes variables for two separate future time periods (2040-2050 and 2090-2100) with two different possible future greenhouse gas emission pathways (RCP 4.5 [moderate intensity emissions] and RCP 8.5 [high intensity emissions]).

2) Constructed a draft list of risks and opportunities associated with key climate change variables to inform the He Wake Eka Noa work program on what climate change might mean for primary industries in A-NZ.

This information is collated from existing sources or the authors experience and is suitable for inclusion in the forthcoming publication "Greenhouse Gases: Farm Planning Guidance".

2 Methods

Two key tasks that were undertaken as part of the project: first the construction of regional climate change summary tables and second the creation of a draft set of risks and opportunities afforded by the various changes. Each activity is discussed separately in the following subsections.

2.1 Summaries of climate change variables by zone

To provide a useable summary of climate change impacts, we have used six regional groupings that represent similar climatic zones (or sub-national climatologies) across mainland A-NZ (Table 2-1). The zones are based on broadly defined zones of rainfall that NIWA uses for seasonal forecasting (Kidson and Renwick, 2002). The areas within each zone will likely experience broadly similar trends, while there may be significantly different climate changes and impacts between regions. The zones align with those described in the National Climate Change Risk Assessment Framework (MfE, 2019) and were used in the National Climate Change Risk Assessment (MFE, 2020) and NIWA's Climate Change Adaptation Toolbox[1] (see NIWA, 2021) in order to maintain constant regional divisions across various publications.

Table 2-1: Regional groupings that represent similar climate zones and their geographical area.

Zone	Description
Zone 1: Upper North Island (Te Ika a Maui)	Extends to Mōkau on the west coast and Lottin Point (Wakatiri) in eastern Bay of Plenty, and the northern part of Lake Taupō.
Zone 2: Western lower North Island (Te Ika ā Māui)	Covers Taranaki to Wellington (Te Whanga-nui-aTara) and includes National Park and southern Lake Taupō. Includes the regions of Taranaki, Manawatū–Whanganui (Horizons) and Wellington.
Zone 3: Eastern lower North Island (Te Ika ā Māui)	Extends from Hicks Bay (Wharekahika) to Palliser Bay (Te Waha o te Ika ā Māui) and back to the Ruahine and Kaweka ranges. Includes Gisborne, Hawke's Bay and the Wairarapa catchment of Wellington.
Zone 4: Northern South Island (Te Wai Pounamu)	Covers Marlborough (from Kaikōura north), Nelson (Whakatū) and around to Punakaiki on the West Coast. Includes Tasman, Nelson, Marlborough and Buller District.
Zone 5: Eastern South Island (Te Wai Pounamu)	From Kaikōura to Owaka (South Otago) and includes Central Otago and the MacKenzie Basin including Lakes Tekapo to Ōhau to the east of the Southern Alps. Includes the West Coast, inland Otago and Southland.
Zone 6: Western and southern South Island (Te Wai Pounamu)	Covers the West Coast, Fiordland, Southland and Stewart Island (Te Punga o Te Waka ā Māui) and includes the Southern Alps and southern lakes. Includes Canterbury and Otago.

For each of the six mainland A-NZ zones, we present climate change variables of relevance to the primary sector (Table 2-2) that are available for every zone without any further interrogation of

[1] https://niwa.co.nz/climate/information-and-resources/climate-change-adaptation-toolbox)

regional climate models. The data we have summarised is based on regional downscaling of the IPCC Fifth Assessment Report (AR5) (IPCC, 2013) climate model simulations. For further information the reader is directed to either the Climate Change Adaptation Toolbox: Regional Projections[2] (NIWA, 2021) or Climate Change Projections for New Zealand[3] (MfE, 2018). The recent publication of the IPCC Sixth Assessment (AR6) Working Group 1 report (IPCC, 2021) will enable updated projections of New Zealand's regional climate once downscaling has been completed. Sea level rise has been defined using the report Coastal Hazards and Climate Change: Guidance for Local Government[4] (Bell et al. 2017)

Table 2-2: Climate change variables detailed report and the source of this data.

Climate change variables	Descriptor and information source	Source of Data
Air temperatures	Average change in air temperature Number of hot days (days over 25 degrees Celsius)	Climate Change Adaptation Toolbox: Regional Projections (NIWA, 2021) Climate Change Projections for New Zealand (MfE, 2018)
Mean rainfall	Average annual rainfall Seasonal rainfall changes	Climate Change Adaptation Toolbox: Regional Projections (NIWA, 2021) Climate Change Projections for New Zealand (MfE, 2018)
Rainfall extremes: dry days	Dry days are days days where no measurable rainfall occurs	Climate Change Projections for New Zealand (MfE, 2018)
Rainfall extremes: very wet days	Days of very heavy rainfall (defined as 99th percentile days)	Climate Change Projections for New Zealand (MfE, 2018)
Potential Evapotranspiration Deficit (PED)	PED is the difference between how much water could potentially be "lost" from the soil through evapotranspiration and how much is available. It is also represents the amount of water required by irrigation to avoid plant stress.	Climate Change Projections for New Zealand (MfE, 2018)
Frost, snow and ice cover	Incidence of frost events and snowfall	Climate Change Projections for New Zealand (MfE, 2018)
Storminess and extreme winds	Incidence of storms events and high winds	Climate Change Projections for New Zealand (MfE, 2018)
Sea level rise	The increase in sea level rise in metres relative to a baseline in 2000	Coastal Hazards and Climate Change, Table 9 (Bell et al. 2017).

[2] https://niwa.co.nz/adaptationtoolbox/regionalprojections
[3] https://environment.govt.nz/publications/climate-change-projections-for-new-zealand/
[4] https://environment.govt.nz/assets/Publications/Files/coastal-hazards-guide-final.pdf

The time periods selected for this summary were 2040-2050 and 2090-2100 - principally because the time frames are in line with MfE's Climate Change Projections for New Zealand (MfE, 2018). In addition, the application of existing modelling data and information maintains a consistency with other publications and compiling these data did not require any further modelling effort. The data in this report provide climate change projections for the mid-century and end-century planning horizons.

We recognise that shorter timeframes in the order of 5-10 years into the future are perceived as more helpful for primary producers to plan their various activities, but we do need to recognise that the pace of change is unknown. This means that a more adaptive response involving monitoring of on-going change is more helpful than working to fixed time horizons. However, the timeframes are important in terms of signalling that the climate is shifting and providing an indicative direction of that change.

The RCP (Representative concentration pathways) chosen for the climate variable tables use two different projection scenarios: RCP 4.5 (moderate greenhouse gas emissions mitigation) and RCP 8.5 (continuing high global greenhouse gas emissions). The concept of RCPs originated in the IPCC's 5th Assessment report (IPCC, 2013) and is a way of representing different possible future worlds, with different responses from the climate system. For a further description of RCPs the reader is directed to MfE's Climate Change Projections for New Zealand (MfE, 2018).

Of the possible RCPs described in the IPCC AR5 report we have chosen two scenarios, to provide a range of future possible climates without over complicating the results. RCP 4.5 represents a world where some global-scale mitigation of greenhouse gas emissions has occurred, warming continues through the first half of the 21st century but begins to stabilize around the year 2050. By contrast, RCP 8.5 is a world that has continually high greenhouse gas emissions with little mitigation effort and continued steady warming throughout the 21st century. The selection of the RCPs is not because these possible futures are more likely than any of the others, but to show a reasonable range of climatic futures that A-NZ could experience.

2.2 Risks and opportunities table

A draft climate change risk and opportunities table for A-NZ was compiled to create a foundation from which information for each zone can be extracted. It has been built around important topics for primary producers and was generated from a brainstorming session by the authors grounded in their collective experiences. However, the table will not be exhaustive and is designed to support further discussions with key primary sector organisations as part of the ongoing conversations within the He Wake Eka Noa program.

Key questions covered include:

- What are the risks climate change may cause?

- What are the key adaptation questions we will need to consider?
- How do we know climate change is happening? What should we be measuring to know that the situation is changing?

3 Results and Discussion

The results are presented in two subsections: first are the climate variables classified into regions, and second is a base table that outlines the key risk and opportunities for each region.

3.1 Climate variables by region

3.1.1 Zone 1: T: he Upper North Island (Te Ika a Maui)

This zone extends to Mōkau on the west coast and Lottin Point (Wakatiri) in eastern Bay of Plenty, and the northern part of Lake Taupō.

Table 3-1: Climate variables for the upper North Island (Zone 1) at time steps 2040-2050 and 2090-2100 for RCPs 4.5 (moderate intensity emissions) and 8.5 (high intensity emissions).

Climate Variables	Changes under RCP 4.5	Changes under RCP 8.5
Air temperatures	**2040**: Annual average air temp to increase 0.7-0.9˚C. Increase of 10-20 more hot days/year (>25˚C).	**2040**: Annual average air temp to increase 0.7-0.9˚C. Increase of 15-20 more hot days/year (>25˚C).
	2090: Annual average air temp to increase 1.3-1.4˚C. Increase of 25-30 more hot days/year (>25˚C).	**2090**: Annual average air temp to increase 1.3-1.4˚C. Increase of 50-70 more hot days/year (>25˚C).
Mean rainfall	**2040**: Minimal change in annual rainfall. Reduction in rainfall in winter and spring, and small increases in summer.	**2040**: Minimal change in annual rainfall. Reduction in rainfall in winter and spring, and small increases in summer.
	2090: Minimal change in annual rainfall. Seasonal rainfall will increase or decrease by <5%. Spring has largest rainfall deduction (5%).	**2090**: Minimal change in annual rainfall. Seasonal rainfall will increase or decrease by <5%. Spring has largest rainfall deduction (5%). 10-20 more dry days/year.
Rainfall extremes: dry days	**2040:** 0-8 more dry days/year.	**2040:** Increase in 3-9 dry days/year, larger increase in dry days projected for spring (3-6 days).
	2090: 5-10 more dry days/year.	**2090:** 10-20 more dry days per year.
Rainfall extremes: very wet days (99th percentile days)	**2040:** No significant change projected.	**2040:** No significant change projected.
	2090: Small decrease projected.	**2090:** ~10% increase across Auckland region. Otherwise, no change.
Potential Evapotranspiration Deficit (PED)	**2040:** Increase in PED of 60-100 mm. Low river flow thresholds reached earlier in the year.	**2040:** PED increase of 60-100 mm. Low river flow thresholds reached earlier in the year. Drought conditions projected to become more frequent.

	2090: Increase in PED of 60-100mm.	**2090:** Increase in PED of 100-150 mm. Low river flow thresholds to be reached earlier in the year (>40days earlier than present). Drought probability up 50-70%. Time spent in drought to increase 5-20%.
Frost, snow and ice cover	**2040:** Decrease of 10-25 frost days.	**2040:** Decrease of 10-25 frost days.
	2090: Decrease of 10-25 frost days.	**2090:** Decrease of 25-50 frost days for central North Island. Many areas frost-free.
Storminess and extreme winds	**2040**: 0-2% decrease in extreme wind. Intensity of (ex)tropical cyclones projected to increase.	**2040:** 0-2% decrease in extreme wind. The most severe ex-tropical cyclones are expected to be stronger.
	2090: 1-4% decrease in extreme wind. Frequency of extreme wind is likely to increase in winter and decrease in summer. Intensity of (ex)tropical cyclones projected to increase.	**2090:** 2-4% decrease in extreme wind. The most severe ex-tropical cyclones are expected to be stronger.
Sea level rise	**2090:** 0.36–0.71m sea level rise	**2090:** 0.53–0.98m sea level rise

3.1.2 Zone 2: Western lower North Island (Te Ika ā Māui)

Zone 2 covers Taranaki to Wellington (Te Whanganui-a-Tara) and includes National Park, southern Lake Taupō, and the regions of Taranaki, Manawatū–Whanganui (Horizons) and Wellington.

Table 3-2: Climate variables for the Wester Lower North Island (Zone 2) for time periods 2040-2050 and 2090-2100 for RCPs 4.5 and 8.5.

Changes	RCP 4.5	RCP 8.5
Air temperatures	**2040**: Annual average air temp to increase 0.7-0.9˚C. Increase of 5-15 more hot days/year (>25˚C).	**2040**: Annual average air temp to increase 0.8-1.1˚C. Increase of 15-20 more hot days/year (>25˚C).
	2090: Annual average air temp to increase 1.3-1.4˚C. Increase of 5-25 more hot days/year (>25˚C).	**2090**: Annual average air temp to increase 2.8-3.1˚C. Increase of 30-40 more hot days/year (>25˚C).
Mean rainfall	**2040**: Minimal change in annual rainfall, most change seen at seasonal scale. Reduction in rainfall in winter and spring, and small increases in summer.	**2040**: Minimal change in annual rainfall. Largest increase in winter.

	2090: Minimal change in annual rainfall. Largest rainfall increase in winter (e.g. +5% for Whanganui).	**2090**: Annual rainfall increases. Small decreases in spring, summer and autumn, and large increase in winter (10-20%).
Rainfall extremes: dry days	**2040:** 0-8 more dry days/year.	**2040:** 0-8 more dry days/year.
	2090: 0-8 more dry days/year.	**2090:** 5-15 more dry days/year - largest increase across Mt Taranaki region.
Rainfall extremes: very wet days (99th percentile days)	**2040:** No significant change	**2040:** No significant change
	2090: No significant change	**2090:** 5-10% increase along coastal areas of zone 2.
Potential Evapotranspiration Deficit (PED)	**2040:** Increased PED of 0-100 mm. Low river flow thresholds reached earlier in the year.	**2040:** PED increase of 0-100 mm. Low river flow thresholds reached earlier in the year. Drought conditions projected to become more frequent.
	2090: Increase in PED of 25-150 mm.	**2090:** Increase in PED of 50-100 mm. Low river flow thresholds to be reached earlier in the year (> 40 days earlier than present).
Frost, snow and ice cover	**2040:** Decrease of 10-25 frost days/year.	**2040:** Decrease of 10-25 frost days/year.
	2090: Decrease of 10-25 frost days/year.	**2090:** Decrease of 25-50 frost Days/year for central North Island. Many areas frost-free.
Storminess and extreme winds	**2040**: Up to 10% increase in extreme wind. Intensity of (ex)tropical cyclones projected to increase.	**2040:** Up to 10% increase in extreme wind. The most severe ex-tropical cyclones are expected to be stronger.
	2090: Intensity of (ex)tropical cyclones projected to increase.	**2090:** The most severe ex-tropical cyclones are expected to be stronger.
Sea level rise	**2090:** 0.36–0.71m sea level rise	**2090:** 0.53–0.98m sea level rise

3.1.3 Zone 3: Eastern lower North Island (Te Ika ā Māui)

Zone 3 extends from Hicks Bay (Wharekahika) to Palliser Bay (Te Waha o te Ika ā Māui) and back to the Ruahine and Kaweka ranges, and includes Gisborne, Hawke's Bay and the Wairarapa catchment of Wellington.

Table 3-3: Climate variables for the Easter Lower North Island (Zone 3) at time periods 2040-2050 and 2090-2100 for RCPs 4.5 and 8.5.

Changes	RCP 4.5	RCP 8.5
Air temperatures	**2040**: Annual average air temp to increase 0.7-0.9˚C. Increase of 5-15 more hot days/year (>25˚C).	**2040**: Annual average air temp to increase 0.8-1.1˚C. Increase of 5-25 more hot days/year (>25˚C).
	2090: Annual average air temp to increase 1.3-1.4˚C. Increase of 5-25 more hot days/year (>25˚C).	**2090**: Annual average air temp to increase 2.8-3.1˚C. Increase of 30-40 more hot days/year (>25˚C).
Mean rainfall	**2040**: Minimal change in annual rainfall, most change seen at seasonal scale. Reduction in rainfall in winter and spring, and small increases in summer.	**2040**: Small reduction in annual rainfall. Largest decreases in winter and spring.
	2090: Minimal change in annual rainfall, most change seen at seasonal scale. Small decrease in annual rainfall. Largest decrease in winter and spring (e.g., spring, -6% Gisborne, -5% Napier).	**2090**: Annual rainfall increases. Small decreases in spring, summer and autumn. Largest increase in winter (10-20%) projected.
Rainfall extremes: dry days	**2040:** 5-8 more dry days/year.	**2040:** 5-8 more dry days/year.
	2090: 5-15 more dry days/year.	**2090:** 10-20 more dry days/year.
Rainfall extremes: very wet days (99th percentile days)	**2040:** No significant change	**2040:** No significant change
	2090: No significant change	**2090:** 10% increase for South Coast, Hawkes Bay, East Cape areas.
Potential Evapotranspiration Deficit (PED)	**2040:** Increased PED of 50-100 mm. Annual PED exceeding 300 mm (very dry conditions) increases throughout the region, except for highest Tararua Range altitudes.	**2040:** Increased PED of 50-100 mm. Annual PED exceeding 300mm (very dry conditions) increases throughout the region, except for highest Tararua Ranges.

	2090: PED 100-150 mm for most areas. The annual PED exceeding 300 mm (very dry conditions) increases throughout the region, except for highest Tararua Range altitudes.	**2090:** PED 100-150mm for most areas. The annual PED exceeding 300 mm (very dry conditions) increases throughout the region, except for highest Tararua Range. Drought probability up 50-70%. Time spent in drought increases 5-20%
Frost, snow and ice cover	**2040:** Decrease of 10-25 frost days/year.	**2040:** Decrease of 10-25 frost days/year
	2090: Decrease of 10-25 frost days/year.	**2090:** Decrease of 25-50 frost Days/year for central North Island. Many areas frost-free. Snow days/year reduce by 30 days/year or more. Tararua Ranges will experience at least 60 fewer nights >5˚C
Storminess and extreme winds	**2040**: Extreme wind speeds increase up to 10%. Intensity of (ex)tropical cyclones projected to increase.	**2040:** Extreme wind speeds increase up to 10%. Frequency of extreme winds is likely to increase in winter and decrease in summer. Intensity of (ex)tropical cyclones projected to increase.
	2090: The most severe (ex)tropical cyclones are expected to be stronger.	**2090:** The most severe (ex)tropical cyclones are expected to be stronger. Frequency of extreme winds is likely to increase in winter and decrease in summer
Sea level rise	**2090:** 0.36–0.71m sea level rise	**2090:** 0.53–0.98m sea level rise

3.1.4 Zone 4: Northern South Island (Te Wai Pounamu)

Zone 4 covers Marlborough (from Kaikōura north), Nelson (Whakatū) and around to Punakaiki on the West Coast. Includes, and Tasman, Nelson, Marlborough and Buller District.

Table 3-4: Climate variables for the Northern South Island (Zone 4) at time periods 2040-2050 and 2090-2100 for RCPs 4.5 and 8.5

Changes	RCP 4.5	RCP 8.5
Air temperatures	**2040**: Annual average air temp to increase 0.7-0.9˚C. Increase of 0-15 more hot days/year (>25˚C).	**2040**: Annual average air temp to increase 0.8-1.1˚C. Increase of 0-10 more hot days/year (>25˚C). Largest increase in Marlborough valleys.
	2090: Annual average air temp to increase 1.3-1.4˚C. Increase of 5-20 more hot days/year (>25˚C). Largest increase in Marlborough valleys.	**2090**: Annual average air temp to increase 2.8-3.1˚C. Increase of 5-35 more hot days/year (>25˚C). Largest increase in Marlborough/Tasman valleys.
Mean Rainfall	**2040**: Minimal change in mean annual rainfall; most changes predicted at seasonal scale. Reduction in rainfall in winter and spring, and small increases in summer.	**2040**: Minimal change in mean annual rainfall. Increase in winter of 15-20% (interior areas); and decrease in summer of 5-15%.
	2090: Small increase in annual rainfall. Largest increase for winter (e.g., Nelson +7%).	**2090**: Annual rainfall increase of 5-10%. Significant increases in winter of >20%.
Rainfall extremes: dry days	**2040:** -5 to +5 change in dry days/year.	**2040:** -5 to +5 change in dry days/year.
	2090: 0-10 more dry days/year.	**2090:** 5-20 more dry days/year. Largest increases in Kaikoura Ranges
Rainfall extremes: very wet days (99th percentile days)	**2040: ~**10% increase in Marlborough sounds region. No change other areas.	**2040: ~**10% increase in Marlborough Sounds region. ~5% decrease in inland Marlborough region.
	2090: ~10% increase in Marlborough Sounds region. ~5% decrease in inland Marlborough region.	**2090:** 10-20% increase across the whole region. Largest increase in Marlborough Sounds.
Potential Evapotranspiration Deficit (PED)	**2040:** Increased PED of 50-100 mm for most areas, 100-150 mm for inland valleys. Low river flow threshold reached earlier in the year.	**2040:** Increased PED of 50-100 mm for most areas, 100-150 mm for inland valleys. Low river flow threshold reached earlier in the year.
	2090: Increase in PED of 50-100 mm for most areas, 100-150 mm for inland valleys. Low river flow threshold reached earlier in the year.	**2090:** Increase in PED of 50-100 mm for most areas, 100-150 mm for inland valleys. Low river flow threshold reached earlier in the year.
Frost, snow and ice cover	**2040:** Decrease of 10-25 of frost days for most of South Island. Largest change in absolute snow amounts is along the Main Divide of the Alps. Greatest percentage change is at lower altitudes. Snowline elevation (exceeding 3 months): lifts from 1550 m to between 1550 to 1750 m.	**2040:** Decrease of 25-50 frost days for high elevations in Southern Alps.

	2090: Decrease of 10-25 of frost days for most the South Island and a decrease of 25-50 for high elevations in the Southern Alps. Largest change in absolute snow amounts is along the Main Divide of the Alps. Greatest percentage change is at lower altitudes. Snowline elevation (exceeding 3 months): lifts from 1550 m to between 1700 to 2000 m.	**2090:** Decrease of 50-75 frost days for Southern Alps. Peak snow accumulation projected to decline by 32-79% at 1000 m and 6-51% at 2000m.
Storminess and extreme winds	**2040**: Extreme wind speeds increase up to 10%. Intensity of (ex)tropical cyclones projected to increase	**2040:** Extreme wind speeds increase up to 10%. Frequency of extreme winds is likely to increase in winter and decrease in summer. Intensity of (ex)tropical cyclones projected to increase.
	2090:. The most severe ex-tropical cyclones are expected to be stronger. Intensity of (ex)tropical cyclones projected to increase.	**2090:** The most severe ex-tropical cyclones are expected to be stronger. Frequency of extreme winds is likely to increase in winter and decrease in summer. Intensity of (ex)tropical cyclones projected to increase. Occurrence conditions conducive to storm development is projected to increase by 3-6%, relative to the period 1970-2000
Sea level rise	**2090:** 0.36–0.71m sea level rise	**2090:** 0.53–0.98m sea level rise

3.1.5 Zone 5: Eastern South Island (Te Wai Pounamu)

Zone 5 is from Kaikōura to Owaka (South Otago) and includes Central Otago and the MacKenzie Basin including Lakes Tekapo to Ōhau to the east of the Southern Alps, as well as the West Coast, inland Otago and Southland.

Table 3-5: Climate variables for the Eastern South Island (Zone 5) at time periods 2040-2050 and 2090-2100 for RCPs 4.5 and 8.5.

Changes	RCP 4.5	RCP 8.5
Air temperatures	**2040**: Annual average air temp to increase 0.7-0.9˚C. Increase of 5-15 more hot days/year (>25˚C).	**2040**: Annual average air temp to increase 0.8-1.1˚C. Increase of 5-25 more hot days/year (>25˚C). Highest in Canterbury Plains.
	2090: Annual average air temp to increase 1.3-1.4˚C. Increase 5-25 more hot days/year (>25˚C). Highest in Canterbury Plains.	**2090**: Annual average air temp to increase 2.8-3.1˚C. Increase 25-40 more hot days/year (>25˚C).

Mean Rainfall	**2040**: Negligible change in annual rainfall, most change seen at seasonal scale. Small increases in autumn-winter; small decreases in winter for Canterbury.	**2040**: Small increase in annual rainfall (e.g., +6% for Tekapo). Largest increase for winter (e.g.,+14% for Tekapo); small decreases for winter (-4% for Christchurch and Hanmer Springs).
	2090: Minimal change in annual rainfall. Increase in winter of 5-10% (most areas); and decreases for interior areas in other seasons.	**2090**: Annual rainfall increase of 5-10% (most areas). Dominated by winter increases of >10%.
Rainfall extremes: dry days	**2040:** 0-5 fewer dry days/year on Canterbury plains and coastal areas. 0-10 more dry days in inland areas.	**2040:** 0-5 fewer dry days/year on Canterbury plains and coastal areas. 0-10 more dry days in inland areas.
	2090: 0-5 days/year reduction in dry days on Canterbury plains and coastal areas. 5-15 more dry days in inland areas.	**2090:** 0-10 fewer dry days/year on the coast and plains, 10-20 more dry days/year in inland areas.
Rainfall extremes: very wet days (99th percentile days)	**2040:** -5% to +5% change in extreme precipitation. Largest decrease across Eastern Otago regions.	**2040:** 5% to +5% change in extreme precipitation. Largest decrease across Eastern Otago regions.
	2090: -5% to +15% change in extreme precipitation. Largest increase across inland Southern Otago.	**2090:** 5 -20% increase in extreme precipitation. Largest increase across Southern Otago.
Potential Evapotranspiration Deficit (PED)	**2040:** Increase in PED of 50-100mm for lowland and coastal areas, 100-150mm for inland areas. Low river flow threshold reached earlier in the year.	**2040:** Increase in PED of 50-100mm for lowland and coastal areas, 100-150mm for inland areas. Low river flow threshold reached earlier in the year.
	2090: Increase in PED of 50-100 mm for lowland and coastal areas, 100-150 mm for inland areas. Low river flow threshold reached earlier in the year.	**2090:** Increase in PED of 50-100 mm for inland areas, 150-200 mm increase at high elevations. Low river flow thresholds to be reached earlier in the year (>40 days earlier than present).
Frost, snow and ice cover	**2040:** Decrease of 10-25 of frost days for most of South Island. Largest change in absolute snow amounts is along the Main Divide of the Alps. Greatest percentage change is at lower altitudes. Snowline elevation (exceeding 3 months): lifts from 1550 m to between 1550 to 1750 m.	**2040:** Decrease of 25-50 frost days for high elevations in Southern Alps.
	2090: Decrease of 10-25 frost days for most the South Island and a decrease of 25-50 for high elevations in the Southern Alps. Largest change in absolute snow amounts is along the Main Divide of the Alps. Greatest percentage change is at lower altitudes. Snowline elevation (exceeding 3 months): lifts from 1550 m to between 1700 to 2000 m.	**2090:** Decrease of 50-75 frost days for Southern Alps. Peak snow accumulation projected to decline by 32-79% at 1000 m and 6-51% at 2000 m.

Storminess and extreme winds	**2040**: Extreme wind speeds increase up to 10%. Intensity of (ex)tropical cyclones projected to increase	**2040:** Extreme wind speeds increase up to 10%. Frequency of extreme winds is likely to increase in winter and decrease in summer. Mean westerly flow of wind to increase ~20% in spring and ~70% in winter; decrease by ~20% in summer and autumn.
	2090: The most severe ex-tropical cyclones are expected to be stronger. Intensity of (ex)tropical cyclones projected to increase.	**2090:**. The most severe ex-tropical cyclones are expected to be stronger. Frequency of extreme winds is likely to increase in winter and decrease in summer. Intensity of (ex)tropical cyclones projected to increase. Occurrence conditions conducive to storm development is projected to increase by 3-6%, relative to the period 1970-2000.
Sea level rise	**2090:** 0.36–0.71m sea level rise	**2090:** 0.53–0.98m sea level rise

3.1.6 Zone 6: Western and southern South Island (Te Wai Pounamu)

Zone 6 covers the West Coast, Fiordland, Southland and Stewart Island (Te Punga o Te Waka ā Māui) and includes the Southern Alps, southern lakes, Canterbury and Otago.

Table 3-6: Climate variables for the Western and Southern South Island (Zone 6) at time periods 2040-2050 and 2090-2100 for RCPs 4.5 and 8.5.

Changes	RCP 4.5	RCP 8.5
Air temperatures	**2040**: Annual average air temp to increase 0.7-0.9˚C. Increase 0-20 more hot days/year (>25˚C). Highest in Central Otago; lowest in Fiordland.	**2040**: Annual average air temp to increase 1.3-1.4˚C. Increase 0-25 more hot days/year (>25˚C). Highest in Central Otago.
	2090: Annual average air temp to increase 1.3-1.4˚C. Increase 0-28 more hot days/year (>25˚C). Highest in Central Otago.	**2090**: Annual average air temp to increase 2.8-3.1˚C. Increase 0-50 more hot days/year (>25˚C). Highest in Mackenzie; lowest in Fiordland.
Mean Rainfall	**2040**: Small increase in annual rainfall. Larger increase in winter (e.g., +10% for Hokitika).	**2040**: Increase in annual rainfall of +5-15%. Largest increase in winter of >+20%
	2090: Increase in annual rainfall. Largest increase in winter (e.g., +16% for Hokitika and +19% for Queenstown).	**2090**: Annual rainfall increase (e.g., >+20% for West Coast). Increases in all seasons, especially in winter (>+40% in some areas).

Rainfall extremes: dry days	**2040:** 5-10 fewer dry days/year on the central West Coast. Increase of 5 dry days per years for Kahurangi National Park and Southland.	**2040:** 5-10 fewer dry days/year on the central West Coast. Increase of 5 dry days per years for Kahurangi National Park and Southland.
	2090: 0-5 fewer dry days/year in the East, 5-15 fewer dry days/year in the West, and 0-5 more dry days in the interior areas.	**2090:** 15-20 fewer dry days/year on West Coast. 5-15 more dry days/year for much of Southland and Otago.
Rainfall extremes: very wet days (99th percentile days)	**2040:** 0-5 % increase in extreme precipitation. Largest increase Southland.	**2040:** 0-10 % increase in extreme precipitation. Largest increase Southland.
	2090: 0-5 % increase in extreme precipitation. Largest increase Southland.	**2090:** 15-20 % increase in extreme precipitation. Largest increase Southland.
Potential Evapotranspiration Deficit (PED)	**2040:** Increase in PED of 0-50 mm in most areas. Low river flow threshold reached later in the year for western and southern areas.	**2040:** Increase in PED of 0-50 mm in most areas. Low river flow threshold reached later in the year for western and southern areas.
	2090: Increase in PED of 0-50mm for most areas, 50-100 mm increase for interior areas. Low river flow threshold reached later in the year for western and southern areas.	**2090:** Increase in PED of 0-50mm for most areas, 100-150 mm increase for interior areas. Low river flow thresholds to be reached later in the year for western and southern areas.
Frost, snow and ice cover	**2040**: Decrease of 10-25 of frost days for most of South Island. Largest change in absolute snow amounts is along the Main Divide of the Alps. Greatest percentage change is at lower altitudes. Snowline elevation (exceeding 3 months): lifts from 1550 m to between 1550 to 1750 m.	**2040:** Decrease of 25-50 frost days for high elevations in Southern Alps.
	2090: Decrease of 10-25 of frost days for most the South Island and a decrease of 25-50 for high elevations in the Southern Alps. Largest change in absolute snow amounts is along the Main Divide of the Alps. Greatest percentage change is at lower altitudes. Snowline elevation (exceeding 3 months): lifts from 1550m to between 1700 to 2000m.	**2090:** Decrease of 50-75 frost days for Southern Alps. Peak snow accumulation projected to decline by 32-79% at 1000m and 6-51% at 2000m.
Storminess and extreme winds	**2040**: Extreme wind speeds increase up to 10%. Intensity of (ex)tropical cyclones projected to increase.	**2040:** Extreme wind speeds increase up to 10%. Frequency of extreme winds is likely to increase in winter and decrease in summer. Mean westerly flow of wind to increase ~20% in spring and ~70% in winter; decrease by ~20% in summer and autumn.

		Intensity of (ex)tropical cyclones projected to increase.
	2090: The most severe ex-tropical cyclones are expected to be stronger. Intensity of (ex)tropical cyclones projected to increase.	**2090:**. The most severe ex-tropical cyclones are expected to be stronger. Frequency of extreme winds is likely to increase in winter and decrease in summer. Intensity of (ex)tropical cyclones projected to increase. Occurrence conditions conducive to storm development is projected to increase by 3-6%, relative to the period 1970-2000.
Sea level rise	**2090:** 0.36–0.71m sea level rise	**2090:** 0.53–0.98m sea level rise

3.2 Risk and opportunities for primary producers under a changing climate

The risks to the primary sector that arise from the impacts of climate change are numerous and pervasive. However, change also brings opportunity. Table 3-7 captures a draft set of critical risks facing the sector and provides a list of questions for primary producers to answer to better understand what that risk may mean for them, at their place. The table is organised around the interests of farmers and growers rather than linking directly with the suite of climate change variables presented in the proceeding tables. Finally, the final column in the table suggests ways that the risk may be tracked over time as the climate changes to help inform adaptation decisions. Please note that this table is not linked to any single zone.

We suggest this draft table is tested and further developed with the aid of representatives from the primary sector. This can then lead to the creation of a complete table for each zone if this is desirable. However, given that many of the regions faced the same sorts of impacts a single table may be adequate.

Table 3-7: The critical risks facing the Primary sector as a result of a changing climate.

What are the risks that a changing climate may cause?	What are the key questions we will need to consider?	How do we know change is happening? What should we be measuring?
Plant health and productivity Increased humidity presents a risk to crop health Seasonal changes in rainfall through the year affects plant growth and development Increased incidence of floods, storm and windiness may cause increased damage to pasture/crops/trees – especially near critical times (e.g., fruit set or harvesting)	Will my crops be affected by changes in the timing of rainfall? Can I still manage my water supply to meet the plants' needs? How and when are my crops affected by humidity and temperature change? Are there any new or existing plant diseases that could affect my crops?	Monitor Local Weather information for warnings of events, humidity and heat waves. Track the incidence and cost of disease and damage caused by humidity across seasons Monitor local temperature changes – how close is it to the upper tolerance range of my crops

Increased numbers of pests and arrival of new pests due to reduced frost and increased temperatures Change in temperature may lead to changes in crop production, timing and quality Changes in temperature may affect the harvesting process and post-harvest storage Sea level rise will increase coastal inundation in lowland areas causing plants saltwater stress. Increased storm activity (high winds and hail) damaging horticultural crops <u>Opportunities:</u> Reduced chance of frost damage as days of frost decrease Increases in temperature and humidity may allow new crop options to become available	Are there any actions I can take to reduce the impact of humidity, disease and pest? What are the tolerance limits of my current crops - Do I have the best variety or would another be better? What pests should I be looking out for? What does an increase in salt water concentrations mean for my pasture/crop? What other grass species or crops could work for my place?	
Stock health More days above 25^{O}C may cause animals increased heat stress and decrease in productivity and growth. Flood risk to stock in flood prone paddocks Poor drainage due to changes in groundwater or sea levels may cause increased lameness and poor foot health Warmer temperatures and higher humidity may increase the incidence of disease and infection Higher temperatures and increased incidence of drought may affect feed quality and abundance for stock <u>Opportunities:</u> New breeds may create new markets and products and reduce the health risks	Are my animal likely to suffer from heat stress (access to water, distance walked, available shelter, water supply). Where are the areas on my property where heat stress could occur? Are the areas that could be developed to provide shade for stock and/or wind breaks? Are there places on my property where an extreme event could affect my stock (i.e., flood plain)? What areas on the property are likely to experience water logging? What are the symptoms of disease and infection to look out for and how can I check for these? What are the signs of drought on my property? What is my response plan and when do I activate it? What other stock options do I have?	Monitor weather forecasts for temperatures and warnings of extreme events. Monitor early signals of drought Monitor expenditure of imported/supplemental feed costs

Property based Infrastructure Increased incidence of floods, storm and windiness may cause increased damage to property based infrastructure (i.e., irrigation infrastructure) that affects the properties ability to function or undertake key activities Sea level rise may lead to infrastructure that no longer works as it was intended <u>Opportunities:</u> Careful siting of new infrastructure to ensure longevity	What infrastructure on this property could be damaged by storm events flood or sea level rise? e.g., fences, races, buildings, irrigation units Are there any options to increase the resilience of this property to extreme events? Is there any infrastructure that requires moving to avoid flood damage or sea level rise? Where are "safe" areas on my property for critical infrastructure?	Monitor the performance of the infrastructure and record the frequency of failure
Supporting off farm infrastructure Increased incidence of floods, storm and windiness may cause increased damage to the infrastructure that support the property's day to day operation (e.g., roads, power, factories/packhouses transport systems) Sea Level rise may affect infrastructure that supports the property's day to day operation Increased incidence of floods, storm and windiness and on-going sea level rise may affect the key assets and transport networks required to get my product to market <u>Opportunities:</u> Changing environmental conditions may support new crops	What are the services beyond this property that are necessary to the property operating? Are any of the key roads, power supplies under threat? What will I do during any type of outage? Is there any way to make the property more self-sufficient or cope with any outages? e.g., increased storage capacity How does my product(s) get to market and how could this chain be affected? e.g., port facilities or packing houses, milk tanker pick up routes. Diversification and new products that are less dependent on immediate transport	Monitor the performance of the infrastructure and record the frequency of failure.
Water management? Variable rainfall and increased incidence of drought may affect the continuity of water supply Increased water demand of crops and pasture species may experience increased potential evapotranspiration deficit Changing seasonal rainfall patterns means that water availably may not match demand Increased intense rainfall events may overwhelm existing drainage systems Sea level rise will cause changes in the intrusion of salt water into groundwater	Can I achieve improved water efficiency? Am I able to access additional water – through varying existing consent, or through shared, global consent with neighbours in catchment? How can the deficit between water availability and water demand be managed on this property? Is my water supply at risk of slow salinisation? What can I do about this?	Monitor on-going water demand and water use. Plan irrigation events carefully and link to weather forecasting and soil moisture deficit Monitor effectiveness of drainage networks – how many nuisance flood events have I had? Monitor salt water concentrations in the water supply

and the saltwater wedge will extend up rivers. This will affect water quality in some areas Opportunities: Changing environmental conditions may support new crops	How good is my existing drainage network? Are there any actions I can take to manage intense rainfall events? Diversification and new products that are able to cope with changing water availability	
Staff Increased risk to staff due in increased floods, storm and windiness Increase in temperature and days over 25°C could cause heat stress for workers, especially for those undertaking physical labour Opportunities: Warmer (winter) temperatures may increase staff comfort levels during certain tasks	Do I have a health and safety plan for adverse events? Is it too hot to undertake physical activities outside? How hot is too hot and how else can the activities be undertaken (i.e., cooler times of the day)	Monitor local weather warnings Monitor temperatures, how many hot days are there in a year. Monitor staff wellbeing/absenteeism
Farm physical environment Increased frequency of floods, droughts, storm and windiness and on-going sea level rise may impact the physical characteristics of the property	Are there any highly erodible areas on this property that could be affected by extreme events? What action(s) could be taken? Are there any flood prone areas, or places where a waterway could change course?	

3.3 Next Steps

This report has provided regional climate variable tables and a draft set of risks and opportunities for the primary sector for inclusion in the forthcoming primary sector adaptation guidance. We suggest several next steps:

1) The risks and opportunities for the primary sector will need testing and extending with primary sector experts to ensure its complete. In particular, the how do we know things are changing column. The risks and opportunities could then be regionalised if this was desirable.

2) That the He Waka Eka Noa team consider using the risk and opportunities table to underpin:

    a) what thresholds may exist the in the various production systems and what early warning signs (triggers and signals) may provide a warning of change, and

    b) the adaptation options, or posing a set of questions that encourage primary producers to consider and evaluate their own possible options. Questions could be supported by the NIWA Adaptation Tool Box (NIWA 2021).

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