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Executive summary

Quantifying climate change adaptation plans

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This Sustainable Land Management and Climate Change (SLMACC) project "Quantifying climate change adaptation plans" uses kiwifruit and avocado as exemplars of high-value crops. It aims to predict the performance of horticultural crops under climate change, to quantify growers' exposure to climate change, and to model how this exposure is affected by adaptations designed to ameliorate climate impacts.

- We consulted with the avocado and kiwifruit industries, local governments and a development trust to identify climate risks of importance and developed production models to model risks.
- We used the financial concept of value at risk (VaR) as a measure of risk and calculated production VaR and the contributions to VaR from underlying risk factors.
- Production models were calibrated to industry data and used to project impacts on production and VaR under climate change, and to quantify the benefits of adaptations.
- The modelled outcomes indicated differential climate change effects on existing avocado and kiwifruit supply areas, and potential increases in demand for natural resources.
- Although social and economic issues were not explicitly modelled, project outcomes identified the potential to conduct research on these issues in some supply areas.

Value at risk (VaR)

VaR is a risk measure that reflects uncertainty in outcomes and is based on the standard deviation of the outcome variable. It is calculated for a confidence level and expresses the biggest loss within that confidence. VaR is normally calculated in terms of financial outcomes, but in the absence of financial information, we specified VaR in production terms, which allows flexibility in applying VaR calculations to orchards with different cost structures. We calculated VaR for overall production using modelled production outcomes and quantified the separate contributions to VaR from underlying risk variables.

A climate effect may contribute negligibly to VaR while having a big impact on yield. In this context, risk is associated with uncertainty: a consistently deleterious effect is not a risk but a certainty.

Consultations

We consulted with the following organisations on perceived climate change risks and adaptations relating to horticulture: Northland Regional Council, Gisborne District Council, Tairawhiti Trust (Gisborne), Bay of Plenty Regional Council, Western Bay of Plenty District Council, New Zealand Avocado Industry Limited (NZ Avocado) and Zespri International Limited (Zespri).

Water resilience was a key theme that was identified by these discussions. Environmental considerations (especially protection of the environment) by Councils increasingly takes precedence over the water requirements of primary industries, thus growers could be faced with limitations that severely affect their ability to grow crops in the future. Climate change projections indicate that reduced water supply could be exacerbated in some regions by changing rainfall patterns that result in greater risk of drought. There is an inequity between different stakeholders in their access to consented water takes and/or financial resources to invest in water storage options, leaving disadvantaged stakeholders more vulnerable to climate change impacts than others. Māori growers in some areas were identified as particularly disadvantaged and at risk. Possible adaptations for this include more equitable distribution of water rights and use of new cultivars or crops with lesser water requirements, and identification of critical crop survival limits.

There is also a tension between the aspirations of high-value horticultural industries to expand in some areas and pressure on the available resources, as well as pressure on local communities and economies. Investment in high-value crops was often undertaken by enterprises outside the region and involved workers from outside the community, resulting in value not being retained within the region. Monocultures were seen as particularly vulnerable to extreme weather events, and land-use change from a diversity of crops to one or two high-value crops (whether economically driven or climate-change driven) was also regarded as undermining future resilience.

Model calibrations

We obtained data from NZ Avocado on yield for individual avocado orchards for 12 harvest years. We obtained data from Zespri for kiwifruit yield and DM content of fruit, at the level of harvested orchard blocks, for a period of 4 years. The kiwifruit data were available for *Actinidia chinensis* var. *chinensis* ‘Zesy002’ and *A. chinensis* var. *deliciosa* ‘Hayward’ from both organic and conventional orchards. The production data were used to calibrate predictive models for yield in avocado and yield and DM in kiwifruit. In these datasets there was an absence of information on orchard-level management and adaptation practices that would affect productivity. Thus, we needed to make several assumptions about management and adaptation practices during the model calibration process, and we were not able to estimate the impact of adaptations and management practices directly from the data.

Avocado yield was fitted to 5000 measurements from 428 orchards, with an R^2 of 0.54 and adjusted R^2 of 0.34. Kiwifruit yield was fitted to 29,000 measurements from 3100 orchards model with an R^2 of 0.46 and an adjusted R^2 of 0.40. Kiwifruit DM was fitted to the same number of measurements with R^2 value of 0.71 and an adjusted R^2 value of 0.67. The relatively low R^2 values reflect the unknown variation between orchards in management and adaptation practices.

Adaptations that were modelled

For avocado yield, the adaptations that we modelled were irrigation to ameliorate low soil moisture, frost protection, covers to ameliorate non-optimal temperature and barriers against wind damage.

For kiwifruit yield, the adaptations that we modelled were irrigation to ameliorate low soil moisture, frost protection and covers to ameliorate non-optimal temperature. The use of budbreak enhancers for inadequate chill are reflected in the differences between conventional and organic orchards and were not modelled explicitly. We did not model adaptations specifically for maintaining DM. However, we modelled the side effect on DM from adaptations (irrigation and covers) to maintain yield.

Climate change projections

Projections were obtained using simulated climate data for three climate-change scenarios, referred to as Representative Concentration Pathways (RCPs): RCP 4.5, RCP 6.0 and RCP 8.5.

Summary of mid-century projections for avocado

- Production was projected to increase under all RCPs by the mid-century.

  The greatest benefit will likely be in the Bay of Plenty, and Whangarei will become more productive than the Far North. VaR will decrease for Bay of Plenty but increase elsewhere. VaR relative to yield will increase for the Far North but decrease elsewhere.

- Frost will continue to be an issue for the Bay of Plenty and the “Rest of NZ” supply area, but the threat will be decreased compared with historical threats, and more so for higher RCPs.

  Frost protection could save 1.9 t/ha (RCP 8.5) to 2.7 t/ha (RCP 4.5) of production in the Bay of Plenty, potentially increasing pressure on water takes or energy consumption.

- The impact of irrigation is only very slightly affected by RCP, and irrigation could improve avocado yields by 0.6 to 2.7 t/ha depending on region.

  Irrigation demands are likely to be the greatest in the Far North and least in the Bay of Plenty.

- Disease risk is projected to increase, and more so with increasing RCP.

- Windbreaks would increase yields depending on their design and effectiveness.

  Increases in yield from 2.5–5 t/ha could be realised in the Bay of Plenty and Far North, and from 1.3–2.5 t/ha in the “Rest of NZ” and Whangarei. The impacts of wind were only very slightly affected by RCP.

- Warmth covers could substantially improve yield in some areas.

  Yield increases of 10, 11 and 8 t/ha could be obtained in the Bay of Plenty under respectively RCP 4.5, 6.0 and 8.5. Yield increases of 2.1 to 3.5 t/ha could be obtained in the “Rest of NZ” and Whangarei. Little benefit from covers is expected for Far North.

- However, both windbreak and warmth adaptations will increase VaR as well as yield.

  This could incentivise further adaptations to remaining risks, which could increase pressure on resources.

- Climate change will provide incentives to increase avocado plantings in all supply areas under all three RCPs. The outlook for the Bay of Plenty is especially favourable in this respect.

Summary of mid-century projections for kiwifruit

- Projected climate change impacts on yield were highly variable with region, but patterns were similar between the RCPs considered, and between conventional and organic growing methods:

  For 'Hayward', the kiwifruit supply areas Motueka, Nelson, Maketu and Golden Bay are projected to be consistently top for yield. For 'Zesy002', the supply areas Nelson, Motueka and Maketu are projected to be consistently top for yield. For both cultivars, the largest increases in yield are projected to occur in Nelson, Motueka and Wanganui, while the largest declines in yield are projected to occur in Auckland, Kerikeri and Whangarei.

  Opotiki and Whakatane are projected to become productive to the extent that an increased pressure on resources might occur due to expansion of plantings.

  VaR for yield is projected to decline in most areas, with most instances of increase in VaR being slight. However, small to moderate increases in risk are expected for 'Hayward' in Nelson.

- DM is projected to increase for all areas under all RCPs, with increases from 0.2% to 0.9% expected for 'Hayward' and 0.1% to 0.8% expected for 'Zesy002'. Changes in VaR for DM are projected to be insignificant.

  For 'Hayward', the supply areas Auckland, Waikato, Kerikeri and Katikati are projected to consistently be top for DM of fruit. For 'Zesy002', the supply areas Auckland, Waikato and Katikati are projected to consistently be top for DM.

- Irrigation is projected to significantly increase yield in many areas, under all RCPs, and is expected to be more beneficial for 'Zesy002' orchards than 'Hayward' orchards.

  The areas with the greatest expected benefit include the Hawke's Bay, Poverty Bay, Motueka, Nelson and "Wanganui" supply areas. However, the impacts in some supply areas are not hugely different from historical patterns, while in other areas such as Auckland, the benefit of irrigation decreases with warming climates, likely due to lack of chill.

- Expectedly, frost risk is projected to decrease, and more so with increasing RCP. However, frost protection is expected to remain beneficial and increase yield in the South Island and some North Island areas.

  Most benefit is expected in Nelson, Waikato, Motueka, Opotiki, Hawke's Bay and "Wanganui".

- Adaptations to maintain optimal temperature are projected to provide little benefit.

  The least benefit is expected for RCP 6.0 under which mean growing temperatures would be closest to optimal. Under RCP 4.5, covers to increase warmth could provide some benefit during the growing season. Under RCP 8.5, photo-selective nets to exclude certain frequencies and reduce effective temperatures could provide some benefit.

Future steps

Our modelling of adaptations to risks showed how benefits would vary with location and over time, as climates changed. Projections of how risks would evolve were generally in line with trends of warming temperature and declining wind speed, and showed the effect of different rainfall patterns.

This could provide guidance for considering climate change risks and adaptations, by providing an insight into the more pressing risks, thus identifying which adaptations are most likely to be required in the future. By modelling the effect that an adaptation would have, rather than the adaptation itself, we provided a more general assessment that allows a range of different adaptations to be considered. Based on the potential benefits of an adaptation in terms of production saved, growers and industry can decide on whether to implement an adaptation or to choose an alternative strategy.

Areas where resource-hungry adaptations (like irrigation) are likely to provide the most benefit are more likely to experience an increase in pressure on natural resources. Our projections have identified the current growing regions where this is most likely to occur, thus providing forewarning of increased competition for resources, which could be exacerbated by parallel increases in non-horticultural demands. In these areas, stakeholders who are currently disadvantaged by lack of equity or resource rights could be further disadvantaged.

Thus, there would be benefit in studying potential changes to financial streams, and pressures on infrastructure and natural resources that would be associated with the risk and benefits of adaptations that we have modelled. The impact of the land-use change could affect employment opportunities either negatively or positively, depending on the crop ecology, and thus implications for the local economy and society. Differences in the ability to obtain financial resources between stakeholders would determine their ability to invest in the new opportunities or to adapt in response to worsening conditions. This highlights the research avenues on how to assist disadvantaged stakeholders.

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1 Introduction

New Zealand's horticultural industry is a significant export earner, and in 2021 generated NZ$6.68 billion of export revenue annually (11.1% of NZ's total merchandise exports) along with a strong domestic market of NZ$3.7 billion (Fresh Facts 2021). Horticultural exports have tripled in value over the last two decades and both the kiwifruit and avocado industries are actively engaged in expansion of their sectors. For example, the New Zealand Avocado Industry Limited (NZ Avocado) planned to increase avocado orchard plantings to 10,000 ha, in order to increase sales by $1billion by 2040 (https://issuu.com/apn_mediaservices/docs/btg_avocadofeature_jan). Zespri International Limited (Zespri) forecasted NZ$4.5 billion in kiwifruit exports by 2025 (https://www.nzkgi.org.nz/wp-content/uploads/2018/12/2018-Kiwifruit-Book.pdf). If expansion of these industries involved replacement of high-emission industries, then that would accord with the need to accelerate the change of land use to low emissions, profitable horticulture that was highlighted in the Productivity Commission's report on a Low Emissions Economy (NZPC 2018).

However, horticultural production systems are strongly regulated by climate and weather pattens, which influence plant growth and fruit development through temperature and rain (Hatfield & Prueger 2015; Snyder 2017), indirectly through soil processes (Orwin et al. 2015), as well as affecting the prevalence of pests and disease prevalence (Jones 2016; Trębicki et al. 2017; Wakelin et al. 2018). This poses a challenge for consistent production of high-quality fruit. Additionally, New Zealand's primary sector is potentially vulnerable to climate-change-induced declines in yield and quality, with flow-on profitability and socio-economic impacts (Hopkins et al. 2015; Ausseil et al. 2016; Cradock-Henry et al. 2019). Conversely, climate change could open up new areas for agricultural endeavours with economic benefits (Hall et al. 2018).

New Zealand has experienced changing rainfall patterns and a 0.9°C increase in average annual temperature over the last century, these trends are expected to continue into the future (Kim 2013) and are anticipated to have significant impacts (Manning et al. 2015). Because New Zealand has a diversity of climatic systems that will evolve in different ways under climate change, it is important to understand how possible impacts on different horticultural systems will vary with geographical location (Hall et al. 2018). Some regions may become less suitable while other regions might improve over time, and since horticulture is distributed across niche locations across the country, this poses both threats and opportunities (Clothier et al. 2012).

Projecting climate change impacts on horticulture serves to stimulate adaptation responses to ameliorate damage or exploit beneficial opportunities (Glenn et al. 2013). Adaptations can be considered within a tri-level scheme of (i) tactical adaptations which involve modifying production practices within the current system, (ii) strategic adaptations that involve a substantive modification to the current production system, and (iii) transformational adaptations that change the spatial footprint of the production system (Clothier et al. 2012). Strategic and transformational adaptations provide, respectively, medium and longer terms benefits under continual climate change, while tactical adaptions which are incremental in nature provide only short-term benefits (Glenn et al. 2013), but are the most commonly adopted (Rickards & Howden 2012). Reliance on tactical adaptation may even may lead production systems into sub-optimal trajectories that are unable to deal with rapid shifts and tipping points related to climate change (Vermeulen et al. 2018).

Adaptation decisions can be complicated by a number of socio-economic considerations (such as labour availability, market access and proximity to processing plants), long re-establishment periods for perennial crops, and can involve regulatory and economic constraints and trade-offs (Glenn et al.

2013). Growers are often stimulated by increased availability of information, and motivated by improving financial positions (Li et al. 2017). In some situations, adaptations that reduce climate risk may not be the most financially optimal option; insuring a high-yield, high-climate risk cultivar may increase the long-term wealth and resilience of growers, compared with an adaptation strategy that trades yield for reduced climate risk (Linnerooth-Bayer & Hochrainer-Stigler 2015). Key considerations also include timeliness and motivation, and grower adaptation practices may be reactive in nature, for example responding only to severe weather events and drought rather than to incremental change (Li et al. 2017). This could pose a threat to long-term viability and result in growers exiting the industry. For example, West (2019) noted that cultivar replacement results in an irreversible revenue loss in the years taken for perennial crops to mature, and thus growers exposed to a changing climate can be incentivised against switching to more suitable cultivars if prices are high and rates of yield reduction are moderate, until it is too late for adaptive changes.

Forecasting prices, production and degradation rates can provide increased confidence in strategic adaptation decisions because economic and climatic conditions can interact to adversely affect mistime investment decision (West 2019). It is important to consider both the impact and probability of events/occurrences when framing risk, and to reflect “autonomous” adaptations, grower roles in decision-making and future technologies in assessments (Challinor et al. 2018). The insurance industry is likely to be integral in managing future climate-related losses, and would also benefit if assessments were based on future climate projections and quantified climate risk within confidence bounds (Linnerooth-Bayer & Hochrainer-Stigler 2015).

In this Sustainable Land Management and Climate Change (SLMACC) project “Quantifying climate change adaptation plans”, we have developed the capability to support growers, industry, local government and other organisations by developing methodologies that quantify climate-related risks and opportunities for production systems, project the impacts of climate change on production and production risk under different climate change pathways, and quantify the effectiveness of adaptation plans. We have used kiwifruit and avocado as exemplars of high-value crops. Knowledge of the likelihood of an impact and the potential damage or benefit would allow informed decision making on whether to implement adaptations, and which adaptation strategies are likely to be optimal. Growers would have timely warning for preparation. Growers and industry would thus have information to make decisions that improve the resilience of crop production, which will have flow-on economic and social implications for communities associated with these industries.

In this report, we describe the different steps involved in the development and application of models with climate projection data to i) estimate climate change impacts on production, ii) the climate-risk exposure for growers; and ii) the effect that the adaptations would have on risk exposure.

1.1 Work described in this report

1.1.1 Consultations with stakeholders

We consulted with several organisations to learn their perceptions of climate-related issues, risks and adaptations, and what they considered important in the context of climate change. These included representatives of the avocado and kiwifruit industries (respectively NZ Avocado and Zespri), and local bodies such as the Northland Regional Council, Gisborne District Council, Tairawhiti Trust (Gisborne), Bay of Plenty Regional Council and Western Bay of Plenty District Council. The purpose of these consultations was to identify the types of questions and issues that would be addressed in the

project, and this in turn would inform model development by identifying the model variables and capabilities that were required. We additionally obtained data from NZ Avocado and Zespri in order to calibrate the predictive models developed and used in the project.

1.1.2 Production models

Based on the outcomes of the consultations, we developed models to predict production from avocado and kiwifruit orchards as functions of daily weather inputs and then calibrated these models by using the industry-provided data. These models provide a means to investigate how production would vary under variable weather patterns, and their climate-related variables determine the types of risks that could be modelled and thus investigated.

1.1.3 Modelling risks

In this project, we applied the financial concept of “value at risk” (VaR) as a metric for quantifying the exposure of production to climate effects. In our application in this project, VaR quantifies the maximum loss of production below expected production in any year, for a specified level of confidence. We developed models to calculate VaR in terms of the outputs of the calibrated production models and to attribute the contribution of different risk factors to the overall VaR.

1.1.4 Modelling adaptations

The effect of different adaptations was modelled by appropriately modulating the corresponding input variables to the calibrated models. For each adaptation, expected production and production were calculated, and compared with calculations for expected production and production VaR without adaptations. This allowed the impact of each adaptation to be estimated separately.

1.1.5 Climate change impacts

The impacts of climate change at the mid-century and late-century periods were projected for three different Representative Concentration Pathways (RCPs). Each RCP represents a scenario of future atmospheric greenhouse gas (GHG) concentrations; thus three different levels of global and regional warming were considered. The modelled climate data for the three RCPs were derived from several climate model simulations for periods starting in 1971 and extending to at least 2099. These simulations used a hindcast period of 1971–2005, referred to as “RCP Past”, and data for this period are considered to represent historical weather patterns. Climate change impacts on production and yield are obtained by comparing production and yield calculations using RCP data for a future period with the same calculations using RCP Past data.

1.1.6 Modification of climate data

Synthesis of VCSN-based historical data

Data from NIWA’s Virtual Climate Station Network (VCSN) database were used as a proxy for historical weather data. This dataset was available from 1972 to 2022, although missing wind speed information for the years before 1996. However, we needed a complete dataset for a sufficiently long (ideally 30-year) period between 1972 and 2005, in order to do our climate change impact comparisons. To meet this requirement, we applied change signals to “back-shift" the VCSN data

series for 1997–2022 to 1977 to 2002, to provide the necessary complete dataset ("SLM VCSN" dataset).

Superimposing modelled change signals onto VCSN data

The climate projection (RCP) datasets need to have appropriate statistical agreement with observed data for the historical period if they are to be used for climate change impact studies. This agreement is often carried out by corrections for bias in means and variances, which entails considerable expenditure of time. We took an alternative and expedient approach of extracting climate change signals from the climate projection datasets and superimposing them on the SLM VCSN dataset, to create new RCP datasets ("SLM-VCSN-RCP" datasets) to use in our modelling.

1.1.7 Climate change impacts and adaptation to risk

This was done for mid-century and late-century periods using modelled daily weather data corresponding to three different RCPs. Each RCP represents a scenario of future atmospheric GHG concentrations, thus three different levels of global and regional warming were considered.

The modelled climate data for the three RCPs were derived from several climate model simulations for periods starting in 1971 and extending to at least 2099. These simulations used a hindcast period of 1971–2005, referred to as "RCP Past", and data for this period are considered to represent historical weather patterns. Climate change impacts on production and yield are obtained by comparing production and yield calculations using RCP data for a future period with the same calculations using RCP Past data.

2 Data used

2.1 Observed, historical climate data

We obtained estimates of historical values of daily weather variables for the years 1972–2022 from NIWA's VCSN database that has a grid with a resolution of approximately 5 x 5 km. The VCSN data are daily estimates of weather variables obtained from spatial interpolation of actual observations made at climate stations and span the country (Tait et al. 2006; Tait 2008). As noted in the introduction, this dataset was missing windspeed information from 1972 to 1996.

We used daily data for maximum and minimum temperature, relative humidity (RH), rainfall, solar radiation, wind speed at 10-m elevation, sea-level pressure, and soil moisture. Descriptions of these variables (detailed at https://cliflo.niwa.co.nz/pls/niwp/wh.do_help?id=vcsn_det) are as follows (where "local day" refers to the 24-hour period from midnight):

- Maximum temperature (°C) for each day is the maximum recorded **from** 0900 h local day.
- Minimum temperature (°C) corresponds to the minimum recorded **to** 0900 h local day.
- RH (%) is humidity at 0900 h local day.
- Sea-level pressure is pressure reduced to mean sea level in hPa at 0900 h local day.
- Rain (mm) is total rain in mm from 0900 h local day.
- Soil moisture in mm from 0900 h local day for a standardised soil, calculated from rainfall and evapotranspiration.
- Solar radiation is amount of accumulated global solar radiation in MJ/m2 (MJ m^{-2}) from midnight local day.
- Wind speed is mean wind speed in m/s at 10 m above ground level over 24 h from midnight local day.

2.2 Projected climate data

We reproduce below a description of climate model data from a previous report (Vetharaniam et al. 2021).

The modelled climate data were derived from NIWA's high resolution Regional Climate Model (RCM), which is applied on a domain that encompasses all of New Zealand. When the RCM is run, it is constrained by conditions for the boundary of this domain. In alternative simulations, these 'boundary conditions' were provided by outputs from six CMIP5 (Coupled Model Intercomparison Project (CMIP) Phase 5) global climate models (GCMs): BCC-CSM1.1, CESM1-CAM5, GFDL-CM3, GISS-EL-R, HadGEM2-ES and NorESM1-M. Each was run under four RCPs. Each RCP represents a different scenario of future atmospheric GHG concentrations, thus four different levels of global and regional warming were considered.

The daily RCM data start in 1971 and extend until at least 2099, with the end date of simulations varying with climate model and RCP. Simulations for the period 1971–2005 are considered to be historical simulations and are referred to as 'RCP Past'; for each CMIP5 model, all four RCPs share the same RCP Past dataset. Simulations from 2006 onwards are considered as future simulations. Daily water vapour pressure was supplied in lieu of RH data.

Raw RCM data for precipitation and maximum and minimum temperature had been “bias corrected” so that they would have the same annual mean for 1986–2005 as the corresponding VCSN variables (Ministry for the Environment 2018). Vapour pressure, solar radiation, 10-m wind speed and sea-level pressure were not bias corrected.

2.2.1 SLM RCP datasets

For maximum and minimum temperature, precipitation and RH (calculated from vapour pressure and temperature) we used the SLM RCP datasets that were obtained from the RCP data by further variance and bias corrections performed at the monthly level without affecting the underlying climate change signal (Vetharaniam et al. 2022b).

2.3 Land and soil information

Data were from the Functional Soil Layers (FSL), New Zealand Land Resource Information (NZLRI) and Land Environments of New Zealand (LENZ) databases, which were available via the LRIS portal (https://lris.scinfo.org.nz). These included data on the potential rooting depth (PRD), soil drainage class, land use capability (LUC) class, slope, soil pH, total available water (TAW), which assumes that rooting depth is the minimum of PRD and 0.9 m. These databases contain information for irregular polygons covering the country, a format not readily compatible with the gridded climate data. We had previously sampled the information from these databases onto a grid resolution of approximately 1 x 1 km in a previous SLMACC project (Vetharaniam et al. 2021).

2.4 Production data for used for calibration

2.4.1 Avocado data

Data obtained from New Zealand Avocado provided information for 1720 avocado orchards, spanning the 12 growing years 2009/2010 through to 2020/2021. These data relate to fruit processed through registered packhouses. For each orchard, the following information was provided:

- PPIN (orchard identifier)
- GIS location
- Crop volume (trays harvested)
- Area planted (hectares)
- Yield (t/ha) for the period September to March of the growing year
- Irregular bearing index
- Limited weather data from four meteorological stations from 2017 or later.

Reported crop volumes were harvested in the months September to March of the growing year. The associated fruit thus would have developed from flowers from the preceding year. In New Zealand, the main flowering period is mid-October to mid-November, with floral buds generally initiating in April or May, but possibly as early as March in the western Bay of Plenty (Dixon & Barber 2008). Thus weather from three different calendar years could potentially affect yield, e.g. the crop reported for 2009/2010 would have come from flowers that were initiated in April to May 2008 and bloomed in October to November 2008.

Area planted was reported for each growing year, and for some orchards varied over time. Reported yield had been calculated from reported crop volume by using a conversion factor of 5.5 kg of fruit per tray, and then dividing by the reported yield for the year in question.

The irregular bearing index had been calculated as the ratio of the difference in yield between two consecutive growing years divided by the combined yield, but set to zero if yield was monotonically increasing over the two growing years and the preceding growing year. The term “irregular bearing” is used rather than “biennial bearing” to reflect that for some orchards a cycle of high yields followed by low yields occurred over a period of three or more years, rather than two.

A large number of orchards were missing data for one or more years. Where data were missing at the start or end of the reporting period, this could have been due to new orchards coming on stream or orchards being retired. Missing data could also arise from no harvest occurring or to the harvest being processed through an unregistered packhouse. A large number of zero yields were also recorded. It is unclear whether these corresponded to no or very small yields, to no harvesting despite a good crop, or to harvests being processed via unregistered packhouses.

According to New Zealand Avocado, harvests from different orchards with the same owners might be processed under one PPIN instead of being distributed among the different PPINs. This could cause anomalies such as unrealistic yields being reported. Some PPINs were “archived” and do not relate to current orchards; these were generally missing data for some or all years. In some cases this could have been due to land-use change, while in other cases fluctuations in reported area could reflect a variation in the number of orchard blocks harvested or whose harvest was processed through a registered packhouse.

Information on pruning regimes, irrigation, fertiliser applications, frost protection and other management or adaptation practices was not available for individual orchards. This precluded consideration of these issues in the model calibration.

The weather data were made available from a portal. These were measured from four meteorological stations in or nearby an orchard. One dataset extended from 2017 onwards, and others provided only more recent information. Thus it was decided to use VCSN data for all orchards when calibrating the models.

2.4.2 Kiwifruit data

Data on kiwifruit production from 3311 orchards were supplied by Zespri Group Ltd for the years 2015 to 2019, and for individual blocks of the same orchards from 2016 to 2019. These data related to three different kiwifruit crops: *Actinidia chinensis* var. *chinensis* ‘Zesy002’ (commonly known to growers as Gold3), *A. chinensis* var. *deliciosa* ‘Hayward’, and *A. chinensis* var. *chinensis* x *A. chinensis* var. *deliciosa* ‘Zesh004’ (commonly known as Green14). Organic vs conventional production was indicated for ‘Zesy002’ and ‘Hayward’, but not for ‘Zesh004’. Data provided included:

- KPIN (orchard identifier)
- Grower Number (identification of different orchard managements under one KPIN)
- GIS location tagged to KPIN
- Crop volume (trays)
- Area harvested (Canopy ha)
- Yield (trays/Canopy ha)

- Mean percent dry matter (DM) content of fruit for each harvested block
- Mean Taste Zespri™ Grade (TZG) score for each harvested block, a measure of taste experience developed by Zespri based on market research
- Harvest dates (for years 2016 to 2019) by orchard blocks within a KPIN.

Some KPINS were associated with more than one kiwifruit crop. Multiple Grower Numbers were associated with some KPINS. Area harvested was reported rather than total crop area for each orchard, and these could fluctuate from year to year. Communications from Zespri indicated some of these fluctuations may have been due to weather-induced crop loss in some blocks. Since the outcomes of such unfavourable weather conditions were not identified in the dataset, they could not be used to inform the model calibration without making ad hoc assumptions.

As was the case for avocado, information on pruning regimes, irrigation, fertiliser applications, frost protection, hydrogen cyanamide use and other management or adaptation practices was not provided for individual orchards. This generally precluded consideration of these issues in the model calibration. An exception is that we know Hi-Cane® or similar budbreak enhancers would not have been used for organic orchards. Communication from Zespri indicated that about one third of orchards would probably have irrigation systems, and these would also be available for frost protection, but Zespri did not identify these orchards.

2.5 Association of orchard locations with GIS data

To obtain climate and soil or terrain data, each orchard was assigned to the closest node in the VCSN or soil/terrain databases. Where a node had no information available or was located offshore, the next closest suitable node was assigned. When a soil/terrain database node had incomplete information, the missing information was retrieved from the closest suitable node. Thus, the same weather or soil information could be associated with a number of orchards that were relatively spatially distant, while conversely orchards that were relatively close could be assigned to different database nodes (see Figure 1).

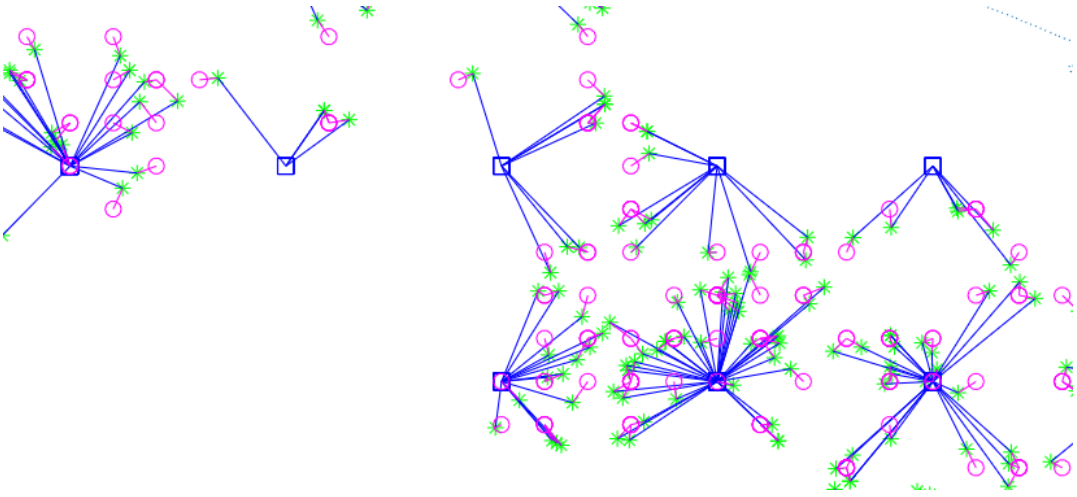


Figure 1. An example of orchards (indicated by green asterisks) that were assigned to the nearest climate database node (blue squares) and soil/land database node (magenta circles), to provide the required information for model calibration. Blue lines indicate which climate node an orchard is assigned to, and magenta lines indicate the soil/land database node. Climate nodes are on a 5 km x 5 km grid. Soil/terrain databases are on a 1 km x 1 km grid. Unassigned nodes are not shown.

3 Issues identified in consultations with stakeholders

Consultations on climate-change-related risk issues and adaptations were held via a workshop involving representatives from NZ Avocado, Zespri, the Bay of Plenty Regional Council (BOPRC) and the Western Bay of Plenty District Council (WBPDC). The Northland Regional Council, the Gisborne District Council (GDC) and the Tairawhiti Trust were consulted via several online discussions. The following agenda was used for all meetings and the workshop:

1. Identify areas of interest in climate change risks, for example around:

    a. Impacts on yield and profitability
    b. Labour capacity
    c. The regulatory environment
    d. How risks interact with management practices
    e. How risks interact with differences in soil properties and between regions
    f. Impacts on the local economy and the environment.

2. Identify/discuss possible adaptation strategies
3. Discuss risks that may relate directly to adaptations themselves.

    a. For example, success of transition if land-use change is involved
    b. Impacts on resources and the environment.

These agenda items were not intended to be prescriptive, and we cast a wide net and explored a range of issues raised by meeting participants. Key points and issues for different organisations are listed below.

3.1 Water resilience

Water resilience was the main theme across the discussions and related to both horticultural needs and environmental concerns. The primary focus of regional councils is on environmental protection, which increasingly takes precedence over (and can be at odds with) the water requirements of primary industries. Climate change projections indicate that in many areas changes in rainfall patterns could result in less frequent but more intense rainfall events and longer periods without rain, increasing the risk of drought. Available ground water in some areas is already allocated and there will be no new allocations. There is an inequity in water allocation, creating an unequal playing fielding dealing with climate risks to water. The aspirations of high-value horticultural industries to expand in some areas places pressure on the available resources, as well as pressure on local communities and economies.

3.1.1 Water availability risks

- Increased intensification of horticulture causes pressure on water supply.
- Urban expansion in horticultural areas can reduce water availability to growers.
- Allocation limits may be reduced to protect wetlands and aquifers, which will affect water usage for primary production.
- Drought may cause loss of rootstock causing long-term damage, especially if water takes are stopped by very low flows.

- Lack of access to water.
- High-value crops will become more intensely established and irrigated, resulting in greater pressure on water resources.
- Surface water is very unreliable, but users are not readily aware of this.
- The large number of growers reliant on water for frost protection will be at risk if water takes are stopped by very low winter flows.
- The inequity between different stakeholders in their access to consented water takes and/or financial resources to invest in water storage or access options; leaves disadvantaged stakeholders more vulnerable to climate change impacts than others:
    - Māori growers in some areas were identified as particularly disadvantaged and at risk.
- Water storage risks relate to a lack of capital for building and connecting users to storage, as well as the lack of suitable locations for dams.
- Lack of knowledge of water storage capacity required for severe droughts may result in shortfalls.
- Increased salinity of water in aquifers poses threat to horticultural industries.

3.1.2 Amelioration of water availability risks

- Investing in water storage that can be replenished when surface flows are high:
    - Enabling ponds, dams and wetlands.
- Government investment into water storage at a large scale and reticulation.
- Manipulation of crops to reduce water requirements – changing canopy size, irrigated vs non-irrigated.
- Manage reduced water by accepting decrease in yield.
- Adjust water allocation based on stage of establishment and management:
    - Better understanding of rooting depth and plant requirements.
    - Need to better quantify rootstock survival water requirements.
    - Cultivar differences in water requirement.
    - Impact of canopy area and growing systems on water requirements.
- Use new cultivars or crops with lower water requirements.
- Diversification using crops with different water requirements to reduce water risk.
- More equitable distribution of water rights.
    - This is particularly pertinent for Māori.
- Alternative frost protection methods other than sprinklers.
- Adoption of salinity-tolerant cultivars.

Risk to whenua Māori

Whenua Māori is more susceptible to climate change because of lack of access to water. The following adaptation strategies are needed to address the exclusion of whenua Māori from access to water:

- Increase water allocation to Māori.
- Treat iwi as treaty partners rather than stakeholders, so that they can form part of governance around water allocation.
- More equitable distribution of water resources.
- Improved efficiency of water use (irrigation methods, crop selection etc.).

3.2 Environmental and ecological issues

3.2.1 Risks

- Increased salinity of coastal wetlands and aquifers due to sea-level rise:
    - Depletion of aquifers and water bodies by water takes increases saline sensitivity.
- Nutrient leaching:
    - Exacerbated by intensification of high-input crops.
    - When combined with warmer streams, enhances algal blooming.
- Increased runoff causes the following to increase in water bodies:
    - Sedimentation.
    - *Escherichia coli.*
    - Nutrients and pesticides.

3.2.2 Adaptations

- Stricter limits on discharge to protect water quality may affect primary industries.
- Saline water management.
- Recharge aquifers with treated grey water.

3.3 Extreme climate events

3.3.1 Risks

- Flooding risks, especially in low-lying areas:
    - Erosion and loss of land.
    - Crop loss due to water logging (avocados are particularly at risk).
- Drought (covered in Section 4.1 on water resilience).
- Hail damage to fruit.
- Wind damage to fruit and trees.

3.3.2 Adaptations

- Funding of stop banks for flooding risks.
- Selection of cultivars and crops more resistant to water logging.

3.4 Warming temperatures

3.4.1 Risks and opportunities

- Lack of winter chill.
- Reduced frost risk provides opportunities for expansion of crops into new areas.

- Temperature rise will generally be beneficial for avocados.
- Increased risk of pests and diseases:
    - Incursions of exotic pests and diseases.
- Thermal stress damages fruit.

3.4.2 Adaptations

The development and use of lower-chill cultivars were identified as an adaptation to ameliorate lack of chill.

3.5 Economic and social issues

There is an increased cultivation of high-value crops that has and continues to replace a diversity of land use with a pressure towards monocultures. This not only increases the risk to the region of climate-change-related impacts, but also affects the labour market and has social consequences. For example, arable cropping was considered by some stakeholders as providing more to the local economy than kiwifruit. The perception was that kiwifruit is invested in by out-of-town syndicates and companies, and seasonal workers are also from out of town, which results in a flow of profits and income out of the region. Often local landowners cannot afford conversion costs to high-value crops and are incentivised to sell. Market forces were considered the key drivers behind land-use change.

3.5.1 Risks and opportunities

- Finance and insurance*:
    - Risk of increased drought and weather events.
    - Finance and insurance become more expensive or maybe unavailable.
- Climate-change-induced land-use change to kiwifruit or avocado monocultures from a mix of diverse land uses could negatively affect the local economy:
    - The opportunity of continuous work within the community could be reduced.
    - Employment opportunities becoming more seasonal in nature and undertaken by transitional workers.
    - Profits may not stay in the local economy if the land-use change is driven by out-of-town investors buying into the region.
    - There -may be local resentment of out-of-towners buying land and water allocation to high-value crops potentially depriving other industries of water.
    - Monocultures increase the risk of climate impacts to the local economy.
    - Pressure on infrastructure and municipal supplies.
- Conversely, some land-use change may increase jobs (e.g. avocado replacing dairy).
- An infrastructure deficiency in remote areas prevents taking advantage of climate-change-driven opportunities for land-use change to high-value crops.
- Risks to workforce if extended periods of drought.
- Loss to economy if growers exit the region due to unfavourable climate change impacts:
    - Increased unemployment.
    - Loss of revenue streams.
- Land-use transition or relocation of production to new areas may not be successful.

3.5.2 Adaptations

- Spread labour requirement by having a mix of crops and being proactive in seasonality of labour demand, timing, sustainable employment, etc.
- Alleviate monocultures of high-value crops by alternative high-value crops to increase diversity.
    - Avocado and kiwifruit offer work at complementary times.
- Maintain diversity of land use by incentivising away from high-value crops.

4 Scope of the predictive modelling

4.1 Production

The industry data available to us established that the scope of the modelling would be production at orchard level. These data were used to calibrate models to predict yield, and for DM for kiwifruit. In the absence of financial, orchard employment and other information we were not able to model flow-on impacts on the community.

Many factors affect orchard production, including climate, soil properties, management practices and adaptations. Orchard level information on management and adaptation practices were not available and thus parameters and equations reflecting these practices were not included in the calibrated model. A number of these factors relate to climate-related risks.

4.2 Inequities between stakeholders out of scope

The inequity between different stakeholders in their ability to access consented water takes, and in their financial ability to invest in water storage options could lead to disparities between groups of stakeholders regarding their vulnerability to climate change impacts. Māori growers in some areas were identified in the consultations as particularly disadvantaged and at risk. The impact of this could be investigated by contrasting the outcomes of adaptation versus no adaptations for water risks.

Risks were also identified around water storage for individual growers, and were related to a lack of capital for building and connecting users to storage, the lack of suitable locations for dams, and lack of knowledge of what storage capacity is required for severe droughts may result in shortfalls. These risks can be discussed in the same manner as inequities between stakeholders, by associating outcomes under availability vs unavailability of water storage with irrigated vs non-irrigated production.

4.3 Economic, political and social issues

Several political, social and economic issues were identified in the consultation workshops. In discussions with Gisborne-based organisations, Māori were identified as a group more susceptible to climate change because of lack of access to water for their whenua, with a number of adaptation strategies falling into the political realm. This is out of scope for this project and was not modelled.

Also identified was a tension between the aspirations of high-value horticultural industries to expand in some areas and pressure on the available resources, as well as pressure on local communities and economies. Investment in high-value crops was often undertaken by enterprises outside the region and involved workers from outside the community, resulting in loss of revenue and jobs in the region. Monocultures were seen as particularly vulnerable to extreme weather events, and land-use change from a diversity of crops to one or two high-value crops (whether economically driven or climate-change driven) was also regarded as undermining future resilience. Our approach will be to analyse such issues in the context of climate risk projections in subsequent stages of the project.

4.4 Environmental and ecological issues

A few environmental and ecological risks were identified in the workshops. Sea level rise could result in increased salinity of coastal wetlands and aquifers, and depletion of aquifers and water bodies by water takes could also increase saline sensitivity. Nutrient leaching could be exacerbated by intensification of high-input crops, resulting in increased algal blooms in receiving waters, which would be enhanced in warmer climates. Increased runoff could result in increases in nutrients, sediments, *Escherichia coli*, pesticides and nutrients.

While environmental and ecological risks are important, modelling them is out of scope for this project.

4.5 Extreme climate events

A number of extreme climate risks were identified during the consultation workshops. These included flooding, especially in low-lying land, which could lead to erosion and loss of land, and water logging to which avocados are particularly at risk. Additionally, wind and hail can damage fruit and storms can damage fruit and trees and support structures.

Prediction of flooding would require catchment modelling, which is outside the scope of this project. The future climate data at our disposal is not well suited to predict hail and storm events. Thus, development of predictive models of the losses associated with these risks is not appropriate within the framework developed for this milestone, and these risks, along with increased salinity of ground water affecting crops, can be considered on a probabilistic basis.

Drought was also identified as an extreme climate event and is a focus of the issues around water resilience discussed above.

5 Model predictors and considerations

We considered a large range of different combinations of possible predictors, including functions of climate variables. Predictors that provided little meaningful explanation were excluded from the model. Describing these all would not be worthwhile and thus below we discuss only key predictors.

5.1 Climate driven factors as model predictors

5.1.1 Crop evapotranspiration as predictor of yield

Water resilience was identified as a key theme in our consultations with stakeholders. Resilience itself is not clearly defined, being a context-dependent concept, but, in the case of primary food systems under threat from climate change, entails the ability to prepare for, adapt to, endure, or recover from the effects of a hazardous event in a timely manner (Hess et al. 2020; Hossard et al. 2021).

Councils are increasingly integrating the principles of Te Mana o te Wai and the environment when it comes to freshwater management, and may reduce allocation limits in order to meet environmental obligations. This could affect the ability of primary industries in some areas to meet their water requirements. Increased intensification and irrigation of high value horticultural crops, compounded by urban expansion into horticultural areas, could also reduce water availability to growers. Thus, some growers could in the future face water shortages that severely affect their ability to grow crops. This is especially relevant since changing rainfall and evapotranspiration patterns from climate change projections indicate greater risk of drought for some areas in the future. There is a risk that yields and even plant survival may be threatened in extreme cases.

Kiwifruit requires high relative humidity and precipitation for optimal growth and production, and even short periods of drought can cause a loss in yield and quality of fruit (Gucci et al. 1997). In kiwifruit, reproductive tissues are more sensitive to drought than vegetative tissues, but sustained drought can cause irreversible dehydration of branches and canes and even result in loss of the vine itself (Zhong et al. 2018). The root systems of mature avocado trees were found to be two-thirds smaller in clay soil compared with sandy soil, with 80% of root mass in the top 60 cm of clay soil compared with the top 80 cm of sandy soil, although root systems can extend to 1.2 m deep or more (Salazar-Garcia & Cortés-Flores 1986). Avocado is highly susceptible to water deficits, which can result in root damage and reduced growth and yield (Celedón et al. 2012). Unlike in kiwifruit, growth of fruit in avocado is more resistant to water deficits than buds and leaves, with young fruit continuing to grow at the expense of vegetative growth, but eventually dropping with drying of the root zone (Carr 2013).

Crop evapotranspiration (actual crop evapotranspiration, ETa) can be used to model crop yields and in addition to being affected by solar radiation, air temperature, relative humidity and wind speed is responsive to available soil water under conditions of soil water stress (Allen et al. 1998). Available soil water is in turn dependent on the balance of water entering the soil (through rain or irrigation) and leaving through evapotranspiration and total available water depends on soil water holding capacity and soil depth (Allen et al. 1998). Thus, ETa is a useful predictor of yield that can reflect water deficits.

5.1.2 Crop loss from frost damage

In areas that are subject to cold temperatures, frost is a potential source of production lost and thus an important risk to model. Avocados have a low tolerance of cold temperatures, having a frost resistance

down to –1.1°C (Dubrovina & Bautista 2014), with extensive loss of foliage when temperatures drop below –3°C (Malo et al. 1977). Kiwifruit are a little hardier, with newly formed kiwifruit vine shoots suffering no damage at −1°C and slight damage at −2°C, but being significantly damaged (95% kill rate of buds) at −3°C (Hewett & Young 1981).

The proportion of yield lost due to frost can be modelled as a function of minimum daily temperature to obtain a discounting factor representing the proportion of potential yield that survives frost damage (Vetharaniam et al. 2022a). We used this discounting factor as predictors for both crops.

For kiwifruit, we had information on the actual day of harvest for each orchard block, for each year. This allowed us to estimate frost damage based on the actual exposure window for each orchard block. Thus our implementation of the model for frost risk varies a little from the implementation of Vetharaniam et al. (2022a) who estimate the frost-related suitability of GIS grids containing arbitrary numbers of orchards and no specified harvest dates. This is discussed in Appendix A2.6.

5.1.3 Sufficient warmth during the year

All horticultural production requires conditions of sufficient warmth for development, growth and maturation of fruit, although excessive temperatures can be detrimental. Warmth can be expressed using a number of different metrics such as mean temperature (either annual or shorter period) or accumulated units above a base temperature, such as growing degree days (GDD) or hours (GDH).

Warmth requirements for kiwifruit are often expressed in terms of growing degree days (GDD). For New Zealand conditions, ‘Hayward’ requirements are 1100 d°C accumulated during October to April using a GDD base of 10°C (Salinger & Kenny 1995). There is little information on GDD requirements for other cultivars. Additionally, Snelgar et al. (2005) found that the optimal temperature for fruit growth in kiwifruit is 17°C and thus mean temperature could also be used as a predictor for kiwifruit yield.

The literature gives requirements for avocado in terms of temperature ranges, but lacks a consensus on what constitutes an optimal range (Dubrovina & Bautista 2014). Type A or Type B cultivars, which are opposite in the time of day that flowers open at the male and female stage (Davenport 1986), vary in sensitivity to low temperature during pollination (Ish-Am & Eisikowitch 1991). Temperatures above 20°C inhibit flower initiation (Buttrose & Alexander 1978; Nevin & Lovatt 1989), which occurs in New Zealand from March to May (Dixon et al. 2006). In studies, optimal pollination and yield occurred for a daily temperature of 20°C at night and 25°C in the day compared with a high temperature regime of 33°C day/28°C night and a low temperature regime of 17°C day/12°C night (Davenport 1986). New Zealand avocado orchards tend to be regions with mean annual temperatures about 14°C, considered to be at the climatic margin for successful production (Dixon & Barber 2008). The flowering period for New Zealand is mainly mid-October to mid-November (Dixon & Barber 2008).

Temperatures for avocado flower bud initiation and flowering as predictors

We investigated including mean temperatures for April-May (bud initiation time) and mid-October to mid-November (flowering time) as separate additional predictors for avocado. However, April-May temperatures in the dataset were in an optimal range and thus not effective as predictors. Mean temperature for mid-October to mid-November was also found to be unsuitable as a predictor.

5.1.4 Winter chill

Kiwifruit requires a sufficiently cold winter (winter chilling) for budbreak to occur after a dormant rest period and for subsequent flowering to be adequate and occur within a compact period. For New Zealand conditions, the best model for expressing chill requirements to obtain at least one king flower per winter bud is average May to July temperatures (Snelgar et al. 2008; Hall & Snelgar 2014). Chill requirements are considered met if the average May to July temperature is less than 11.7°C for *Actinidia chinensis* var. *deliciosa* 'Hayward' (Hall et al. 2018) and 12.7°C for a commonly grown tetraploid variety (Snelgar et al. 2008; Hall & Snelgar 2014).

5.1.5 Impact of disease

Crop production can be affected by a range of plant pathogens having different temperature and humidity requirements for optimal growth, with most plant-pathogens preferring high moisture conditions, although some are favoured by low moisture (Velásquez et al. 2018). Examining the threat posed by each pathogen is out of scope for this project, and thus we used the broad-brush suitability function described by Vetharaniam et al. (2021) who used temperature and relative humidity (RH) to develop a generic disease risk model. RH is a more reliable proxy for moisture than rainfall and often used in developing disease risk thresholds (Creasy 1980; Wilks & Shen 1991; Beresford et al. 2016).

This generic disease risk function was found to be useful for avocado but not for kiwifruit. This function does not address root diseases associated with waterlogging.

5.1.6 Rain

Although rainfall was used for calculating ET from the point of view of soil moisture availability, rainfall was included as a predictor, to look at the possible other effects of rain, including root diseases associated with waterlogging. Rainfall was found to be a useful predictor for yield in avocado but not in in kiwifruit. However, rain was useful predictor for DM in kiwifruit.

5.1.7 Wind damage

Wind can cause damage to plants throughout the year. We used the root mean squared (RMS) wind speed over a period as a predictor, rather than mean wind speed. Using the RMS speed would average adays proportional to the kinetic energy of wind and allow more influence from days with high wind speeds. This was a useful predictor for yield in avocado, but not in kiwifruit.

5.1.8 Heat stress score

High temperatures can cause damage to fruit and Lomas & Zamet (1994) gave 33°C as a threshold temperature for fruit damage in avocado. We modelled heat stress damage using the same function for avocado and kiwifruit. This predictor provided only minimal improvement to model fitting for avocado yield and was not useful for predicting kiwifruit yield. This could be because the effect of heat stress was already captured in the predictors relating to optimal warmth.

5.2 Soil and terrain properties

Soil and terrain properties are important considerations in horticultural production and in a previous SLMACC project 405421 report, several soil/terrain properties were considered for developing crop suitability criteria (Vetharaniam et al. 2021). We discuss these briefly below.

In the absence of management and adaptation information for individual orchards, we had no data on whether soil properties had been modified on orchards or how they differed from database values. This would be a source of uncertainty if soil or terrain related variables were used in the modelling.

5.2.1 Soil depth

Deeper soils allow the development of stronger root systems and provide more capacity for holding water, and this arguably confers more tolerance to drought. Shallower soils can be ameliorated by deep ripping, mounding or irrigation. Although kiwifruit can perform well over a range of different soil depths, soil depths of at least 0.6m is preferred (Hall et al. 2018). Avocado requires soil depths greater than 0.8 m for adequate performance, with much deeper soils required for very good performance (McCarthy 2001; Dubrovina & Bautista 2014).

PRD (see section 2.3) which measures the depth of soil to an impermeable layer provides a GIS-based measure of soil depth and is used to estimate available soil moisture in the calculation of crop evapotranspiration. PRD could potentially be used as a predictor of yield in its own right but was not included as a separate predictor in the final production models, because of over-fitting issues which are discussed later in this report.

5.2.2 Sufficient soil drainage

Kiwifruit showed varied sensitivity to waterlogging, with previous vine vigour and soil properties (especially soil structure) being major determiners of feeder root death and vine decline (Reid et al. 1991; Reid et al. 1992). Avocado does not tolerate water logging and requires good drainage (Ticho & Gefen 1965; McCarthy 2001; Dubrovina & Bautista 2014). Poor drainage can be improved by several different adaptations such as subsoil ripping, installation of drainage systems, mounding, application of soil amendments, or minimising of soil compaction through reducing traffic in orchards.

Soil drainage is included in the databases as a categorical rather than numerical value. Nevertheless, it could potentially be included as a predictor of yield since waterlogging associated with high rainfall could result in yield loss. However, as for soil depth above, drainage was not included as a predictor in the final production models due to over-fitting issues.

5.2.3 Slope requirements

Slope of land is relevant to issues such as access for machinery and erosion risk (Rowland et al. 2016) and construction of supporting structures for vines. It is however unlikely to affect production and was not considered as a predictor.

5.2.4 Appropriate Land Use Capability class

Land Use Capability (LUC) class descriptors (Lynn et al. 2009) are a generic descriptor of the suitability of land for different uses, and had been used as a criterion when constructing suitability

scores in previous work (Vetharaniam et al. 2021). These descriptors provide a holistic appraisal across a range of soil properties, and thus can reduce the need to include minor properties as separate criteria. As with drainage, LUC in the databases was provided in the form of categories rather than a numerical variable. It too could potentially be included as a predictor of yield but was not included as a predictor in the final production models because of over-fitting issues.

5.2.5 Soil pH

Soil pH is a more important consideration for avocado than kiwifruit, which can tolerate a wide range of pH values. Ideal soil pH ranges for avocado have been variously reported as 6.0 to 6.5 (Griffiths et al. 2003), 6.7 to 7.3 (Dubrovina & Bautista 2014) and 6.0 to 7.0 (Selladurai & Awachare 2020). Avocado is at risk of zinc deficiency in alkaline soils, and at risk of manganese toxicity in soils with a pH <6 (Selladurai & Awachare 2020). Soil pH could potentially be included as a predictor of yield but was not included as a predictor in the final production models because of over-fitting issues.

5.3 Temporal factors as predictors

5.3.1 Inclusion of previous years' yield as predictors for avocado

Avocado production is subject to irregular bearing effects, where a large yield in one year can have a detrimental effect on yield in subsequent years. The datasets indicated that for some orchards there was an alternate year effect, while other orchards showed a 1-in-3-year effect.

We investigated this effect by considering for alternative models for previous years' yields as predictors:

- No effect from previous years.
- Previous year's yield as predictor.
- Previous two years' yield as predictors.
- Previous three years' yield as predictors.

These alternatives were paired with alternative combinations of other potential predictors.

Irregular bearing is affected, and can also be managed, by appropriate pruning and weather events. Based on discussions with NZ Avocado, it is likely there would have been a range of pruning strategies employed across the orchards and some orchards may have had minimal pruning. In the absence of management information, fitting of parameters for lagged years was done on an orchard basis.

The time period between flower initiation and harvest of fruit from those initiated flowers spans up to three calendar years, and three consecutive years of harvest can be on the tree at the same time. Thus, for predicting production corresponding to one harvest period, our model refers to three different calendar years:

- Year 0, in which flower initiation and flowering took place
- Year 1, following the flowering year
- Year 2, the second year following the flowering year.

Fruit from flowering that occurred in Year 0 was harvested in the period from the end of the third quarter of Year 1 to the first quarter of Year 2. For example, for the crop reported for 2009/2010, 2008 is Year 0 (flowering October/November 2008), 2009 is Year 1 and 2010 is Year 2 (harvest from September 2009 to March 2010). Predictor variables were calculated for combinations of quarters for different years.

Unless expertly managed, avocado can have considerable variation in yield from year to year, with previous production levels influencing current production, an effect that is referred to as ‘irregular bearing’. We found that model prediction of production was optimal when yields in the previous two years were used as predictors.

5.3.2 Kiwifruit Day of harvest

Harvest of kiwifruit begins in early March and continues through to June. Unharvested fruit continue to grow and mature during this period, and thus yield can be affected by day of harvest. The datasets included the day of harvest for each block for each year. We used the number of days from the end of February to the day of harvest as a predictor to investigate the effect.

5.3.3 Kiwifruit year effect

The harvest year minus 2016 (the earliest year with harvest date data that we used) was considered as a predictor since there appeared to be small changes in yield over time.

6 Modelling production and adaptations

The predictors in our production models included several sub-models that are functions of climate variables and reflect impacts on yield. These are described in Appendix A. Included in these sub-models are criterion-related suitability scores (providing a value from 0 to 1) using the approach developed in a previous SLMACC project (Vetharaniam et al. 2021).

6.1 Yield

For modelling yield in both avocado and kiwifruit, we considered a general equation of the form

$$Y = W_0 \cdot \mathrm{ETa} \cdot S_{frost} \prod_{i=1}^{N-1} S_i^{w_i} \prod_{i=1}^{M} f_i^{v_i} \exp\left(\sum_{i=1}^{P} u_i\, g_i\right) \quad (1)$$

Here W_0 implicitly includes a maximum yield multiplier and a proportionality constant for actual crop evapotranspiration, ETa (see Appendix A1.1). S_{frost} is the frost suitability score that also represents yield loss due to frost (see Appendix A1.2). The first product is over the remaining suitability scores, with N being the total number of suitability scores used. The second product is over a range of M other functions (f_i, $i = i \ldots M$) raised to powers v_i. Additionally, we included the exponential of a range of P other functions (g_i, $i = i \ldots P$) weighted by parameters u_i.

Equation (1) can be linearised by taking logarithms:

$$\ln Y = \ln W_0 + \ln \mathrm{ETa} + \ln S_{frost} + \sum_{i=1}^{N-1} w_i \ln S_i + \sum_{i=1}^{M} v_i \ln f_i + \sum_{i=1}^{P} u_i\, g_i \quad (2)$$

When two or more predictors are collinear, their separate effects on yield cannot be reliably estimated, although their combined effect can be. Including all collinear predictors can increase the goodness of fit and could increase overall predictability. However, we wanted not only to predict yield, but also to predict how variation of each predictor will affect yield, so that we could investigate the effectiveness of individual adaptations. Thus, we excluded collinear predictors at the expense of goodness of fit and strove to keep the number of estimated predictor parameters to a minimum.

Management practices, including adaptations, will influence W_0, and since these are unknown W_0 was estimated separately for each orchard. The effects of time-invariant predictors such as soil properties, would then be absorbed into W_o and these predictors were excluded from calibration. However, soil properties were used for calculating evapotranspiration (ET), which is used in the models.

6.2 Dry matter content

Dry matter content (DM) in kiwifruit was modelled using a linear equation with variables being functions of climate variables.

Green (2007) found that the DM of 'Hayward' harvested at Te Puke could be modelled using mean air temperatures, soil water deficit and rainfall for specific periods. We will not present the equation since it was contained in a confidential report. However, it provided guidance for our model. Some of the time periods used by Green (2007) are not appropriate for our case when harvests occur from early March to the end of June. Thus, we considered alternative time periods. While Green (2007) also used weighted means of temperature for some periods, we found no advantage in doing the same.

We found that for DM, GDD was as effective a predictor as mean temperature, which is not unexpected since GDD is calculated as the mean temperature over a reference temperature. ETa and soil water deficit had a high negative correlation, which is expected since the latter is used to calculate ETa; we found that ETa was a suitable alternative to soil water deficit as a predictor. We also considered the candidate predictors that we considered for predicting yield and found that rain (separate from its contribution to ETa) and day of harvest to be important predictors. The latter is not surprising because accumulation of DM continues while fruit is on the vine. Additionally, we found that yield of kiwifruit also influenced DM.

6.3 Modelling the impacts of adaptations

While modelling can be a valuable tool for exploring adaptation strategies, it is imperative that adaptations are properly represented, and that the model focus on the adaptive process should not obscure system dependencies on the particular impacts and responses (Holman et al. 2019). This requirement is more readily met when using mechanistic models such as SPASMO, which accounts for all flows of water into and out of the root-zone soil of orchards and vineyards (Clothier et al. 2012) compared with empirical approaches. Empirical approaches include assumptions that an adaptation provides a particular level of performance, such as a percentage increase in yield or a minimum irrigation efficiency (Ignaciuk & Mason-D'Croz 2014).

Thomson et al. (2018) used a simplified inventory model to quantitatively assess outcomes of alternative climate-change adaptation plans. However, this approach did not include probability considerations or a GIS component, both of which are necessary when dealing with the uncertainty of weather patterns under changing climates with differential spatial impacts.

Within the context of our yield models, an adaptation to a climate risk could be modelled by either (i) modifying the response of the corresponding impact sub-function, (ii) modifying the input climate variables to the impact sub-function or (ii) modifying the sensitivity of yield to the impact sub-function. For example, the frost suitability score, S_{frost} in Equation (1) takes minimum daily temperature as an input and contains a threshold temperature as a parameter. Modelling the use of frost protection using approach (i) above corresponds to decreasing this threshold, while using approach (ii) corresponds to increasing the input minimum temperature values. While approaches (i) and (ii) might also be appropriate for a risk corresponding to any of functions S_i, f_i, and g_i in Equation (1), approach (iii) could also be used by adjust of the relevant weight w_j, v_i, or u_i.

However, implementation of approaches (i) or (iii) would require knowledge of how an adaptation would change the value of the corresponding parameter. It had been our intention to estimate these changes in parameters for at least some adaptations, by fitting the model to data, but this was generally not possible since there was no information on individual orchard management and adaptation practices alongside the production data. Thus, in later stages of the project, only option (ii) was available to us.

7 Model calibrations

The equations for dry matter content and yield for both crops are linear or linearisable functions of the impact sub-models. Because the lack of data on orchard practices and adaptations precluded us from estimating adaptation-related changes in parameters that are internal to the sub-functions, the model calibrations involved fitting a linear model, e.g. estimating values for only w_j, v_i, or u_i in Equation (*2*). This was readily performed by linear regression, with the use of "dummy variables" to allow fitting of 'structural' effects such as cultivar or growing method (conventional vs organic) in kiwifruit.

When comparing the large number of alternative predictive models (arising from different combinations of possible predictors), we compared performance used adjusted R^2 as the statistic, since it takes into account the number of explanatory variables when calculating goodness of fit, and will decrease if a predictor with insufficient explanatory power is included in the model.

7.1 Avocado yield calibration

7.1.1 Calibrated model for avocado yield

We found that including both the previous year's yield (Y_{-1}) and the penultimate year's yield (Y_{-2}) as predictors gave the most efficient explanation of the data compared with the alternatives discussion in section 5.3.1.

The final fitted model for avocado yield is shown here in Equation (1):

$$Y = w_0 \times \mathrm{ETa}_{\text{q2y0 to q1y2}} \times S_{\text{frost q2y0 to q1y2}} \times \left(S_{\text{warmth q2y0 to q1y2}}\right)^{p_1} \times \left(S_{\text{disease q3y0 \& q3y1}}\right)^{p_2} \times \exp\left(p_3 \mathrm{rain}_{\text{q2y0 to q1y2}} + p_4 \mathrm{windRMS}_{\text{q2y0 to q1y2}}\right) \times \exp(p_5 Y_{-1} + p_6 Y_{-2}) \quad (3)$$

where the parameters $p_0 = \ln(w_0)$ and $\mathrm{p_i}$ $(i = 1,..,6)$ were fitted to the data, and the suffix for each predictor variable indicates the period over which the variable was calculated, with q denoting the quarter of the year (denoted by y).

Orchards management, grower skill, soil properties, aspect and so on are reflected in $p0$, and irregular bearing is influenced by pruning strategies, which will vary between orchards and is reflected in p_5 and p_6. Thus, these tree parameters were fitted individually to orchards. The variable ETa is actual crop evapotranspiration, S_{frost}, S_{warmth}, and S_{disease} are suitability scores for, respectively, frost, growing-season warmth, and generic disease risk, and $\mathrm{windRMS}$ is root mean square (RMS) wind speed; the formulae for calculating these are given in Appendix A1. The variable rain is cumulative rainfall.

The R^2 for this fitted model was 0.54 and the adjusted R^2 was 0.34. Including yield from 3 years previous increased the R^2 was to 0.63 but decreased the adjusted R^2 to 0.33, and thus was rejected.

Model variables and parameter values obtained from the calibration are presented in Table 1. Since p_0 is a distributed variable with individual values for each orchard, w_0 is also a distributed variable, and the mean for $w_0$is not the exponential of mean p_0.

Table 1. Fitted parameters, variables and corresponding risk for model calibrated to avocado yield data. Although parameters p_0, p_5 and p_6 were fitted individually for each orchard, only their means and standard deviations (SD) across orchards are presented.

Parameter	Variable name	Estimate	CI lb	CI up	SD	Predictor
p_0		0.94	-	-	1.24	Fitted constant
w_0		5.94			15.7	Yield multiplier constant
-	$\mathrm{ETa}_{\text{q2y0 to q1y2}}$					Crop evapotranspiration
-	$S_{\text{frost q2y0 to q1y2}}$					Frost suitability score
p_1	$S_{\text{warmth q2y0 to q1y2}}$	9.4	6.5	12.3	-	Warmth suitability score
p_2	$S_{\text{disease q3y0 \& q3y1}}$	4.3	3.9	4.8	-	Disease suitability score
p_3	$\mathrm{rain}_{\text{q2y0 to q1y2}}$	-0.053	-0.097	-0.008	-	Rain (on top of input to ETa)
p_4	$\mathrm{windRMS}_{\text{q2y0 to q1y2}}$	-0.17	-0.30	-0.04	-	Wind (RMS)
p_5	Y_{-1}	-0.049	-	-	0.075	Yield 1 year previous
p_6	Y_{-2}	0.014	-	-	0.072	Yield 2 years previous

RMS is the root mean square average. ETa is actual crop evapotranspiration. Variables denoted by S are suitability scores. The parameter w_0 is the exponential of p_0. Abbreviations lb and up refer to the lower and upper bounds of the 95% confidence interval (CI).

7.2 Kiwifruit yield and dry matter content calibration

7.2.1 Fitted model for kiwifruit yield and dry matter

During the processes of model calibration, Zespri provided further yield data for individual harvest blocks for the harvest years 2015, and 2020 to 2021. Unfortunately, there was a mis-match in orchard GIS information between the new data and the originally supplied data for 2016 to 2019. Individual Grower Numbers tagged to KPINs were also unavailable in the new data. The discrepancy in GIS information was not readily resolvable, and so the new data were not included in the calibration.

Climate-related predictors were generally calculated for six separate time periods and for periods made up of these quarters:

- The four quarters of the calendar year in which flowering took place (year 1).
- The first two quarters of the following calendar year in which harvest took place (year 2).

There were a few exceptions to quarterly calculation. Chill suitability scores were based on mean winter temperature in year 1. GDD suitability scores were based on accumulated of October to April GDD, although GDD was also calculated for quarters. Loss from frost damage was calculated for each harvest block, from budbreak to harvest day, which varied from year to year.

GDD accumulation, in quarters in which harvests occurred, was calculated individually for harvest blocks by linear interpolation using day of harvest. This approach was also used for calculating rain exposure, effective mean temperature exposure, ET, etc.

As for avocado, in the model calibration process, we investigated alternative combinations of predictors for different periods.

Since there were comparatively very few 'Zesh004' harvests recorded in the data, we excluded 'Zesh004' from the calibration. One model was fitted across cultivars and growing method. Differences between cultivars (green-fleshed vs gold-fleshed) and growing method (conventional vs organic) were accommodated using dummy variables, and dummy variables were applied where they were relevant. This allowed the same orchard effects to be applied across cultivars and growing methods.

Orchard effects could be modelled by grouping according to KPINS or by Grower Number. Using the latter would improve the fit at the expense of reducing the degrees of freedom in the calibration. Given the limited number of years over which data were available, we used KPIN as a regression category.

The models for both yield and DM of fruit were fitted at the level of blocks within and orchard, using data for 'Hayward' and 'Zesy002' cultivars grown using organic or conventional growing methods. Model predictors of production were calculated for time periods made up of different quarters from the following years:

- the calendar year in which flowering occurred (Year 1)
- the calendar year in which harvest took place (Year 2).

Kiwifruit yield

The best model from the calibration was:

$$Y = \mathrm{w}_0 \times \delta w_{0\,\mathrm{Zesy002}} \times \mathrm{ETa}_{\mathrm{q4y1\ to\ harv}} \times S_{\mathrm{frost\ budbreak\ to\ harv}} \times (S_{\mathrm{chill}})^{p_1} \times \left(S_{\mathrm{warmth\ q4y1\ to\ q1y2}}\right)^{p_2} \times \exp\left(p_{3\,\mathrm{Zesy002}}\mathrm{Year} + p_4 \mathrm{rain}_{\mathrm{q3y1\ to\ harv}} + p_5 \mathrm{Days}_{\mathrm{1Mar\ to\ harv}}\right) \quad (4)$$

where the parameters $p_0 = \ln(w_0)$ (fitted separately for each orchard block) and p_i $(i = 1,..,5)$ were fitted to the data suffixes and follow a similar pattern to that for avocado, with additionally 'harv' and 'Mar' meaning 'harvest' and 'March', respectively. The variable S_{chill} is the chill suitability score for kiwifruit, $\mathrm{T}_{\mathrm{q4y1\ to\ q1y2}}$ is mean October to March temperature, Year is the year of harvest and Days is the number of days from 1 March to harvest date for the block. A dummy parameter $\delta p_0 = \ln(\delta w_{0\ Zesy002})$ was fitted to capture differences in yield between 'Zesy002' and 'Hayward'. Parameter p_1 was fitted separately by cultivar and by growing method. Parameter p_3 was fitted only for 'Zesy002', while p_4 was fitted separately by cultivar.

The different values of the chill parameter, p_1, for the four different cultivar × growing-method options give different sensitivities to lack of chill. With the fitted values, conventional and organic 'Zesy002' are predicted to require mean winter temperatures of, respectively, 12°C and 12.5°C to achieve 90% of potential yield, while conventional and organic 'Hayward' are predicted to require mean winter temperatures of 11.1°C and 11.4°C. The differences in winter temperature requirements between organic and conventional growing are unexpectedly small. This discrepancy could be due to pertinent information (perhaps management) missing from calibration data, our assumptions regarding Hi-Cane use or its effectiveness being wrong, errors in the data, or that we have omitted key predictors from our model. There are also the possibilities that organic growers were using other adaptation practices to compensate for lack of chill, or that most organic growing occurred in areas consistently in the optimal winter chill zones.

Model variables and parameter values obtained from the calibration are presented in Table 2 along with the associated risks to kiwifruit yield that can potentially be modelled with Equation (4). The R^2 for this fitted model was 0.46 and the adjusted R^2 was 0.40.

As was the case for avocado, both p_0 and w_0 are distributed variables with individual values for each orchard, and the mean for $w_0$is not the exponential of mean p_0. A similar consideration also applies to δp_0 and δw_0.

Table 2. Fitted parameters, variables and corresponding risk for model calibrated to kiwifruit yield data. Although the parameters p_0, p_5 and p_6 were fitted individually for each KPIN (an owner identifier), only their means and standard deviations (SD) across orchards are presented.

Parameter	Variable		Estimate	CI lb	CI up	SD	Predictor
p_0			2.97	-	-	0.38	Fitted constant
w_0			20.7			6.8	Yield multiplier constant
$\delta p_{0\ \mathrm{Zesy002}}$			0.195	0.146	0.244	-	'Zesy002' yield effect
$\delta w_{0\ \mathrm{Zesy002}}$			1.22	1.16	1.28	-	'Zesy002' effect multiplier
-	$\mathrm{ETa}_{\mathrm{q4y1\ to\ harv}}$						Crop evapotranspiration
-	$S_{\mathrm{frost\ budbreak\ to\ harv}}$						Frost suitability score
p_1	S_{chill}	Zes Org	0.19	0.02	0.36	-	Chill suitability score
		Hay Org	0.43	0.29	0.57	-	
		Zes Con	0.13	0.10	0.15	-	
		Hay Con	0.33	0.30	0.36	-	
p_2	$S_{\mathrm{warmth\ q4y1\ to\ q1y2}}$		0.99	0.59	1.4	-	Warmth suitability score
p_3	Year	Zes	0.132	0.126	0.139	-	'Zesy002' year effect
p_4	rain	Zes	-4.8E-04	-5.1E-04	-4.4E-04	-	Rain leading to fruit damage
		Hay	-3.1E-04	-3.4E-04	-2.9E-04	-	
p_5	Days		2.0E-03	1.6E-03	2.4E-03	-	Days from 1 March to harvest

The parameter w_0 is the exponential of p_0. Parameter $\delta w_{0\ \mathrm{Zesy002}}$ is the exponential of $\delta p_{0\ \mathrm{Zesy002}}$ and was assumed to be lognormal, with upper (up) and lower (lb) bounds of the 95% confidence interval (CI) calculated using a Monte Carlo approach (Krishnamoorthy & Mathew 2003). Hay = 'Hayward'; Zes = 'Zesy002'; Org = organic growing methods; Con = conventional growing methods.

Dry matter content of fruit

The best model for dry matter content (DM) of kiwifruit was:

$$\mathrm{DM} = b_o + \delta b_{0\ \mathrm{Zesy002}} + \delta b_{0\ \mathrm{Organic}} + b_1 \mathrm{GDD}_{\mathrm{q4y1\ to\ harv}} + \mathrm{b}_2 \mathrm{ETa}_{\mathrm{q1y2\ to\ harv}} + b_3 \mathrm{Days}_{\mathrm{1Mar\ to\ harv}} + b_4 Y + b_5 \mathrm{rain}_{\mathrm{1Apr\ to\ harv}} \quad (5)$$

where the parameters b_0 (fitted separately for each orchard), $\delta b_{0\ \mathrm{Zesy002}}$, $\delta b_{0\ \mathrm{Organic}}$ and $\mathrm{b_i}$ $(\mathrm{i} = 1,..,6)$ were fitted to the data, with $\delta b_{0\ \mathrm{Zesy002}}$ and $\delta b_{0\ \mathrm{Organic}}$ being dummy parameters for 'Zesy002' and organic growing methods, respectively, and b_5 being fitted separately for the two cultivars.

Model variables and parameter values obtained from calibration earlier in the report are presented in Table 3 along with the associated risks to kiwifruit DM that can potentially be modelled with Equation (5). The R^2 for this fitted model was 0.71 and the adjusted R^2 was 0.67.

Table 3. Parameter fits for model calibration to kiwifruit dry matter data. Although the parameter pb_0 was fitted individually for each KPIN (an owner identifier), only the means and standard deviation (SD) across orchards are presented. Other parameter estimates are presented with 95% confidence intervals.

Parameter	Variable name		Estimate	CI lb	CI up	SD	Predictor
b_0			15.39			0.47	Fitted constant
$\delta b_{0\ \mathrm{Zesy002}}$			1.48	1.45	1.51		Fitted constant
$\delta b_{0\ \mathrm{Organic}}$			-0.48	-0.62	-0.34		Fitted constant
b_1	$\mathrm{GDD}_{\mathrm{q4y1\ to\ harv}}$		2.21E-3	2.11E-3	2.31E-3		Growing season warmth (growing degree days)
b_2	$\mathrm{ETa}_{\mathrm{q4y1\ to\ harv}}$		-4.03E-3	-4.11E-3	-3.95E-3		Crop evapotranspiration from October to harvest
b_3	$\mathrm{Days}_{\mathrm{1Mar\ to\ harv}}$		6.16E-3	5.31E-3	7.00E-3		Days after 1 March to harvest
b_4	Y		-3.67E-5	-3.88E-5	-3.46E-5		Yield
b_5	$\mathrm{rain}_{\mathrm{1\ Apr\ to\ harv}}$	Zes	-2.74E-3	-2.89E-3	-2.58E-3		Rain from 1 April to harvest ‘diluting’ fruit
		Hay	-4.46E-4	-5.56E-4	-3.37E4		

DM is dry matter content. Abbreviations lb and up refer to the lower and upper bounds of the 95% confidence interval (CI). Hay = ‘Hayward’; Zes = ‘Zesy002’.

8 Modelling Value at Risk (VaR)

8.1 Background

The concept of VaR was developed in finance to specify the maximum loss exposure of an investment over a specified time for a given level of confidence (Locatelli et al. 2018). VaR has been used to evaluate the effects of weather variability on financial streams and to evaluate financial instruments designed for hedging weather risk (Toeglhofer et al. 2012). Extension to VaR methodology has seen it applied to measure economic risk from climate change and to assess the effectiveness of adaptation strategies for a range of sectors including cropping (Bird et al. 2016; Prettenthaler et al. 2016). VaR estimates for global financial assets under climate change scenarios were developed by Dietz et al. (2016) and used to study risk reduction associated with climate change adaptation.

Locatelli et al. (2018) discussed the application of risk concepts from the financial sector to climate change risks to the forestry sector and listed three alternative measures of risk: VaR, conditional VaR, and risk vs reward ratio (RvR). Those authors noted that i) VaR specifies the maximum loss over a specified time for a given level of confidence; ii) conditional VaR (CVaR) quantifies the expected loss given that VaR has been exceeded; and iii) RvR evaluates the ratio of reward to investment risk.

We chose to formulate risk in terms of VaR because it is the approach most widely used in finance to quantify risk (Locatelli et al. 2018) and been applied to climate change adaptation as discussed above. Additionally, VaR estimates are statistically more stable than CVaR estimates, especially when tails of the loss distribution are not well characterised, even though CVaR has superior mathematical properties (Sarykalin et al. 2008). However, RvR may also be a useful metric, and Locatelli et al. (2018) suggested that in a cropping context RvR could be calculated as the ratio of forecast returns from a cropping system to VaR calculation of the worst-case loss.

The original aim of this project was to model yield and profitability for individual orchards under different climates and for different management practices, and to express risk in financial terms, at the orchard and industry levels, which would also allow us to consider wider economic impacts. However, the orchard data that we were provided by our industry partners had limited phenology and management information. Additionally these data did not provide financial data such as orchard expenses and payments required for calculating profits from yield. This precluded the traditional approach of formulating VaR in terms of nett returns and RvR.

We identified that the best approach was to model VaR in terms of yield (and additionally DM for kiwifruit) and to value adaptations in terms of break-even costs, expressed in terms of production saved or gained, an approach that was supported by both NZ Avocado and Zespri. This change will still allow growers to make decisions on the value of climate change adaptations, with the advantage of being more generally applicable, since growers can make adaptation decisions using different price forecasts and costs for management and adaptation.

Yamai & Yoshiba (2005) noted that VaR is intended to define the "possible maximum loss over a given holding period within a fixed confidence level". Suppose that $X \sim N(\mu, \sigma^2)$, is a normally distributed random variable corresponding to the *loss* from an investment position. For a given confidence level α, Sarykalin et al. (2008) gave the following expression for the VaR for X:

$$\mathrm{VaR}_\alpha(X) = F_X^{-1}(\alpha) = \mu + k(\alpha)\sigma \tag{6}$$

where $k(\alpha) = \sqrt{2}\,\mathrm{erf}^{-1}(2\alpha - 1)$, $\mathrm{erf}(z) \equiv \left(\frac{2}{\sqrt{\pi}}\right)\int_o^z \exp(-t^2)\,dt$ and $F_X(z)$ is the cumulative distribution function of X,.

However, the definition in Equation (*6*), which is the upper α-percentile of the loss variable, is not sensible if we are expressing risk for production which is strictly non-negative. Therefore, we have used the alternative formulation described by Odening & Hinrichs (2003) in which VaR is the difference between the mean and the lower α-percentile of 'gain' variable. When applied to yield, and relaxing assumptions of normality, this is illustrated in Figure 2.

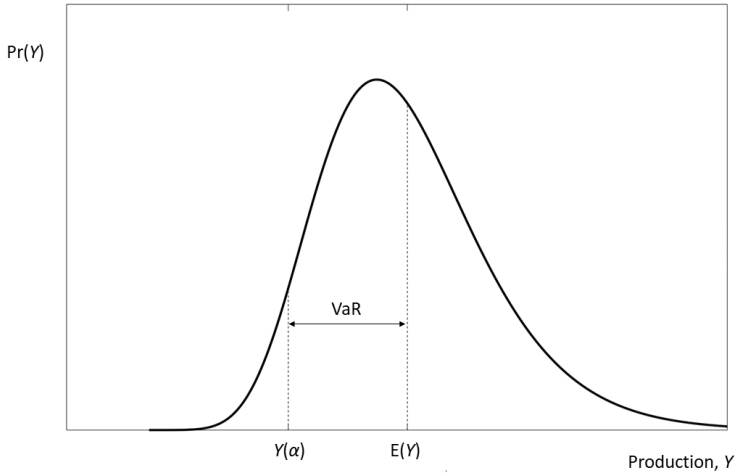


Figure 2. Diagram based on a schema from Odening & Hinrichs (2003) that shows their definition of value at risk (VaR), which we have applied to production. Pr(Y) is the probability density function of production, Y. $Y(\alpha)$ and E(Y) are respectively the lower α percentile and expected value of Y.

8.2 Separating contributions to VaR

From the prediction models, yield and DM can be calculated for each year in a period. VaR for production and DM can be then calculated from their means and variances to indicate risks from varying weather patterns. However, this would reflect the combined impact of multiple risks. To make decisions on the value of individual adaptations, we need to separate the contribution from each risk.

Hallerbach (1999) considered several methods to decompose the VaR of a portfolio into the contributions from its individual components, requiring the assumption of continuous compounded returns. Britten-Jones & Schaefer (1999) examined the contribution from individual components to VaR by using an approximation that was quadratic in underlying factors but linear in time.

For our purposes, we used a first order Taylor expansion of a function as an approximate decomposition of its variance in terms of the underlying variables using the approach of expanding around the variable mean (Champac & Gervacio 2018; Novák & Novák 2020), noting that derivatives will be calculated at the means. Letting f be a 1-D function of n independent, uncorrelated random variables X_i with means μ_i and variances σ_i^2, the mean and variance of the response of f is has the following approximation (Novák & Novák 2020):

$$\mu_f \approx f(\mu_1, \ldots, \mu_n) \tag{7}$$

$$\sigma_f^2 \approx \sum_{i=1}^{n} \left(\frac{\partial f(\boldsymbol{X})}{\partial X_i} \right)^2_{|\boldsymbol{X}=\boldsymbol{\mu}} \sigma_i^2 \tag{8}$$

Since we have expressed yield as a multiplication of factors, in the form,

$$y = \prod_i f_i(x_i) \tag{9}$$

then

$$\frac{\partial y}{dx_j} = \prod_{i \neq j} f_i(x_i) \frac{\partial f_i(x_i)}{\partial x_j} = \frac{y}{f(x_j)} \frac{\partial f_i(x_i)}{\partial x_j} \tag{10}$$

Equation (8), for decomposing VaR into contributions from individual risks, then becomes:

$$\sigma_y^2 \approx \mu_y^2 \sum_{i=1}^{n} \left(\frac{1}{f_i(u_i)} \frac{\partial fi(x_i = \mu_i)}{\partial x_i} \right)^2 \sigma_{x_i}^2 \tag{11}$$

9 Modification of climate datasets

Projected climate change impacts are obtained from climate projection data by comparing calculated outcomes for a future period with calculated outcomes from the historical period of the same dataset (see Figure 3). In order that estimated climate change impacts are meaningful, there should be a level of agreement between calculations using RCP Past data and observed historical weather data for the same RCP past period.

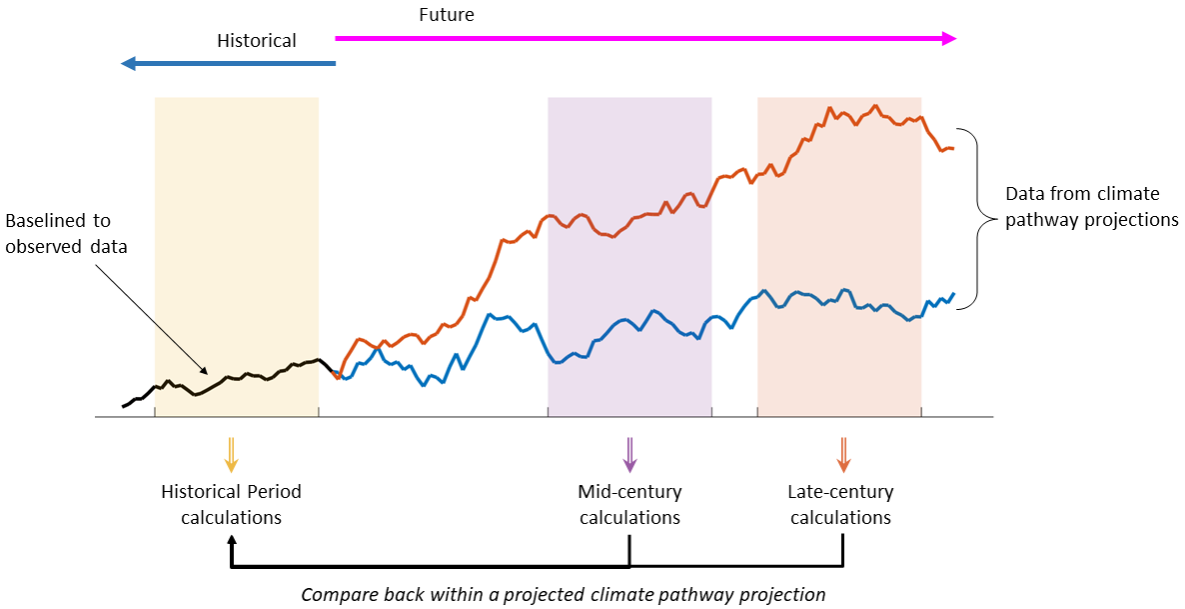


Figure 3. Schema to indicate approach when projecting climate change impacts. Data from future periods of modelled climate data are used to calculate quantities of interest and compared back with parallel calculations using data from the historical (hindcast or RCP past) period of the same dataset. Each simulated climate dataset is bias corrected to get agreement with observed climate data from the historical period.

We used the VCSN dataset as a proxy for the observed historical data. Although we had VCSN data from 1972 to 2022, it was missing windspeed information from 1972 to 1996, and the nine RPC past years with complete data (1997–2005) are not sufficient for representing the historical climate.

The simplest solution to this was to backshift complete VCSN datasets from subsequent years, with an appropriate adjustment to remove any short-term impact on climate means.

Agreement between calculations from RCP Past data and historical weather data generally required bias correction of the RCP data to obtain the necessary agreement. We have previously found that for many biologically driven models, this bias correction should be at the monthly level rather than the annual level and take differences in variance into account. Of the variables used in our modelling, we had available RCP datasets for maximum and minimum temperature, RH and rainfall, that had been adjusted for agreement at the level of the month. RCP data for solar radiation, wind speed and sea-level pressure were not bias corrected.

As an alternative to bias correcting the datasets for solar radiation, wind speed and sea-level pressure, we took the approach of extracting the climate change signals from the RCP datasets and superimposing them on the VCSN dataset. Thus, the data used to represent the RCP Past period are the corresponding VCSN dataset, and this guarantees baseline agreement.

9.1.1 Back-shifting VCSN-based historical data

For each of maximum and minimum temperature, RH, sea-level pressure, wind speed, rainfall and solar radiation, the means for each month of each year were calculated for the period 1977–2022, separately for each GIS location. To address the missing wind data from 1977 to 1996, we performed a linear regression for each calendar month, in which the wind speed for that month was estimated as a function of the yearly series of means of the other variables for the same month, using data from 1997 to 2022. This regression was done separately for each GIS location, and then used to calculate mean wind speed for each month of each year for the period 1977–1996. For all variables, the calculated monthly means were used to obtain representative means for each calendar month for the two periods: 1977–2002 and 1997–2022. Additionally, the variances of maximum and minimum temperature and atmospheric pressure were calculated for each calendar month for the same periods.

The VCSN data from the period 1997–2022 were then back-shifted by 20 years to represent the period 1977–2002. The 20 year-shift ensured that leap years were aligned. To account for differences in statistics between the two periods, the shifted data were adjusted for agreement with monthly statistics of the original VCSN data for 1977–2002. This was done separately for each GIS location in the VCSN dataset.

Maximum and minimum temperature, RH and sea-level pressure underwent an additive adjust for agreement in monthly means. Maximum and minimum temperature, and atmospheric pressure were additionally scaled around their means to achieve a variance adjustment. After the bias correction, RH values were truncated from below at 1% and from above at 100%. Data for rainfall, wind speed and solar radiation were adjusted for means by scaling.For convenience we refer to the new dataset as “SLM VCSN”.

9.1.2 Superimposing change signals from RCP data onto VCSN data

For each RCP 4.5, 6.0 and 8.5, we calculated the change signal for each of the six GCM datasets, for a mid-century period (2037–2062) and a late-century period (2069–2094) with respect to the historical period 1977–2002. These years chosen ensured that the relative positions of leap years between datasets were appropriately aligned.

The change signals were averaged across GCMs to obtain one mean change signal per period for each RCP. These mean change signals were applied to the VCSN dataset in the same manner as the adjustments to obtain the SLM VCSN datasets, described above. For convenience we refer to these as “SLM RCP VCSN” datasets.

The extraction and superimposition were performed for each GIS location covered in the RCP dataset. The RCP grid matched the VCSN grid, and provided values for the same locations that were covered by the VCSN grid, except for a very small number of VCSN locations for which there were no RCP data.

Applying the individual change signals from each GCM dataset to the SLM VCSN dataset would result in six datasets for each RCP that had essentially the same weather patterns, and there would not be the variation provided in the original GCM datasets. Thus, there was no advantage in doing this.

9.1.3 Uncertainty in resulting calculations

If datasets from different GCMS are used to project outcomes, the conventional approach is that separate outcomes can be averaged to provide a representative value, and the variability between model runs to infer projection uncertainty. This would not account for systematic effects that are common to the GCMs or intrinsic to the RCM. Nor would this account to errors due to perturbations of the future climates due to variability in several factors that can affect weather patterns. These include solar variability, volcanoes, other human-produced and natural emissions of GHGs and aerosols and carbon-dioxide levels (Buis 2020).

In the approach we have taken, of superimposing climate change signals on the VCSN datasets, if we had generated separate datasets for each GCM change signal, the variance would be smaller than if bias corrected GCM datasets had been used. This is because the latter would have varied in the patterns of their daily data. In either case, it is unlikely that six GCMs would represent sufficient variation to estimate uncertainties robustly.

Thus, we have used results from a previous SLMACC project (Vetharaniam et al. 2021) to estimate uncertainties in our projections for the current project. Vetharaniam et al. (2021) used an empirical approach to estimating uncertainties when performing projections using the same SLMAC RCP datasets that we have used in this project. The average of the relative uncertainties in their projection across a range of crops are given in Table 4.

Table 4. Relative uncertainties in projections using the SLM RCP datasets for mid- and late century, from Vetharaniam et al. (2021).

	Relative uncertainties in SLM RCP projections		
	RCP 4.5	RCP 6.0	RCP 8.5
Mid-century	22%	22%	23%
Late century	24%	27%	29%

These values do not reflect the (unknown) uncertainty in the calibrated models that take the climate data, so actual uncertainty in projections will be higher.

10 Value at Risk results

The models described in Section 3 were applied to the SLM VCSN data and SLM RCP VCSN data for the mid-century and late-century periods. Prediction of avocado yield requires data from three calendar years, the number of years of yield predicted are two less than the number of years in each period. For kiwifruit this it was one less. The growing period associated with a harvest was linked to the calendar year at the start of that growing period.

10.1 Avocado VaR

The production model was used to calculate yearly yield for each PPIN (avocado orchard identifier) that had been used in the calibration, except for one PPIN whose location was not covered by the RCP dataset, leaving a total of 420 PPINS locations being modelled. The parameter values estimated from the model calibration were used, including the PPIN-specific values for the multiplier, W_0. These yield values were estimated for the 24 harvests (September to March) for each 26-year period, with the last harvest spanning the penultimate and final year of the period. Calculations for the first harvest in a period used data from the first three years of that period. The calculated yield values were then used to obtain the mean yield and the VaR for yield at a 5% confidence, separately for each PPIN and period. For presentation purposes, means and VaR were aggregated by supply region, separately for each period. The number of PPINs associated with each supply region is shown in Table 5.

Table 5. Avocado supply regions and number of PPINs (orchard/owner identifiers) per supply region.

Supply region	Number of PPINs
Bay of Plenty	263
Far North	43
Rest of NZ	16
Whangarei	98

Projected mean yield and VaR for avocado for the mid-century and late century under RCP 4.5, RCP 6.0 and RCP 8.5 are shown in Table 6, along with projected change from the historical period.

Although the Bay of Plenty and the Far North have similar mean yields for the historical period, their yields diverge significantly by the mid-century, and even more by the late century, under each of the three RCPs (Table 6). Far North yields are projected to increase only modestly by the mid-century, with little difference between RCP, and then decline into the late century, with late-century yields for RCP 6.0 and 8.5 dropping below historical values. Bay of Plenty yields are projected to have very significant increases by the mid-century, and then further, but more modest, increases from the mid-century to the late century, under all three RCPs. Yields of orchards in the “Rest of NZ” are projected to increase modestly over time and reach a production level on a par with historical values for the Bay of Plenty and Far North. Whangarei production is projected to follow a similar pattern of change to that of the Rest of NZ, though 1–3 t/ha higher depending on RCP and period (see Table 6).

In the historical period, VaR for the Bay of Plenty is higher than mean yield, indicating the risk exposure encompasses the possibility of total crop loss, even outside the 1 in 20-year scenario. However, VaR for the Bay of Plenty is projected to decline by the mid-century under each RCP scenario and although it is expected to subsequently increase, going into the late century it will remain below its historical values expect for RCP 8.5. Importantly, VaR for the Bay of Plenty is projected to have a significant decline relative to expected yield for both future periods. VaR for the Far North and the Rest of NZ is predicted to increase by the mid-century, with little further change going into the late century, while Whangarei is expected to have a decline in VaR by the mid-century and then an increase by the late century to more or less the historical VaR depending on RCP (see Table 6).

Table 6. Projected mean yield and Value at Risk (VaR) for avocado for the mid-century and late century under three different Representative Concentration Pathways (RCP 4.5, 6.0 and 8.5), and the projected change from a historical period. Results are aggregated by four supply regions.

Avocado projected yields and VaR (tonnes/ha)														
	Historical yield		Mid-century yield						Late century yield					
			RCP 4.5		RCP 6.0		RCP 8.5		RCP 4.5		RCP 6.0		RCP 8.5	
Supply region	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR
Bay of Plenty	12.8	15.8	31.4	11.6	30.7	11.6	35.9	12.0	35.0	12.5	38.7	14.2	43.0	16.9
Far North	13.2	7.7	14.7	9.2	14.6	9.2	14.3	9.4	14.0	9.3	12.6	9.2	11.5	9.3
Rest of NZ	6.4	5.2	12.2	7.7	12.0	7.6	13.9	7.9	12.3	7.7	12.8	7.6	13.5	8.0
Whangarei	8.5	5.7	15.0	7.3	14.7	7.2	16.0	7.9	15.1	8.0	14.8	8.6	14.8	9.6
			Change from historical period											
Bay of Plenty			18.5	-4.2	17.9	-4.2	23.1	-3.8	22.1	-3.3	25.9	-1.6	30.2	1.1
Far North			1.4	1.5	1.3	1.4	1.1	1.6	0.8	1.6	-0.6	1.5	-1.7	1.5
Rest of NZ			5.8	2.4	5.6	2.4	7.5	2.7	5.9	2.4	6.4	2.4	7.1	2.8
Whangarei			6.6	1.6	6.2	1.5	7.5	2.2	6.6	2.3	6.3	3.0	6.3	3.9

The level of increase in mean yield for the Bay of Plenty is considerably more than for other regions, and while these values fall into the range of yearly harvest values across avocado orchards, they suggest a sustained level of production that might be unrealistic. However, examining the contribution of risk factors to VaR for the historical period (Figure 4) can be informative.

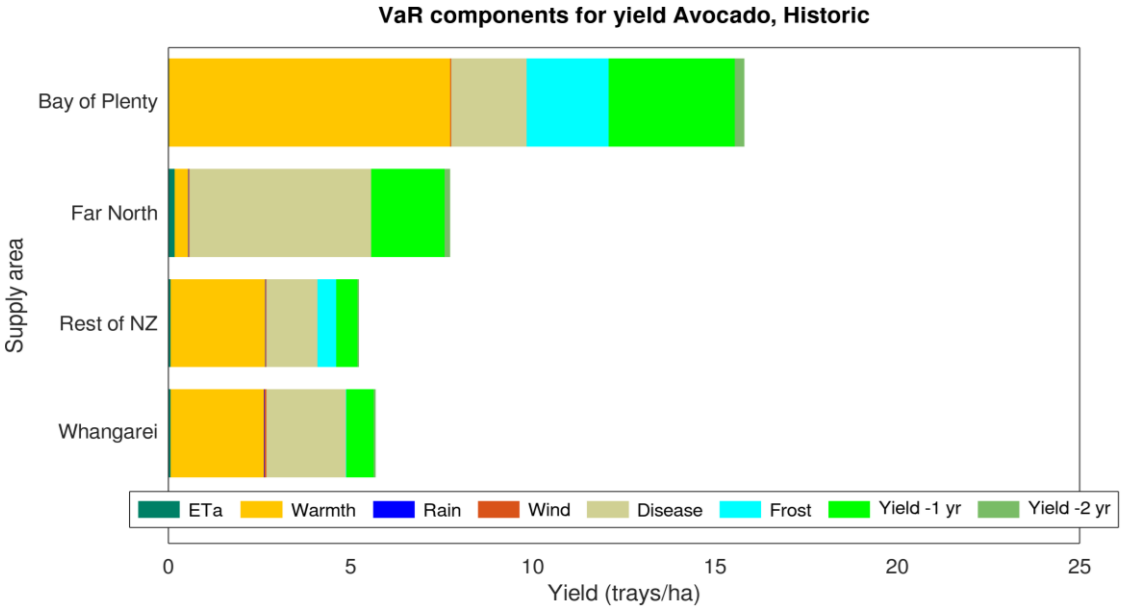


Figure 4. Contribution of different risk factors to Value at Risk (VaR) for avocado yield with a 5% confidence level, plotted for supply regions for the historical period. ETa is actual crop evapotranspiration. Yield -1 yr and Yield -2 yr are the yields from one and two years previous.

Figure 4 shows that much of the risk to production for avocado in the Bay of Plenty is associated with warmth requirement, which also is a major contributor to VaR for the Rest of NZ and Whangarei, while being a minor consideration in the Far North, which has disease at its major risk. An increase in warmth suitability of locations could decrease the contribution of warmth considerations to overall risk and increase yield. Comparison of Table 6 and Figure 4 shows that the regions with highest (lowest) yield gains had the highest (lowest) warmth suitability risks. This accords with the trends in Figure 5 that show a progressive decline in warmth-requirement risk in the mid- and late centuries, with the decline being more pronounced with increased RCP (increased warming).

Concomitantly with warmth-related risks, the risks associated with frost damage also decline, and by the late century are negligible under RCP 6.0 and non-existent under RCP 8.5; however, over time, disease becomes an increasingly dominant component of risk under the warming climates, and this is accentuated under the higher valued RCPs (Figure 5).

The increased dominance of disease in the risk profile could be due purely to the reduction or even disappearance of other risk factors but could also be due to conditions becoming more favourable for disease in some years. For the Far North, which is projected to decline in productivity by the late century under RCP 6.0 and RCP 8.5, the latter is likely.

The reduced impact of risk factors such as warmth suitability and frost will lead to greater production (other factors being equal), and this can result in increased VaR because there is a greater yield at risk from remaining risk factors such as disease, and irregular bearing effects. This can be seen, for example, by comparing the mid-century and late-century VaR and risk components for the Bay of Plenty and Whangarei in Figure 5.

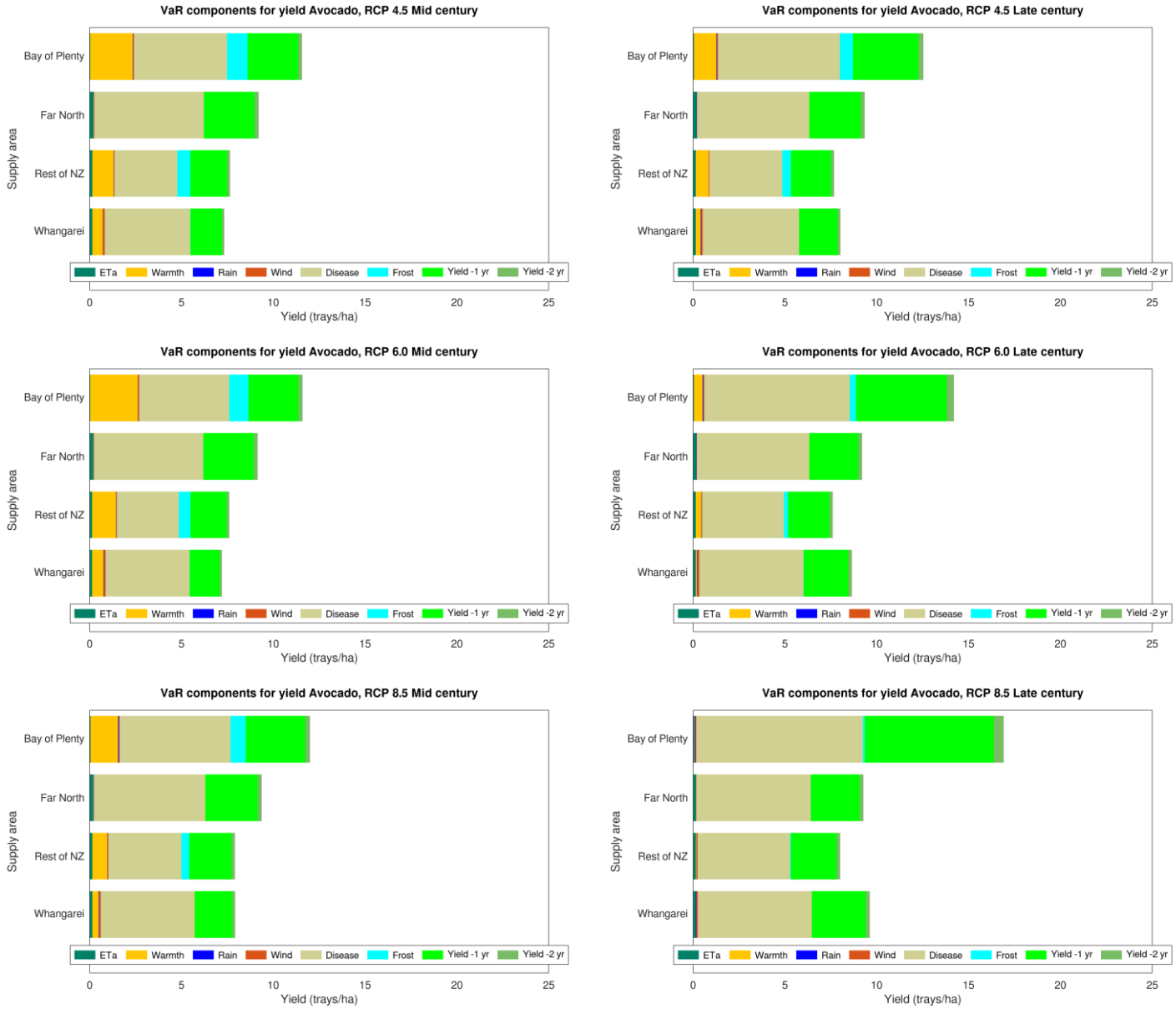


Figure 5. Contribution of different risk factors to Value at Risk (VaR) for avocado yield with a 5% confidence level, plotted for supply regions for the Representative Concentration Pathway (RCP) 4.5 mid-century (upper left) and late century (upper right), RCP 6.0 mid-century (middle left) and late century (middle right) and RCP 8.5 mid-century (lower left) and late century (upper right). ETa is actual crop evapotranspiration. Yield -1 yr and Yield -2 yr are respectively the yields from one and two years previous.

10.2 Kiwifruit VaR

The production models for kiwifruit were used to calculate yearly yield and DM using the parameter values estimated from the model calibration, including values for the multiplier, W_0 that are specific to each KPIN (kiwifruit property identification number). Yields and DM were estimated for 25 harvests for each 26-year period, with the last harvest occurring in the final year of the period. Calculations for the first harvest in a period used data from the first two years of that period.

The calibration data specified whether an orchard block within a KPIN was organic or conventional and whether it grew 'Hayward' or 'Zesy002' kiwifruit. We handled the different cultivars and growing methods in the fitting process by way of dummy variables. However, given the way the data had been structured, the process of assigning each block with corresponding parameters that were specific to cultivar or growing method proved to be intractable, and so simulations were performed at the level of KPINs, some of which could relate to several orchards. Harvest day is driven by commercial decisions, and this was modelled by randomly assigning a harvest day for each KPIN in each simulation, drawing from separate distributions for harvest day between 'Hayward' and 'Zesy002' obtained from the calibration data.

Altogether, 3100 KPINs were used in calibrating the models, and for each of these we performed four simulations for each KPIN: one for each combination of cultivar and growing method. This was done for both yield and DM. Although all four combinations were not represented under each KPIN in the calibration data, this approach allows investigation of the effect of cultivar and growing method for each KPIN. Furthermore, the cultivars and growing methods used in the orchards under a KPIN may change over time.

These calculated yield and DM values were then used to obtain the mean yield and the VaR for yield and for DM at a 5% confidence, separately for each KPIN and period. For presentation purposes, means and VaR were aggregated by supply area, separately for each period. The number of KPINs per supply area are shown in Table 7.

Table 7. Kiwifruit supply areas and number of KPINs (orchard/owner identifiers) per supply area.

Supply region	No. KPINs	Supply region	No. KPINs	Supply region	No. KPINs
Auckland	22	Maketu	98	Tauranga	537
Coromandel	45	Maniatutu	90	Te Puke	645
Franklin	86	Motueka	95	Waihi	50
Golden Bay	8	Nelson	10	Waikato	85
Hawke's Bay	45	Opotiki	222	Wanganui	12
Horowhenua	2	Paengaroa	149	Whakatane	144
Katikati	455	Poverty Bay	64	Whangarei	48
Kerikeri	94	Pukehina	94		

10.2.1 Kiwifruit yield VaR

Conventionally grown 'Hayward'

Calculated mean yield and VaR for conventionally grown 'Hayward' kiwifruit for the historical period are shown in Table 8 along with projected change in mean yield and VaR, from their historical values, for the mid-century and late century under RCP 4.5, RCP 6.0 and RCP 8.5. The decomposition of historical VaR for conventional 'Hayward' into contributions from different risk factors is shown in Figure 6 and similar decompositions for conventional 'Hayward' for future periods is shown in Figure 7 for RCP 6.0 and 8.5.

Predicted historical yield showed large variation between supply areas and ranged from 2900 trays/ha in Horowhenua to 11200 trays/ha in Maketu, with a median of 8800 trays/ha. VaR for yield also showed large variation between supply areas, ranging from a low of 2100 trays/ha for Horowhenua to a high of 7400 trays/ha for Nelson. There was a loose correlation between yield and its VaR, with a median ratio of VaR to yield of 41%.

However, the lowest VaR to yield ratio of 33% was for Whangarei, which although having a similar risk to Horowhenua, had over double the expected yield. Nelson, Waikato and Hawke's Bay with expected yields of, respectively, 8100, 5800 and 5600 trays/ha had very high VaR to yield ratios (respectively, 91%, 90% and 90%), thus the risk exposure in these locations encompasses the potential loss of almost all yield in some years (see Table 8).

By the mid-century, VaR is expected to change for most locations under all three RCPs, with changes in VaR ranging from −1000 to +500 trays/ha for RCP 6.0 and −1200 to + 100 trays/ha under RCP 8.5, with changes under RCP 4.5 being intermediate. The largest increase in VaR occurred for Nelson, while all other locations had either decline in VaR or no change (to the nearest 100 trays). Yield was projected to decline in some areas (with Auckland expected to have the greatest decline, from 2400 to 3400 trays/ha depending on RCP) and increase in others (with Nelson expected to have the greatest increase in yield, from 2600 to 3800 trays/ha depending on RCP) (see Table 8).

With these projected changes, Motueka, Nelson, Maketu, and Golden Bay and Paengaroa would be the top five supply areas in terms of expected yield in the mid-century under RCP 4.5 and 6.0, while under RCP 8.5 Opotiki would displace Paengaroa from the fifth position. All areas except Nelson would experience a reduction in VaR (reduced yield risk). Nelson would remain the supply area with largest risk under all RCPs but would have only a slight increase in VaR under all RCPs, despite having the largest increase in yield.

Projected changes to mean and VaR for the late century with respect to the historical period are qualitatively similar to those projected for the mid-century, with the direction of change generally being maintained, but with generally larger magnitudes of change that increase with RCP. However, under RCP 6.0 and 8.5, more supply areas are projected to experience a decline in yield than an increase, whereas the median change in yield under RCP 4.5 was an increase in yield (Table 8).

In the late century, Nelson is projected to have the largest increase in yield from historical values (3800–6700 trays depending on RCP) while Auckland is projected to have the largest decline (3500–6300 trays/ha depending on RCP). Opotiki is projected to have the largest decline in risk with change in VaR from historical values ranging from −1200 to −2100 trays/ha. Nelson, Motueka, Golden Bay, Maketu and Opotiki would be the top five supply areas in terms of expected yield in the late century, under RCPs 4.5, but Maketu is expected to have relatively lower production under RCP 6.0 and 8.5 and be displaced by respectively Te Puke or Wanganui in the top five supply areas (Table 8).

Table 8. Calculated mean yield and Value at Risk (VaR) for conventionally grown *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit for the mid-century and late century under three different Representative Concentration Pathways (RCP 4.5, 6.0 and 8.5). Results are aggregated by supply area.

Conventional 'Hayward' kiwifruit: Historical yields and VaR, and projected change (1000 trays/ha)													
	Historical yield		Change Historical to mid-century						Change Historical to late century					
			RCP 4.5		RCP 6.0		RCP 8.5		RCP 4.5		RCP 6.0		RCP 8.5	
Supply region	**Mean**	**VaR**	**Hay**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**
Auckland	9.9	3.5	-2.6	-0.4	-2.4	-0.3	-3.4	-0.5	-3.5	-0.5	-4.4	-0.9	-6.3	-1.5
Coromandel	8.1	2.9	-0.6	-0.1	-0.4	0.0	-0.8	0.1	-0.9	0.0	-1.6	-0.1	-3.0	-0.5
Franklin	8.8	3.0	-1.0	-0.1	-0.8	-0.1	-1.2	0.0	-1.5	-0.1	-2.1	-0.1	-3.5	-0.4
Golden Bay	9.2	3.7	1.5	-0.6	1.5	-0.4	1.8	-0.7	2.0	-0.5	2.1	-0.5	2.9	-0.5
Hawke's Bay	5.6	5.1	0.7	-0.3	1.1	-0.1	1.3	-0.5	1.1	-0.5	1.5	-0.8	1.4	-1.2
Horowhenua	2.9	2.1	1.1	-0.2	1.0	-0.2	1.2	-0.2	1.4	-0.2	1.8	-0.3	2.0	-0.5
Katikati	9.4	3.3	-0.1	-0.2	0.0	-0.3	-0.3	-0.2	-0.4	-0.2	-1.0	-0.1	-2.8	-0.3
Kerikeri	7.8	2.7	-1.8	-0.3	-1.6	-0.3	-2.1	-0.3	-2.3	-0.5	-3.0	-0.7	-4.2	-1.1
Maketu	11.2	3.8	-0.6	-0.4	-0.2	-0.5	-0.4	-0.5	-0.8	-0.4	-1.3	-0.4	-3.4	-0.7
Maniatutu	9.5	3.9	0.2	-1.0	0.5	-1.0	0.4	-1.2	0.2	-1.1	-0.1	-1.1	-1.7	-1.1
Motueka	9.0	6.2	2.5	-0.6	2.5	-0.6	3.0	-0.7	3.2	-0.9	3.7	-0.9	4.9	-1.5
Nelson	8.1	7.4	3.3	0.3	2.6	0.5	3.8	0.1	3.8	0.3	5.0	-0.1	6.7	-1.0
Opotiki	8.8	5.4	1.3	-0.8	1.4	-0.9	1.6	-1.2	1.6	-1.2	1.7	-1.6	1.0	-2.1
Paengaroa	10.2	3.9	0.1	-0.8	0.4	-0.8	0.2	-0.9	0.0	-0.8	-0.4	-0.9	-2.2	-1.0
Poverty Bay	8.9	3.5	-0.3	-0.2	0.0	-0.2	-0.2	-0.1	-0.3	-0.1	-0.5	-0.3	-1.7	-0.5
Pukehina	9.4	4.1	0.1	-0.8	0.4	-0.9	0.1	-1.0	0.0	-1.0	-0.4	-1.0	-2.0	-1.2
Tauranga	9.6	3.1	-0.1	-0.3	0.1	-0.3	-0.1	-0.3	-0.3	-0.2	-0.7	-0.2	-2.1	-0.2
Te Puke	9.7	3.8	0.4	-0.8	0.6	-0.8	0.6	-0.9	0.5	-0.9	0.2	-0.9	-1.2	-0.9
Waihi	7.0	3.1	0.2	-0.4	0.3	-0.5	0.2	-0.4	0.1	-0.4	-0.3	-0.5	-1.6	-0.5
Waikato	5.8	5.2	1.5	-0.6	1.6	-0.4	2.1	-0.7	2.1	-0.8	2.4	-1.2	2.1	-1.8
Wanganui	6.4	4.2	2.2	-0.2	2.4	-0.2	2.6	-0.4	2.8	-0.3	3.1	-0.5	3.5	-0.7
Whakatane	7.0	4.1	1.0	-0.8	1.1	-0.7	1.2	-1.0	1.2	-1.0	1.1	-1.3	0.3	-1.5
Whangarei	7.0	2.3	-1.3	-0.1	-1.3	0.0	-1.6	0.0	-1.8	-0.1	-2.3	-0.2	-3.5	-0.5

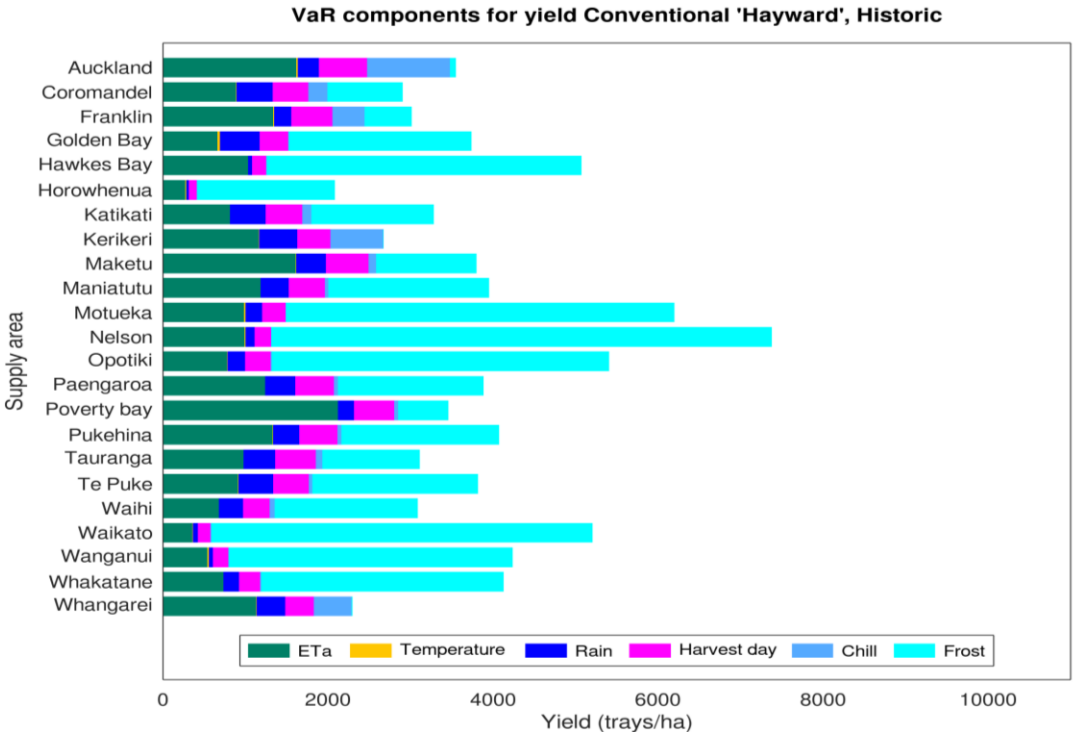


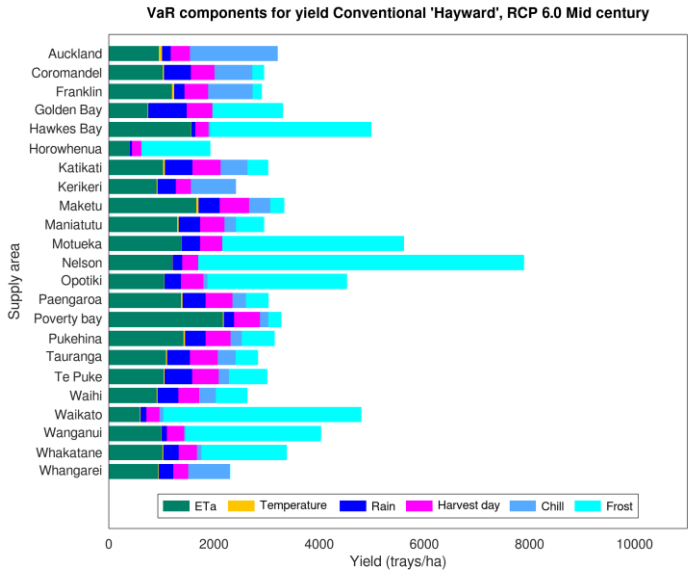
Figure 6. Contribution of different risk factors to Value at Risk (VaR) for yield of conventionally grown *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit for a 5% confidence level, plotted for supply regions for the historical period. ETa is actual crop evapotranspiration.

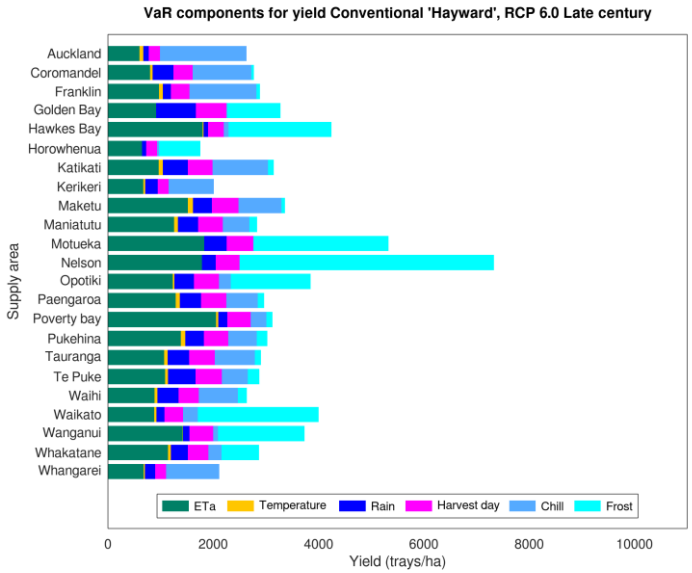
Auckland, Kerikeri and Whangarei are expected to decline in production to be (along with Horowhenua) consistently in or near the lower quartile of supply areas by production in both the mid- and late century (Table 8).

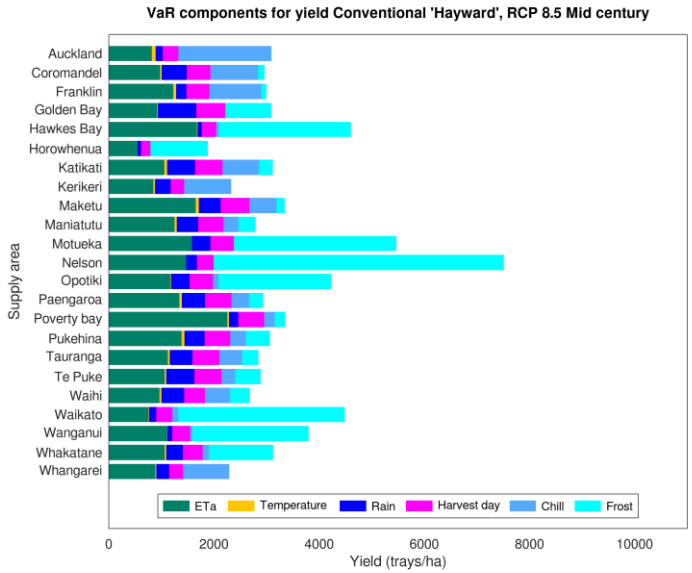
The decomposition of VaR into contributions from different risks in Figure 6 shows that frost damage is generally the most significant contributor to risk, especially in Nelson, Motueka, Waikato, and Horowhenua. Warmer supply areas such as Auckland, Kerikeri and Whangarei have little or no frost risk, but for them, and others such as Franklin, lack of winter chill is a risk despite the use of Hi-Cane. Lack of winter chill is not a large relative contributor to risk in these areas, except for Auckland. Damage from rain increases risks by a small amount in some locations. Delaying day of harvest can increase the risk from frost or rain.

Another key risk indicated in Figure 6 is that associated with crop evapotranspiration, which can be limited by low soil moisture levels due to low rainfalls and lack of irrigation. For several supply areas, especially Poverty Bay, this was the major risk component to VaR.

Figure 7 shows the contribution of factors to VaR for the mid- and late century under RCP 6.0 and RCP 8.5. Compared with the historical period, under RCP 6.0 there is a noticeable reduction in the contribution of frost to the risk profile in several areas by the mid-century and an increase or appearance of lack of chill as a contributor to risk. The risk associated with crop evapotranspiration decrease in some areas, such as Auckland and Whangarei, while increasing in other areas like Hawke's Bay, Motueka, Whakatane and Wanganui. Changes to risk from rain vary between positive and negative between supply areas. The risks from non-optimal temperature are negligible in all supply areas in the historical period and mid-century periods under all RCPs, and similarly in the late century, although having shown some increase (Figure 7) from the mid-century.







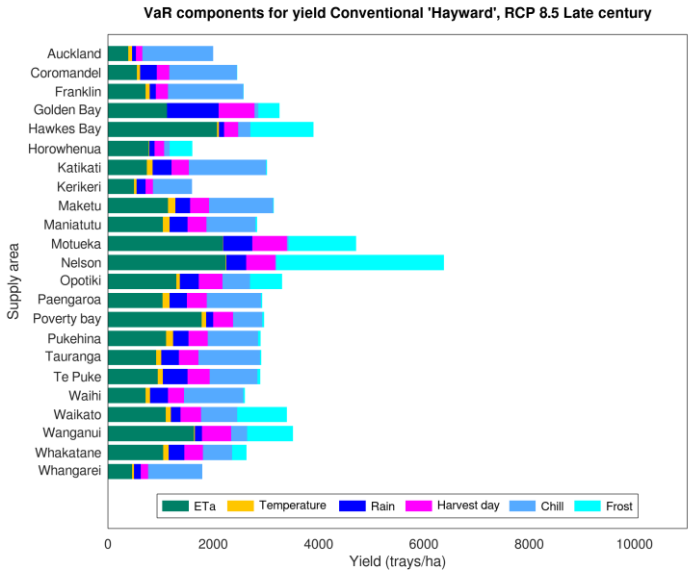


Figure 7. Contribution of different risk factors to Value at Risk (VaR) for yield in conventionally grown *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit yield with a 5% confidence level, plotted for supply areas, for the Representative Concentration Pathway (RCP) 6.0 mid-century (upper left) and late century (upper right), and RCP 8.5 mid-century (lower left) and late century (upper right). ETa is actual crop evapotranspiration.

Although there are apparent changes to risks associated with harvest day, it is important to bear in mind that harvest day was randomly simulated for each simulation, and for supply areas with small numbers of KPINs such as Horowhenua, this can lead to large fluctuations in effect.

For the mid-century, the RCP 8.5 VaR profile is qualitatively similar to that under RCP 6.0, but with smaller contributions from frost and larger contributions from lack of chill. The trend of increasing risk from lack of winter chill and decreasing risk from frost is projected to continue into the late century under both RCP 6.0 and 8.5 (Figure 7). However, frost remains the predominant risk for areas such as Nelson, Motueka, Hawke's Bay, Waikato and Wanganui under RCP 6.0. Under RCP 8.5, frost also remains the predominant risk for Nelson, and a significant risk for Motueka, Hawke's Bay, Waikato and Wanganui. Lack of winter chill is projected to become the predominant risk for several supply areas under RCP 6.0, and more so under RCP 8.5.

Organically grown 'Hayward'

Calculated mean yield and VaR for organic 'Hayward' kiwifruit for the historical period are shown in Table 9 along with projected change in mean yield and VaR, from their historical values, for the mid-century and late century under RCP 4.5, RCP 6.0 and RCP 8.5. The decomposition of historical VaR for conventional 'Hayward' into contributions from different risk factors is shown in Figure 8 and similar decompositions for conventional 'Hayward' for future periods is shown in Figure 9 for RCP 6.0 and 8.5.

As with conventionally grown 'Hayward,' predicted historical yield for organic 'Hayward' showed large variation between supply areas and the range in yield was very similar, from 2900 trays/ha in Horowhenua to 11,000 trays/ha in Maketu. The median projected yield for the historical period was slightly lower at 8700 trays/ha. VaR for yield also showed the same variation between supply areas, from 2100 trays/ha for Horowhenua to 7400 trays/ha in Nelson: there was essentially no or very little (~100 trays/ha) difference in predictions for VaR between organic and conventional 'Hayward' for the historical period (see Table 9).

Differences in yield between conventional and organic 'Hayward' were generally very small for the historic period, with conventionally grown yields being on average slightly higher than organically grown yields. However, for Auckland and Kerikeri, predicted yields were 700 trays/ha (7% to 9%) higher under conventional growing than organic growing and in these areas chill was a significant contributor to VaR (see Figure 6 and Figure 8). That the difference was not greater may be due to Hi-Cane not being used optimally on conventional orchards.

Projected decline for the mid-century and late century for organic 'Hayward' (see Table 9) followed similar patterns to those for conventional 'Hayward', but generally with larger losses and smaller gains in yield for some supply areas, with the greatest divergence occurring in warmer areas. Generally, the relative rankings of supply areas were the same for organic as for conventional 'Hayward' for all time periods. With the projected changes, Motueka, Nelson and Golden Bay would consistently be the top three supply areas in terms of expected yield in both the mid- and late century under all RCPs.

Table 9. Calculated mean yield and Value at Risk (VaR) for organic *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit for the mid-century and late century under three different Representative Concentration Pathways (RCP 4.5, 6.0 and 8.5). Results are aggregated by supply area.

Organic 'Hayward' kiwifruit: Historical yields and VaR, and projected change (1000 trays/ha)														
	Historical yield		Change Historical to mid-century						Change Historical to late century					
			RCP 4.5		RCP 6.0		RCP 8.5		RCP 4.5		RCP 6.0		RCP 8.5	
Supply region	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**
Auckland	9.2	3.7	-2.9	-0.4	-2.8	-0.4	-3.8	-0.5	-3.9	-0.6	-4.8	-1.1	-6.6	-1.9
Coromandel	7.9	3.0	-0.8	0.0	-0.6	0.1	-1.1	0.1	-1.2	0.1	-2.1	-0.1	-3.6	-0.5
Franklin	8.4	3.1	-1.2	0.0	-1.0	0.0	-1.5	0.0	-1.8	-0.1	-2.4	-0.1	-4.0	-0.5
Golden Bay	9.1	3.7	1.4	-0.6	1.5	-0.4	1.8	-0.7	2.0	-0.5	2.1	-0.5	2.8	-0.5
Hawke's Bay	5.6	5.0	0.7	-0.3	1.0	-0.1	1.2	-0.5	1.0	-0.5	1.3	-0.9	1.1	-1.2
Horowhenua	2.9	2.1	1.1	-0.2	0.9	-0.2	1.2	-0.2	1.3	-0.2	1.7	-0.3	1.9	-0.5
Katikati	9.2	3.3	-0.3	-0.1	-0.2	-0.1	-0.6	0.0	-0.8	0.0	-1.5	0.0	-3.5	-0.2
Kerikeri	7.1	2.7	-1.9	-0.4	-1.8	-0.3	-2.3	-0.5	-2.5	-0.6	-3.2	-0.8	-4.4	-1.3
Maketu	11.0	3.8	-0.8	-0.4	-0.4	-0.4	-0.8	-0.4	-1.2	-0.3	-1.8	-0.3	-4.1	-0.6
Maniatutu	9.4	3.9	0.1	-0.9	0.3	-1.0	0.2	-1.1	-0.1	-1.0	-0.5	-1.0	-2.3	-1.0
Motueka	9.0	6.2	2.5	-0.6	2.5	-0.6	2.9	-0.7	3.2	-0.9	3.7	-0.9	4.8	-1.5
Nelson	8.1	7.4	3.3	0.3	2.6	0.5	3.7	0.1	3.8	0.3	4.9	-0.1	6.5	-1.0
Opotiki	8.7	5.4	1.1	-0.8	1.3	-0.9	1.4	-1.2	1.4	-1.3	1.4	-1.6	0.4	-2.1
Paengaroa	10.0	3.8	-0.1	-0.8	0.1	-0.8	0.0	-0.9	-0.3	-0.7	-0.8	-0.8	-2.8	-0.8
Poverty Bay	8.8	3.4	-0.5	-0.2	-0.1	-0.2	-0.4	-0.1	-0.5	-0.1	-0.8	-0.4	-2.1	-0.5
Pukehina	9.3	4.0	-0.1	-0.8	0.2	-0.9	-0.1	-1.0	-0.3	-0.9	-0.8	-1.0	-2.6	-1.1
Tauranga	9.4	3.1	-0.3	-0.2	-0.1	-0.2	-0.4	-0.2	-0.6	-0.1	-1.1	-0.1	-2.7	-0.1
Te Puke	9.6	3.8	0.2	-0.7	0.4	-0.8	0.4	-0.9	0.2	-0.8	-0.1	-0.8	-1.8	-0.8
Waihi	6.9	3.1	0.1	-0.3	0.2	-0.4	0.0	-0.3	-0.2	-0.3	-0.6	-0.3	-2.1	-0.4
Waikato	5.7	5.2	1.4	-0.6	1.5	-0.4	1.9	-0.7	1.9	-0.8	2.2	-1.2	1.7	-1.7
Wanganui	6.4	4.2	2.1	-0.3	2.4	-0.2	2.5	-0.5	2.7	-0.3	3.0	-0.5	3.2	-0.7
Whakatane	6.9	4.1	0.9	-0.8	0.9	-0.7	1.0	-1.0	1.0	-1.0	0.8	-1.2	-0.2	-1.4
Whangarei	6.6	2.4	-1.5	-0.1	-1.5	0.0	-1.8	-0.1	-2.0	-0.2	-2.6	-0.3	-3.8	-0.7

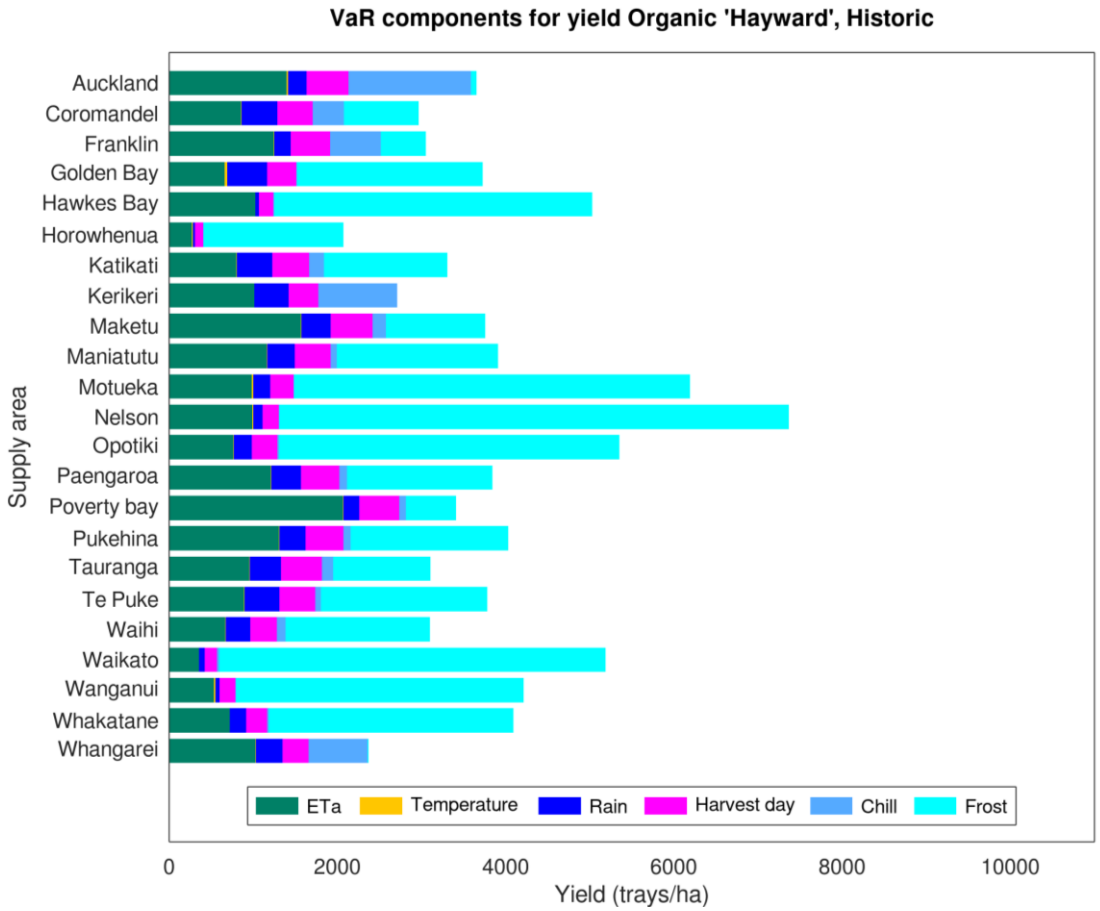


Figure 8. Contribution of different risk factors to Value at Risk (VaR) for yield of organic *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit for a 5% confidence level, plotted for supply regions for the historical period. ETa is actual crop evapotranspiration.

The main difference between conventional and organic 'Hayward' lies in the impact of lack of chill, which is exacerbated under warming climates especially in warmer areas. This can be seen from the decomposition of VaR for the historical period in Figure 8 and for future periods under RCP 6.0 and 8.5 (Figure 9). The increased susceptibility of organically grown 'Hayward' to lack of chill, compared with conventional 'Hayward', is reflected in increases in VaR for the historical period for Auckland, Kerikeri, Whangarei, Franklin and Coromandel. In these areas, the contribution of other risk factors to VaR will be decreased since the impact of the increased susceptibility to lack of chill is to decrease yield, leaving less production at risk from other factors.

Similarly, the smaller contributions to VaR from risks relating to frost and crop evapotranspiration that are depicted for the future periods for organic 'Hayward' (Figure 9) compared with those depicted for the future periods for conventional 'Hayward' (Figure 7) are due to reduced yields from lack of chill, rather than a difference in the intrinsic susceptibility of the growing methods to frosts or to lack of soil moisture.

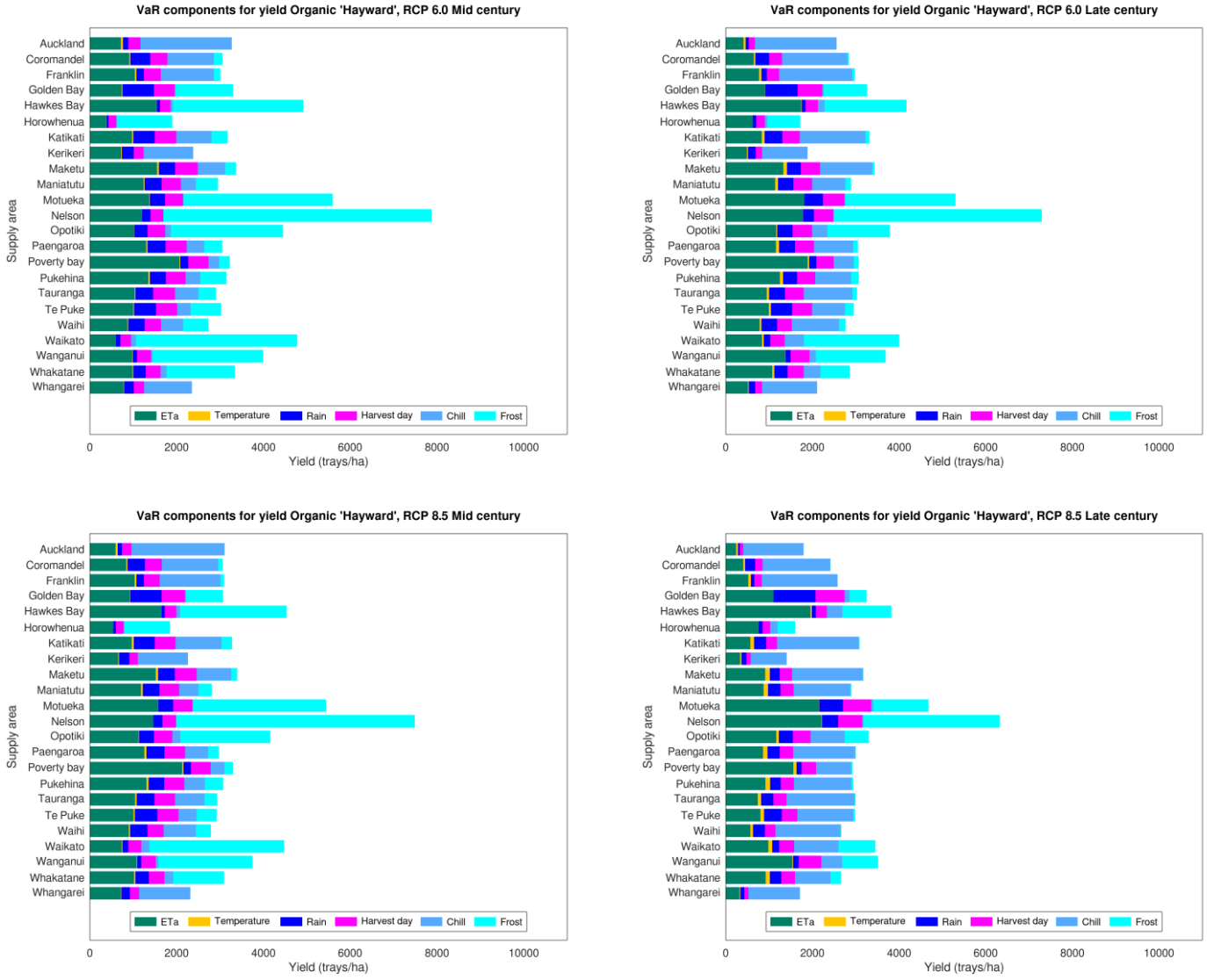


Figure 9. Contribution of different risk factors to Value at Risk (VaR) for yield in organically grown *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit yield with a 5% confidence level, plotted for supply areas, for the Representative Concentration Pathway (RCP) 6.0 mid-century (upper left) and late century (upper right), and RCP 8.5 mid-century (lower left) and late century (upper right). ETa is actual crop evapotranspiration.

Conventionally grown 'Zesy002'

Calculated mean yield and VaR for conventionally grown 'Zesy002' kiwifruit for the historical period are shown in Table 10 along with projected change in mean yield and VaR, from their historical values, for the mid-century and late century under RCP 4.5, RCP 6.0 and RCP 8.5. The decomposition of historical VaR for conventional 'Zesy002' into contributions from different risk factors is shown in Figure 10, and similar decompositions for conventional 'Zesy002' for future periods is shown in Figure 11 for RCP 6.0 and 8.5.

Predicted historical yield showed large variation between supply areas and ranged from 4600 trays/ha in Horowhenua to 15,500 trays/ha in Maketu, with a median of 12,700 trays/ha. VaR for yield also showed large variation between supply areas, ranging from a low of 2600 trays/ha for Horowhenua to a high of 9800 trays/ha for Nelson. The highest and lowest ranked supply areas in terms of these metrics are the exactly the same as for conventional 'Hayward'. However, the relative ranking between supply areas was not the same for conventional 'Zesy002' as for conventional 'Hayward'. While both Te Puke and Tauranga were among the top five yielding supply areas for conventional 'Hayward' in the historical period, for conventional 'Zesy002' their yields were in the second quartile. Conversely, Nelson and Motueka, whose yields for conventional 'Hayward' were, respectively, below or closely above the median yield, were in the top five yielding supply areas for 'Zesy002'.

The median VaR to yield ratio was 38%. VaR to yield ratio was lowest for Franklin (26%), and highest for Nelson, Waikato and Hawke's Bay (respectively 69%, 71% and 79%). as shown in Table 10.

By the mid-century, VaR for conventional 'Zesy002' is projected to decline for most supply areas (or remain unchanged in a handful) under all three RCPs, with declines in VaR having a median and maximum of 500 and 1100 trays/ha, respectively, for RCP 4.5 and 600 and 1600 trays/ha for RCP 8.5, with changes under RCP 6.0 being intermediate. Yield was projected to decline in some areas (with Auckland expected to have the greatest decline, from 1600 to 2500 trays/ha depending on RCP) and increase in others (with Nelson expected to have the greatest increase in yield, from 3100 to 4400 trays/ha depending on RCP) (Table 10).

With these projected changes, Motueka, Nelson, Maketu, Paengaroa and Opotiki would be the top five supply areas in terms of expected yield in the mid-century. Auckland production would decline from the second highest in the historical period to having production at or below the median yield across the different RCPs. Despite having a decrease in VaR under all RCPs, Nelson would remain the supply area with largest risk.

Projected changes to mean yield for the late century with respect to the historical period are similar in pattern to those projected for the mid-century, in that they range from significant decreases to significant increases in yield. As for the mid-century, Auckland was predicted to have the largest decreases in yield (declines of 2600, 3300 and 5700 trays/ha under, respectively, RCP 4.5, 6.0 and 8.5) and Nelson the largest increase (4500, 5700 and 7300 trays/ha under, respectively, RCP 4.5, 6.0 and 8.5). The ordering of the other supply areas in terms of change was not always the same as for the mid-century. VaR was projected to decline for all supply areas by up to 1500 to 2600 tray/ha (depending on RCP) with the exception of Franklin, which was projected to have no or a very small increase in VaR under RCP4.5 and 6.0, respectively.

Table 10. Calculated mean yield and Value at Risk (VaR) for conventionally grown *Actinidia chinensis* var. *chinensis* 'Zesy002' kiwifruit for the mid-century and late century under three different Representative Concentration Pathways (RCP 4.5, 6.0 and 8.5). Results are aggregated by supply area.

Conventional 'Zesy002' kiwifruit: Historical yields and VaR, and projected change (1000 trays/ha)														
	Historical yield		Change Historical to mid-century						Change Historical to late century					
			RCP 4.5		RCP 6.0		RCP 8.5		RCP 4.5		RCP 6.0		RCP 8.5	
Supply region	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**
Auckland	14.4	4.2	-1.8	-0.5	-1.6	-0.3	-2.5	-0.4	-2.6	-0.4	-3.3	-0.7	-5.7	-1.2
Coromandel	11.1	3.6	-0.3	-0.2	-0.2	-0.1	-0.4	-0.1	-0.3	-0.2	-0.8	-0.1	-2.1	-0.3
Franklin	12.7	3.4	-0.7	0.1	-0.5	0.1	-0.9	0.2	-1.1	0.0	-1.5	0.1	-2.8	-0.1
Golden Bay	12.5	4.3	1.5	-0.3	1.5	-0.1	1.8	-0.4	2.0	-0.3	2.1	-0.2	2.5	-0.1
Hawke's Bay	8.9	7.1	0.9	-0.4	1.3	-0.4	1.7	-0.6	1.4	-0.7	1.9	-1.1	1.9	-1.6
Horowhenua	4.6	2.6	1.4	0.0	1.3	0.1	1.3	-0.4	1.7	-0.2	2.3	-0.3	2.6	-0.7
Katikati	12.9	3.9	0.3	-0.4	0.4	-0.5	0.1	-0.4	0.1	-0.3	-0.3	-0.4	-1.8	-0.4
Kerikeri	11.6	3.3	-1.3	-0.2	-1.0	-0.1	-1.4	-0.3	-1.5	-0.3	-2.2	-0.5	-3.5	-0.7
Maketu	15.5	4.9	-0.3	-0.5	0.1	-0.7	-0.1	-0.7	-0.2	-0.6	-0.5	-0.8	-2.5	-0.9
Maniatutu	13.2	5.0	0.5	-1.1	0.9	-1.2	0.8	-1.4	0.7	-1.2	0.6	-1.5	-0.8	-1.6
Motueka	13.9	6.8	2.7	-0.6	2.7	-0.7	3.1	-0.7	3.3	-0.7	3.9	-0.7	5.2	-1.0
Nelson	14.1	9.8	3.7	-0.3	3.1	-0.4	4.4	-0.3	4.5	-0.7	5.7	-0.9	7.3	-1.8
Opotiki	12.7	7.1	1.6	-1.1	1.8	-1.3	2.1	-1.6	2.1	-1.7	2.5	-2.2	2.0	-2.9
Paengaroa	14.0	5.0	0.3	-1.0	0.7	-1.1	0.6	-1.2	0.5	-1.1	0.3	-1.3	-1.3	-1.4
Poverty Bay	12.6	4.7	-0.4	-0.3	0.2	-0.3	0.1	-0.2	-0.1	-0.2	-0.2	-0.4	-1.2	-0.6
Pukehina	13.1	5.2	0.3	-1.0	0.6	-1.1	0.5	-1.3	0.4	-1.2	0.2	-1.4	-1.2	-1.5
Tauranga	12.9	3.9	0.2	-0.4	0.4	-0.5	0.3	-0.5	0.2	-0.5	0.0	-0.5	-1.2	-0.4
Te Puke	13.1	4.8	0.7	-0.9	0.9	-1.0	1.0	-1.2	1.0	-1.2	0.9	-1.3	-0.2	-1.4
Waihi	9.7	3.7	0.5	-0.6	0.6	-0.6	0.5	-0.6	0.5	-0.7	0.3	-0.7	-0.8	-0.6
Waikato	9.7	6.8	1.9	-0.9	2.3	-0.9	2.7	-1.4	2.6	-1.6	3.1	-2.2	2.9	-2.6
Wanganui	9.8	6.2	2.5	-0.4	3.1	-0.5	3.4	-0.6	3.4	-0.7	4.2	-1.2	4.9	-1.7
Whakatane	10.1	5.5	1.5	-0.8	1.6	-0.9	1.9	-1.2	1.9	-1.2	2.2	-1.4	2.2	-1.8
Whangarei	10.0	2.9	-0.7	-0.1	-0.5	0.0	-0.7	0.0	-0.8	0.0	-1.1	-0.2	-1.8	-0.2

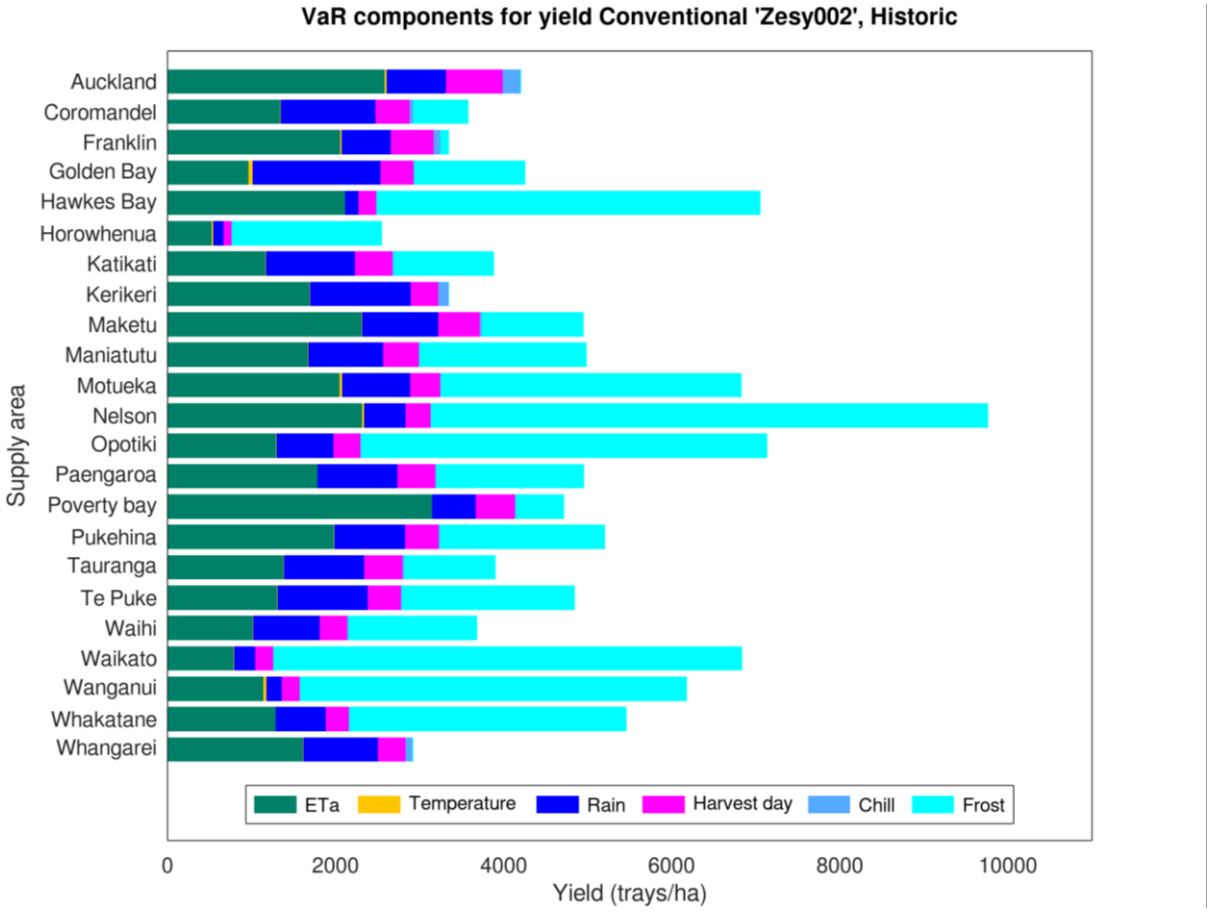
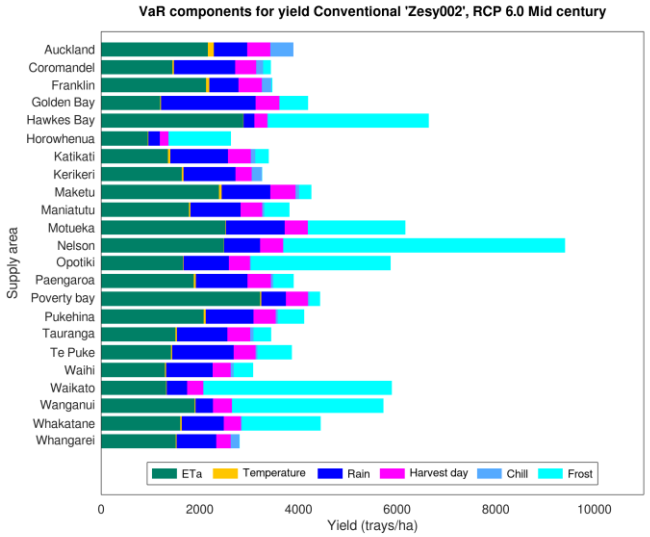


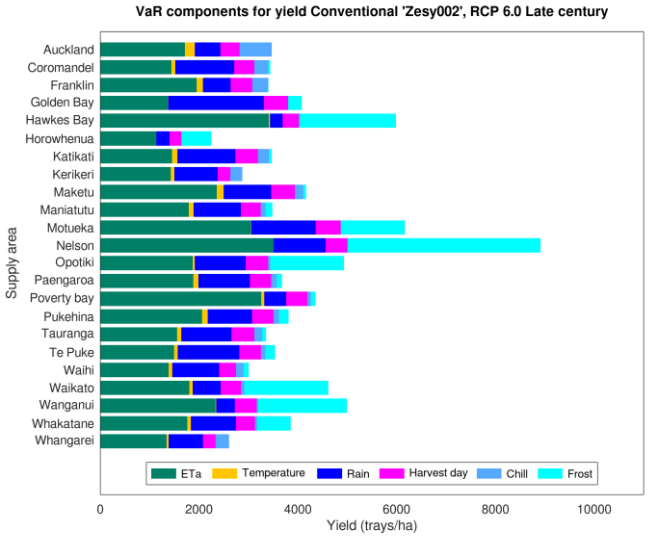
Figure 10. Contribution of different risk factors to Value at Risk (VaR) for yield of conventionally grown *Actinidia chinensis* var. *chinensis* 'Zesy002' kiwifruit for a 5% confidence level, plotted for supply regions for the historical period. ETa is actual crop evapotranspiration.

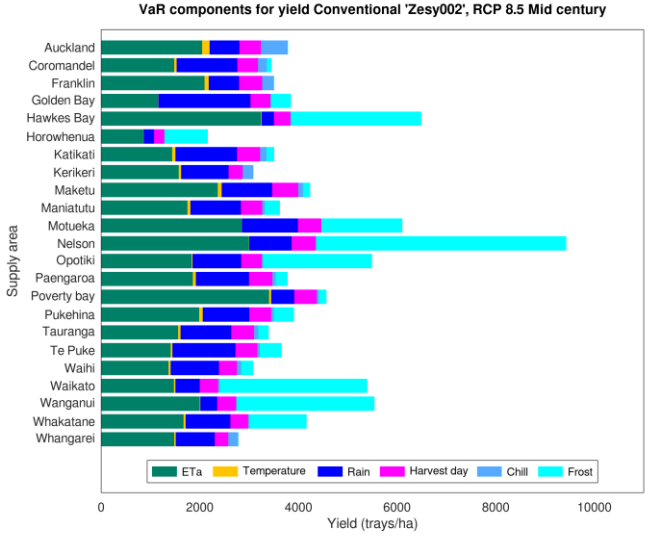
Projections under RCP 4.5 place Motueka, Nelson, Maketu, Opotiki and Paengaroa as the top five production areas by volume in the late century. Under RCP 6.0, Golden Bay is projected to displace Paengaroa as the fifth most productive area. Parallel to the projection for 'Hayward', under RCP 8.5, the conditions for the Wanganui supply area have improved substantially from its historical ranking at the bottom of the second quartile into the top five producing areas at the expense of Maketu.

The decomposition of VaR for conventionally grown 'Zesy002' in Figure 10 shows that insufficient winter chill for the historical period is a very small risk for Auckland, Kerikeri and Whangarei, and negligible in other supply areas. As with 'Hayward', frost damage is generally the most significant contributor to risk in many areas. However, warmer supply areas such as Auckland, Kerikeri, Franklin and Whangarei have little or no frost risk, but alongside others areas, especially Poverty Bay, have the risk of low crop evapotranspiration as a major risk.

Another key difference between the risk profiles is that rain damage is a notably larger contributor to VaR for 'Zesy002' than for 'Hayward'. The greater susceptibility of 'Zesy002' to damage from rain, compared with 'Hayward', is reflected in the different values of the parameter p_4 that were fitted for the two cultivars (see Table 2).







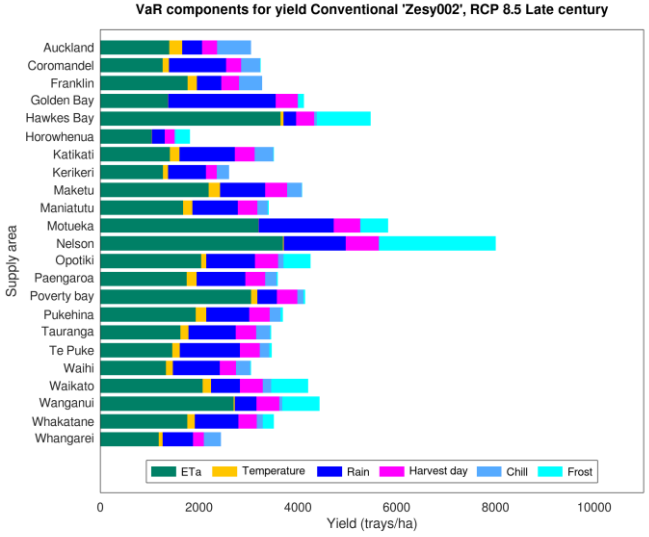


Figure 11. Contribution of different risk factors to Value at Risk (VaR) for yield in conventionally grown *Actinidia chinensis* var. *chinensis* 'Zesy002' kiwifruit yield with a 5% confidence level, plotted for supply areas, for the Representative Concentration Pathway (RCP) 6.0 mid-century (upper left) and late century (upper right), and RCP 8.5 mid-century (lower left) and late century (upper right). ETa is actual crop evapotranspiration.

However, at least some of the greater contributions of risk factors to VaR for 'Zesy002' compared with 'Hayward' will be due purely to yield for 'Zesy002' being higher.

The projected VaR decomposition in Figure 11 depicts frost risk substantially declining by the mid-century and further still by the late century, with declines being more pronounced for RCP 8.5 than RCP 6.0 as would be expected. However, frost risk will still be a major issue in regions such as Nelson, Hawke's Bay, Wanganui and Waikato. Concomitantly, low crop evapotranspiration (which could be associated with drought) and rain damage will become more important risk factors. The risk of excessive temperatures, which is negligible for the historical and mid-century periods, is projected to increase by the late century, more so under RCP 8.5, but will remain a very minor impact.

Organically grown 'Zesy002'

Calculated mean yield and VaR for conventionally grown 'Zesy002' kiwifruit for the historical period are shown in Table 11 along with projected change in mean yield and VaR, from their historical values, for the mid-century and late century under RCP 4.5, RCP 6.0 and RCP 8.5. The decomposition of historical VaR for conventional 'Zesy002' into contributions from different risk factors is shown in Figure 12 and similar decompositions for conventional 'Zesy002' for future periods is shown in Figure 13 for RCP 6.0 and 8.5.

The main impact on organic 'Zesy002' compared with conventionally grown 'Zesy002' is lack of winter chill, and in each supply region, production of organic 'Zesy002' was either the same as or lower than production of conventional 'Zesy002', with the biggest reductions being in warmer areas. Differences in yield between conventional and organic growing were generally very small for the historical period, but for Auckland and Kerikeri predicted yields were 700 trays/ha lower for organic versus conventional 'Zesy002', reflecting the greater risk from lack of chill in these areas (see in Figure 12).

Predictions for historical yield for organics 'Zesy002' were therefore similar to conventional 'Zesy002', ranging from 4600 trays/ha in Horowhenua to 15,300 trays/ha in Maketu, with a median of 12,500 trays/ha. Predicted VaR for yield was from 0 to 100 tray/ha lower for the organic crop. There are differences in the rankings by yield of the supply areas between the organic and conventional crops because of the differences in lack of chill between areas.

Projected changes in production and VaR for organic 'Zesy002' were very similar to those projected for conventional 'Zesy002', with the organic crop being more adversely affected in warmer areas and declining more by the late century compared with the mid-century, and more under RCP 8.5 than under RCP 6.0 than under RCP 4.5.

As expected, the VaR decomposition for organic 'Zesy002' (Figure 12) differs from that for conventional 'Zesy002' (Figure 10) in having a slightly higher winter chill risk in a few warmer supply areas, and comparison of Figure 13 with Figure 11 shows there is only a small additional effect from warming climates. This is because the difference between organic and conventional methods in their fitted value for the chill sensitivity parameter, p_1, is much smaller for 'Zesy002' than for 'Hayward'.

Table 11. Calculated mean yield and Value at Risk (VaR) for organic *Actinidia chinensis* var. *chinensis* 'Zesy002' kiwifruit for the mid-century and late century under three different Representative Concentration Pathways (RCP 4.5, 6.0 and 8.5). Results are aggregated by supply area.

Organic 'Zesy002' kiwifruit: Historical yields and VaR, and projected change (1000 trays/ha)														
	Historical yield		Change Historical to mid-century						Change Historical to late century					
			RCP 4.5		RCP 6.0		RCP 8.5		RCP 4.5		RCP 6.0		RCP 8.5	
Supply region	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**
Auckland	13.7	4.2	-2.3	-0.4	-2.1	-0.3	-3.2	-0.4	-3.3	-0.4	-4.2	-0.8	-6.7	-1.4
Coromandel	10.9	3.6	-0.6	-0.2	-0.4	-0.1	-0.7	-0.1	-0.7	-0.2	-1.4	-0.1	-2.9	-0.4
Franklin	12.3	3.3	-0.9	0.1	-0.8	0.2	-1.2	0.2	-1.5	0.0	-2.0	0.1	-3.6	-0.1
Golden Bay	12.5	4.3	1.5	-0.3	1.5	-0.1	1.8	-0.4	1.9	-0.3	2.1	-0.2	2.4	-0.1
Hawke's Bay	8.8	7.0	0.9	-0.4	1.2	-0.4	1.6	-0.6	1.3	-0.7	1.8	-1.1	1.6	-1.6
Horowhenua	4.6	2.5	1.4	-0.1	1.3	0.1	1.3	-0.4	1.7	-0.2	2.3	-0.3	2.4	-0.8
Katikati	12.7	3.9	0.0	-0.3	0.1	-0.4	-0.2	-0.3	-0.3	-0.2	-0.8	-0.3	-2.7	-0.3
Kerikeri	10.9	3.3	-1.6	-0.3	-1.3	-0.2	-1.9	-0.3	-2.0	-0.4	-2.8	-0.6	-4.3	-1.0
Maketu	15.3	4.9	-0.6	-0.5	-0.1	-0.7	-0.4	-0.7	-0.6	-0.6	-1.0	-0.8	-3.4	-0.9
Maniatutu	13.0	4.9	0.4	-1.1	0.7	-1.2	0.6	-1.4	0.4	-1.2	0.2	-1.5	-1.5	-1.6
Motueka	13.9	6.8	2.6	-0.6	2.6	-0.7	3.1	-0.7	3.3	-0.7	3.9	-0.7	5.1	-1.0
Nelson	14.1	9.8	3.7	-0.3	3.1	-0.4	4.3	-0.3	4.5	-0.7	5.7	-0.9	7.2	-1.8
Opotiki	12.6	7.1	1.5	-1.2	1.7	-1.3	2.0	-1.7	1.9	-1.8	2.1	-2.3	1.4	-2.9
Paengaroa	13.9	4.9	0.1	-1.0	0.5	-1.1	0.3	-1.2	0.2	-1.1	-0.2	-1.3	-2.0	-1.3
Poverty Bay	12.4	4.7	-0.5	-0.4	0.1	-0.3	-0.1	-0.2	-0.3	-0.2	-0.5	-0.4	-1.7	-0.7
Pukehina	13.0	5.2	0.1	-1.0	0.4	-1.1	0.3	-1.3	0.1	-1.2	-0.2	-1.4	-1.9	-1.5
Tauranga	12.8	3.9	0.0	-0.4	0.2	-0.4	0.0	-0.5	-0.1	-0.4	-0.5	-0.5	-1.9	-0.4
Te Puke	12.9	4.8	0.5	-0.9	0.7	-1.0	0.7	-1.2	0.7	-1.1	0.5	-1.3	-0.9	-1.4
Waihi	9.6	3.7	0.4	-0.5	0.4	-0.5	0.2	-0.5	0.2	-0.6	-0.1	-0.6	-1.4	-0.6
Waikato	9.6	6.8	1.8	-0.9	2.2	-1.0	2.5	-1.4	2.4	-1.6	2.9	-2.2	2.3	-2.6
Wanganui	9.8	6.1	2.4	-0.4	3.0	-0.5	3.3	-0.7	3.3	-0.7	4.0	-1.2	4.5	-1.8
Whakatane	10.0	5.4	1.4	-0.9	1.5	-0.9	1.7	-1.2	1.7	-1.2	1.9	-1.4	1.6	-1.8
Whangarei	9.6	2.9	-1.0	-0.1	-0.8	0.0	-1.1	0.0	-1.2	0.0	-1.7	-0.2	-2.6	-0.3

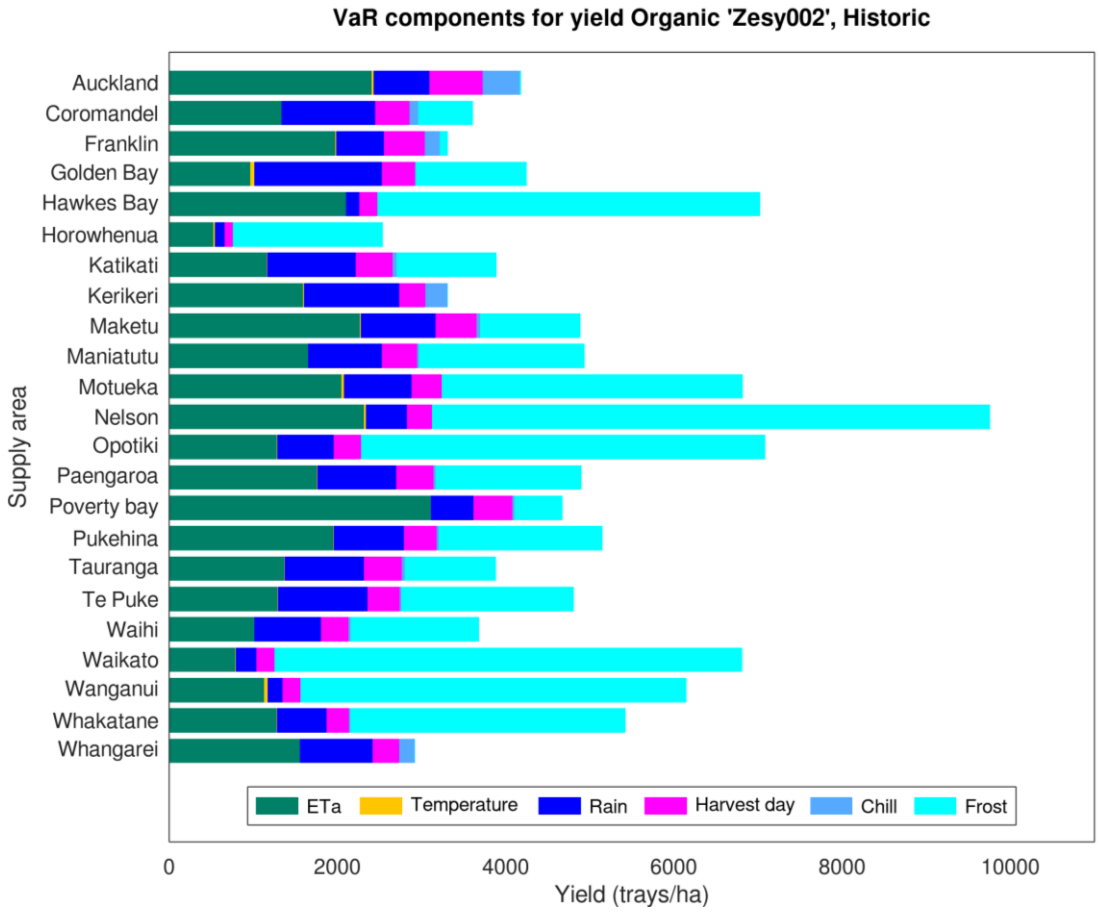
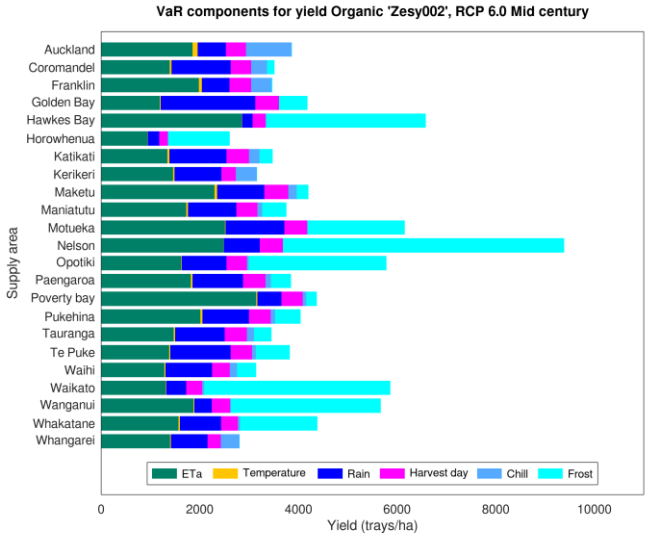
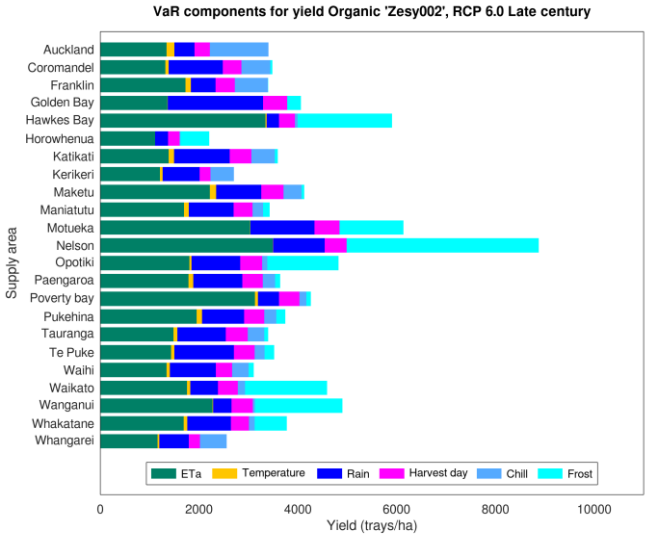
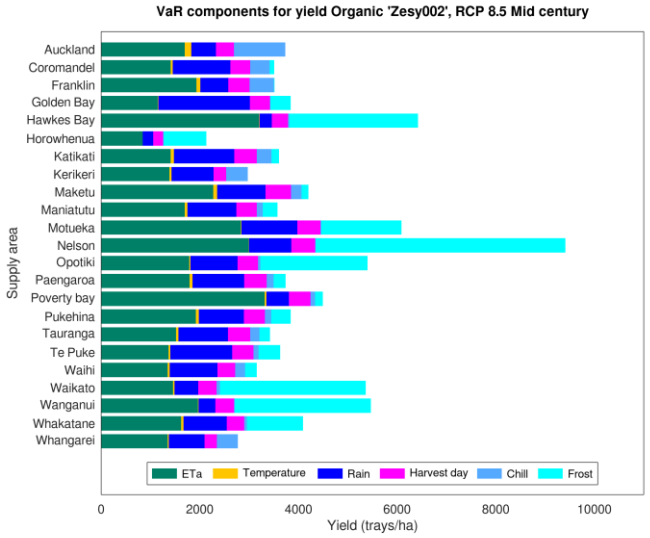


Figure 12. Contribution of different risk factors to Value at Risk (VaR) for yield of organic *Actinidia chinensis* var. *chinensis* 'Zesy002' kiwifruit for a 5% confidence level, plotted for supply regions for the historical period. ETa is actual crop evapotranspiration.







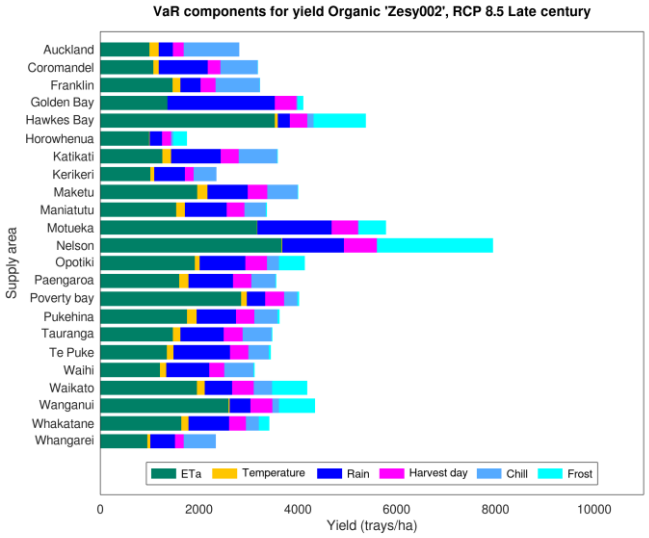


Figure 13. Contribution of different risk factors to Value at Risk (VaR) for yield in organic *Actinidia chinensis* var. *chinensis* 'Zesy002' kiwifruit yield with a 5% confidence level, plotted for supply areas, for the Representative Concentration Pathway (RCP) 6.0 mid-century (upper left) and late century (upper right), and RCP 8.5 mid-century (lower left) and late century (upper right). ETa is actual crop evapotranspiration.

10.2.2 Kiwifruit dry matter VaR

Calculated mean DM for conventionally grown ‘Hayward’ and ‘Zesy002’ kiwifruit are shown in Table 12 for the historical period, and for the mid-century and late century under RCP 4.5, RCP 6.0 and RCP 8.5. DM values for organically grown kiwifruit is lower than for conventional kiwifruit by the parameter $\delta b_{0\,\mathrm{Organic}}$ which was estimated as -0.48 ± 0.14 (Table 3). DM values for ‘Zesy002’ were higher than those for ‘Hayward’, the differences were less than 1.5%, the fitted value of $\delta b_{0\,\mathrm{Zesy002}}$. This is to be expected because of the difference in mean harvest time between ‘Hayward’ and ‘Zesy002’ which gives a longer DM accumulation time for ‘Hayward’.

The VAR for DM ranged from 0.6 to 0.8 and showed little variation between time periods and in most cases were 0.0 to 1 decimal place. VaR is not listed in Table 10, but values can be obtained from the decomposition of historical VaR for conventional ‘Hayward’ (Figure 14) and ‘Zesy002’ (Figure 15) into contributions from different risk factors, and from similar decompositions of mid-century and late century VaR under RCP 6.0 and 8.5 for conventional ‘Hayward’ (Figure 16) and ‘Zesy002’ (Figure 17). There is no difference in VaR decomposition between organic and conventional kiwifruit of the same cultivar.

For the historical period, DM for ‘Hayward’ ranged from 16.5% in the Wanganui supply area to 17.3% in Waikato, while DM for ‘Zesy002’ ranged from 17.6% in the Wanganui supply area to 18.4% in Waikato. Although the extremal supply areas for DM are the same for the two cultivars, relative ranking of supply area on a DM basis were weakly correlated. For example, Auckland had the fifth highest DM for ‘Hayward’ but only the tenth highest DM for ‘Zesy002’ (Table 10). Generally, relative rankings were preserved over time under each of the RCPs, with higher and lower DM supply areas tending to remain respectively higher and lower DM areas. However, both Nelson and, to a lesser extent, Opotiki which were historically among the higher DM producing areas, dropped in ranking over time, which may be linked to large increases in yield.

There was a clear trend of DM increasing for every supply area from the historical to mid-century periods, and also from the mid-century to the late-century periods. Increases in DM for ‘Hayward’ from the historical to the mid-century period were equal to or higher for RCP4.5 compared with RCP 6.0, and equal to or higher for RCP 8.5 compared with RCP 4.5. However, increased in DM for ‘Hayward’ from the historical to the late century were generally higher for RCP 6.0 than RCP 4.5, and higher again for RCP 8.5 (Table 10). For ‘Zesy002’, patterns between the RCPs were less defined for the mid-century period, but the increase in DM from the historical to late-century period was higher for RCP 8.5 than for RCP 6.0, and generally RCP 6.0 was higher than for RCP 4.5 (Table 10).

Increases in DM for ‘Hayward’ were higher than or equal to that for ‘Zesy002’, and differences increased with increasingly warm climates. This is likely due to the typically later harvests of ‘Hayward’, which give more time for GDD accumulation.

Comparing Figure 14 and Figure 15 shows that crop evapotranspiration and GDD accumulation are more prominent contributors to DM VaR for ‘Hayward’ than for ‘Zesy002’. This is likely due to the increased length of time that ‘Hayward’ fruit stay on the vine. Thus, harvest day also is a bigger contributor to DM VAR for ‘Hayward’ than for ‘Zesy002’. Conversely, rain damage is a much larger threat to DM in ‘Zesy002’. Crop yield is also a bigger contributor to DM VaR in ‘Zesy002’ than ‘Hayward’, likely reflecting the larger yields and yield VaR of ‘Zesy002’.

Table 12. Calculated mean dry matter content (DM) for conventional *Actinidia chinensis* var. *deliciosa* 'Hayward' and *A. chinensis* var. *chinensis* 'Zesy002' kiwifruit for a historical period, the mid-century and late century under three different Representative Concentration Pathways (RCP 4.5, 6.0 and 8.5). Results are aggregated by supply area. DM content of organic fruit differs by the constant $\delta b_{0\,Organic} = -0.48 \pm 0.14$ in Equation (5) and Table 3. Value at Risk (VaR) varied between 0.6 and 0.8% (to 1 decimal place) and is not shown.

Projected DM for conventional 'Hayward' and 'Zesy002' (%)														
	'Hayward'							'Zesy002'						
	Historical	Mid-century			Late century			Historical	Mid-century			Late century		
Supply Area		**RCP 4.5**	**RCP 6.0**	**RCP 8.5**	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**		**RCP 4.5**	**RCP 6.0**	**RCP 8.5**	**RCP 4.5**	**RCP 6.0**	**RCP 8.5**
Auckland	17.2	17.9	17.8	18.0	18.1	18.3	18.8	18.1	18.7	18.6	18.8	18.8	19.0	19.5
Coromandel	17.1	17.6	17.6	17.7	17.8	17.9	18.3	18.1	18.5	18.4	18.6	18.6	18.8	19.1
Franklin	17.1	17.6	17.5	17.6	17.7	17.9	18.2	18.1	18.5	18.4	18.5	18.6	18.7	19.0
Golden Bay	17.0	17.2	17.2	17.3	17.3	17.4	17.6	18.0	18.2	18.2	18.3	18.3	18.4	18.6
Hawke's Bay	16.8	17.1	17.1	17.1	17.2	17.3	17.6	17.9	18.2	18.1	18.2	18.2	18.3	18.6
Horowhenua	16.7	17.1	17.0	17.1	17.2	17.3	17.6	17.9	18.1	18.1	18.2	18.2	18.4	18.6
Katikati	17.2	17.8	17.7	17.8	17.9	18.0	18.5	18.2	18.7	18.6	18.7	18.8	18.9	19.3
Kerikeri	17.2	17.7	17.7	17.8	17.8	18.1	18.4	18.1	18.6	18.5	18.6	18.6	18.8	19.2
Maketu	17.0	17.6	17.5	17.6	17.7	17.8	18.3	18.0	18.5	18.4	18.5	18.6	18.7	19.1
Maniatutu	17.0	17.6	17.4	17.6	17.6	17.8	18.3	18.1	18.5	18.4	18.5	18.6	18.7	19.1
Motueka	16.9	17.1	17.1	17.2	17.2	17.3	17.5	18.0	18.1	18.1	18.2	18.2	18.2	18.4
Nelson	17.2	17.4	17.4	17.5	17.5	17.6	17.8	18.3	18.4	18.4	18.5	18.5	18.5	18.7
Opotiki	17.2	17.6	17.5	17.6	17.7	17.8	18.2	18.2	18.6	18.5	18.6	18.6	18.7	19.0
Paengaroa	17.0	17.5	17.4	17.5	17.6	17.8	18.2	18.0	18.5	18.3	18.4	18.5	18.6	19.0
Poverty Bay	17.0	17.5	17.4	17.5	17.6	17.7	18.1	18.1	18.5	18.4	18.5	18.5	18.7	19.0
Pukehina	17.2	17.7	17.6	17.7	17.8	17.9	18.4	18.2	18.6	18.5	18.6	18.7	18.8	19.2
Tauranga	17.1	17.6	17.5	17.7	17.7	17.9	18.3	18.2	18.6	18.5	18.6	18.7	18.8	19.2
Te Puke	17.1	17.6	17.5	17.6	17.7	17.8	18.3	18.1	18.6	18.5	18.6	18.6	18.7	19.1
Waihi	17.0	17.5	17.4	17.6	17.6	17.8	18.2	18.0	18.5	18.4	18.5	18.5	18.7	19.1
Waikato	17.3	17.8	17.7	17.8	17.8	18.0	18.4	18.4	18.7	18.6	18.7	18.8	18.9	19.3
Wanganui	16.5	16.8	16.7	16.9	16.9	17.0	17.3	17.6	17.9	17.8	17.9	17.9	18.0	18.3
Whakatane	16.9	17.4	17.3	17.4	17.4	17.6	18.0	18.0	18.4	18.3	18.4	18.4	18.5	18.9
Whangarei	17.2	17.7	17.6	17.8	17.8	18.0	18.4	18.1	18.6	18.5	18.6	18.7	18.8	19.2

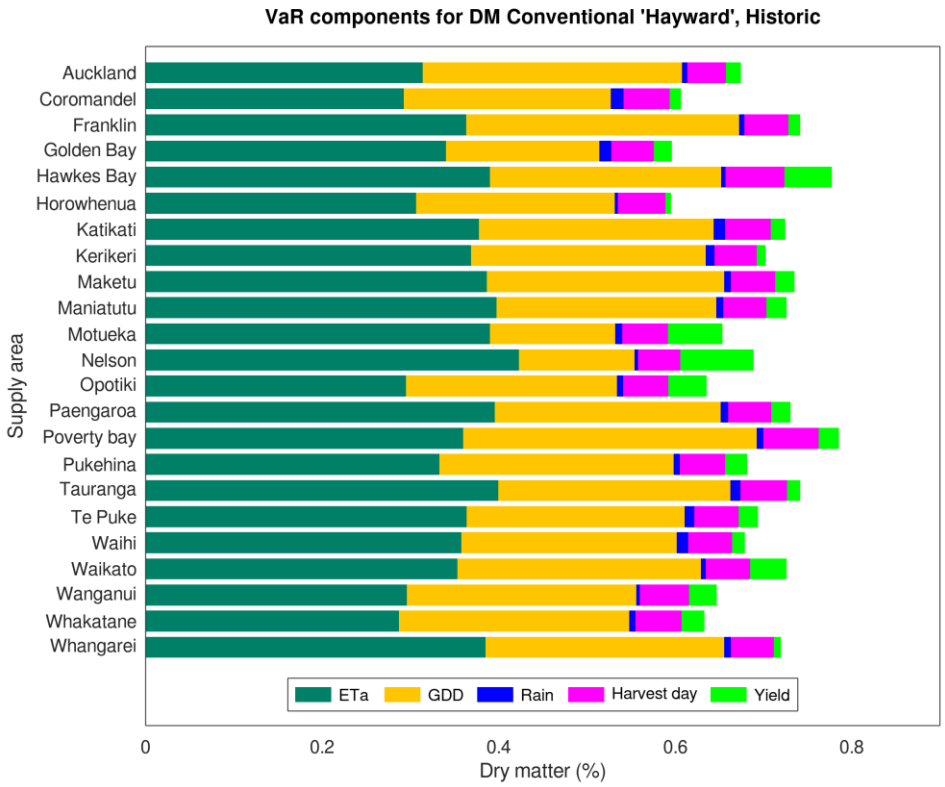


Figure 14. Contribution of different risk factors to Value at Risk (VaR) for dry matter content (DM) of conventional *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit for a 5% confidence level, plotted for supply regions for the historical period. ETa is actual crop evapotranspiration. The decomposition of VaR for DM in organic 'Hayward' is the same.

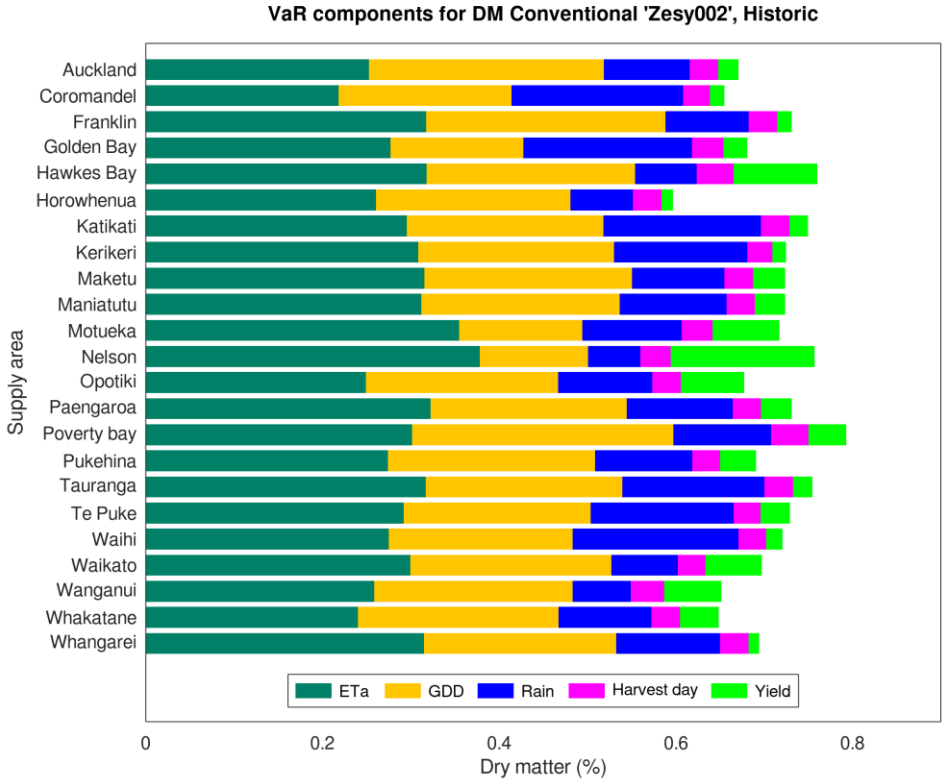
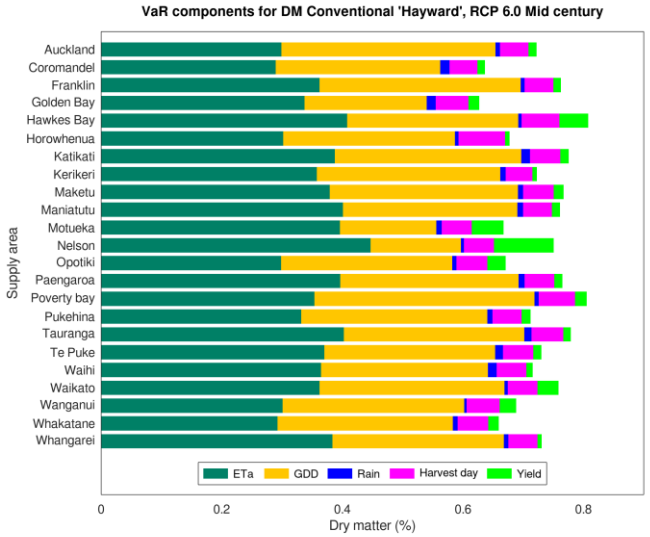
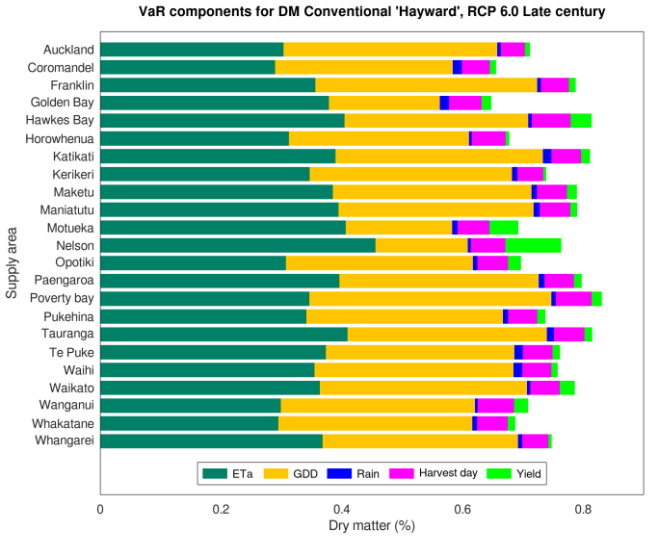
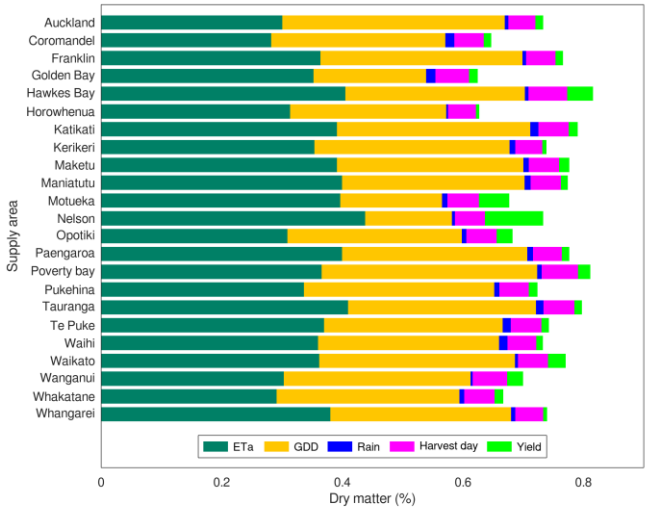


Figure 15. Contribution of different risk factors to Value at Risk (VaR) for dry matter content (DM) of conventional *Actinidia chinensis* var. *chinensis* 'Zesy002' kiwifruit for a 5% confidence level, plotted for supply regions for the historical period. ETa is actual crop evapotranspiration. The decomposition of VaR for DM in organic 'Zesy002' is the same.







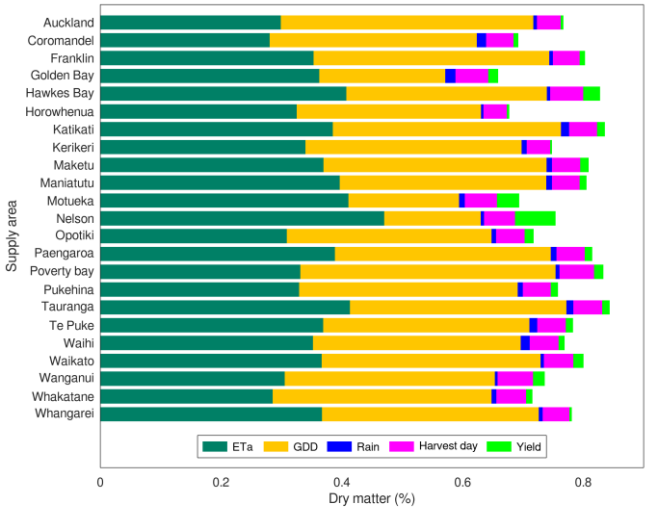
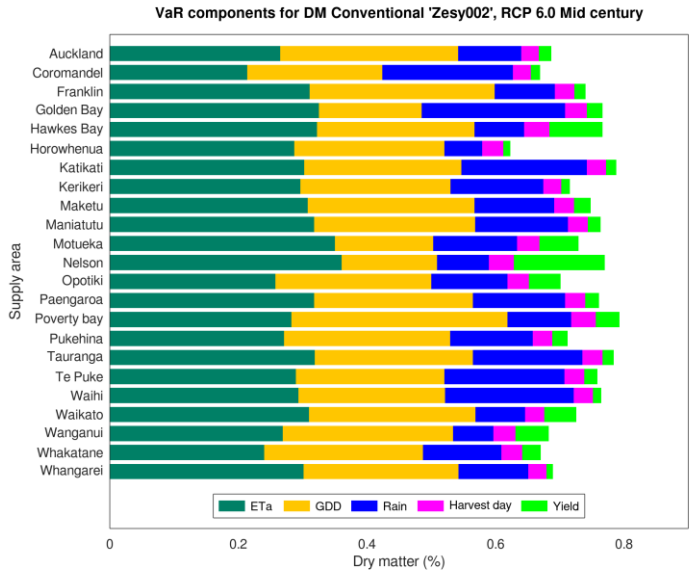
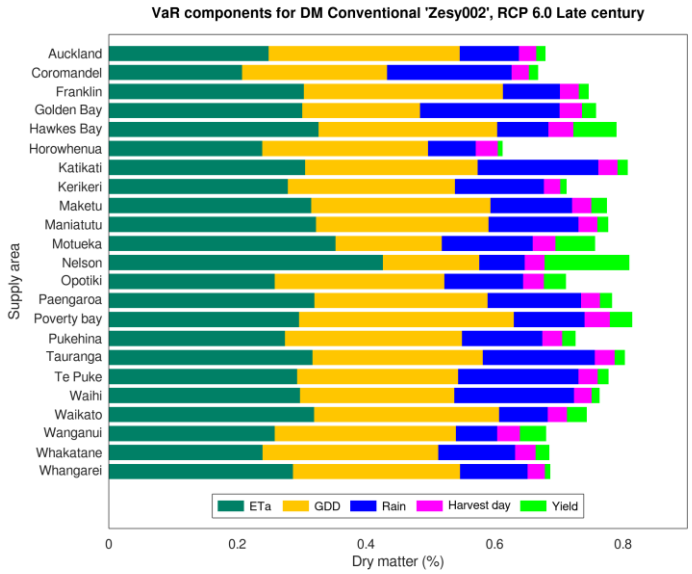
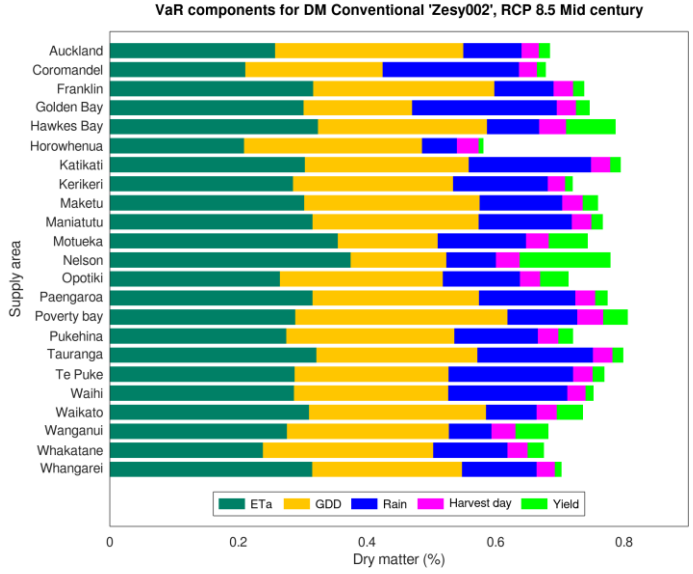


Figure 16. Contribution of different risk factors to Value at Risk (VaR) for dry matter content (DM) of conventional *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit for a 5% confidence level, plotted for supply regions for the Representative Concentration Pathway (RCP) 6.0 mid-century (upper left) and late century (upper right), and RCP 8.5 mid-century (lower left) and late century (upper right). ETa is actual crop evapotranspiration. The decomposition of VaR for DM in organic 'Hayward' is the same.







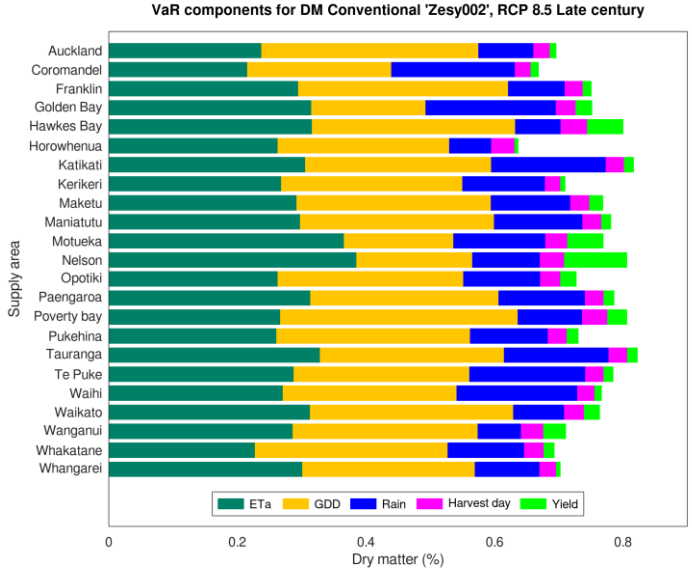


Figure 17. Contribution of different risk factors to Value at Risk (VaR) for dry matter content (DM) of conventional *Actinidia chinensis* var. *chinensis* 'Zesy002' kiwifruit for a 5% confidence level, plotted for supply regions for the Representative Concentration Pathway (RCP) 6.0 mid-century (upper left) and late century (upper right), and RCP 8.5 mid-century (lower left) and late century (upper right). ETa is actual crop evapotranspiration. The decomposition of VaR for DM in organic 'Zesy002' is the same.

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11 Adaptations to risks

Clothier et al. (2012) discussed a range of adaptation strategies for horticulture in the context of the tri-level scheme of (i) tactical adaptations which involve modifying production practices within the current system, (ii) strategic adaptations which involve a substantive modification to the current production system, and (iii) transformational adaptations which change the spatial footprint of the production system. Park et al. (2012) considered adaptation in the framework of 'action cycles' of incremental changes followed by longer-term changes.

For kiwifruit, tactical adaptations are aimed at controlling vegetative growth, maintaining flower numbers (e.g. Hi-Cane) and water use, and protecting against events such as frost, hail and sunburn damage; these measures include seasonally timed pruning strategies, girdling, chemical application to enhance flowering, protective barriers and enhanced irrigation. Strategic adaptations can position a production system to be more suited to its climatic conditions, and can include growing of new cultivars and installation of irrigation schemes. Transformation adaptations may be in response to (i) declining sustainability and profitability of a crop system in its current location, and could include relocation of the crop to more favourable areas and/or adoption of a new crop more suited to the current location; or (ii) to new opportunities that involve an expansion of the crop footprint as areas that were previously less suited become more suitable (Clothier et al. 2012). Transformation adaptations also encompass financial portfolio approaches that involving multiple crops with different risk and return profiles to reduce risk in climate uncertainty (Paut et al. 2019).

The optimal adaptation is context dependent, as observed by Porsch et al. (2018) who found that the yield potential combined with hail risk determined whether it was more efficient for German apple growers to protect with anti-hail nets (high risk, high yield), to insure against hail damage (high risk, low yield), or to take no action at all (low risk, low yield). Those authors additionally identified that for orchards with low hail risk and high yield potential, the most efficient adaptation strategy depended on the risk aversion of the grower.

The variables in the production models determine the types of risks that can be investigated with the models. We have discussed these risks and possible adaptations with industry partners (NZ Avocado and Zespri) to identify which adaptations to model and how. Several possible adaptations could not be modelled because there is a lack of sufficient data.

For example, an adaptation might change plant physiology in a way that reduced the susceptibility of the crop rather than changing the environmental conditions experienced by the crop. In order to model this, we would need information on how model parameter values changed to affect the sensitivity of the crop to the predictor variable. An example of where we do have such information relates to the application of Hi-Cane to ameliorate insufficient chill. The industry datasets on production allowed us to estimate the impact of Hi-Cane via fitted differences in the value of the parameter p_1 in Equation (4). These differences capture the differential sensitivities of 'Hayward' and 'Zesy002' to chill, with and without Hi-Cane (see Table 2).

Other adaptations might directly change the environment experienced by the crop, and may do so in a manner that depends on location, management and other unquantified factors. These adaptations are better modelled by specifying effective changes in risk variables, especially when quite different adaptations can be used to obtain the same effect.

The project team, along with industry representatives discussed the risks and possible adaptations, and identified what risks and adaptations should be modelled. We are grateful to Phillip West (NZ Avocado), Octavio Perez-Garcia, Jayson Benge, William Max (all from Zespri) and Warrick Nelson (Plant & Food Research) for their contributions to these discussions. A summary of these discussions is presented in Appendix B.

11.1 Risks for avocado

The variables in our model and the risks associated with them are presented in Table 13.

Table 13. Predictors used in the avocado yield prediction model and associated risks, and decision on which adaptations will be modelled. RMS is the root mean square.

Variable name	Predictor	Risk	Model adaptation?
$\mathrm{ETa}_{\mathrm{q2y0\ to\ q1y2}}$	Crop evapotranspiration	Insufficient rain/soil moisture	Yes
$S_{\mathrm{frost\ q2y0\ to\ q1y2}}$	Frost suitability score	Frost damage	Yes
$S_{\mathrm{warmth\ q2y0\ to\ q1y2}}$	Warmth suitability score	Inadequate warmth during the year	Yes
$S_{\mathrm{disease\ q3y0\ \&\ q3y1}}$	Disease suitability score	Fungal and other disease	No
$\mathrm{rain}_{\mathrm{q2y0\ to\ q1y2}}$	Rain	Fungal and other disease	No
$\mathrm{windRMS}_{\mathrm{q2y0\ to\ q1y2}}$	Wind (RMS)	Wind damage	Yes
Y_{-1}	Yield 1 year previous	Irregular bearing effect	No
Y_{-2}	Yield 2 years previous	Irregular bearing effect	No

11.2 Risks for kiwifruit

Adjustment to risks to be modelled for kiwifruit

At the time of our consultation, GDD was included in the kiwifruit yield model with a positive coefficient, suggesting that increasing warmth would increase production. That would suggest a risk of insufficient warmth that could be ameliorated by plastic covers, for example.

However, as we have described earlier in the report, the GDD effect was a phantom effect that existed because of a model misspecification, which we have corrected. Reanalysing the model led to the identification that excessive warmth was potentially reducing yield in some areas, and we replaced GDD as a model predictor, using the warmth suitability function described earlier instead. The warmth suitability function has an optimal October to March mean temperature of 17°C (for which the score is 1.0) and declines to zero as temperatures deviate from optimal in either direction.

Although mean October–March temperature was above 17°C 89% of the time for the calibration dataset (which used weather data from 2014 to 2018), for the historical period, across orchards and individual years, October–March temperatures were generally lower than optimal. In most cases the deviation of temperatures from the optimum were low, which is reflected in the very small contribution of temperature to VaR that were discussed in Section 10.2.

The risks associated with warmth are generally the opposite to what was discussed with the kiwifruit industry based on the previous, mis-specified model, though potentially suitable for orchards in cooler temperatures.

Thus, without consultation, we modified the agreed adaptation practice to:

- include temperature reduction when temperatures are excessive
- retain previously agreed temperature increase when temperatures are too low.

We note that while we have modelled the effect of temperature reduction, it is very difficult to achieve in practice and interacts with soil moisture deficit, and can a very challenging adaptation practice to achieve.

Risks to be modelled for kiwifruit

The predictors from the kiwifruit yield model and their associated risks are presented in Table 14, along with whether it was decided to model adaptation of the risks. The lack of winter chill is a major risk, but since organic and conventional cultivation were modelled separately for both 'Hayward' and 'Zesy002', with the value of the chill-related parameter varying with the use or not of Hi-Cane (and cultivar), further analysis was not done.

Table 14. Predictors used in the kiwifruit yield prediction model and associated risks, and whether adaptations to each risk will be modelled.

Variable name	Predictor	Risk	Model adaptation?
$\mathrm{ETa}_{\mathrm{q4y1\ to\ harv}}$	Crop evapotranspiration	Insufficient soil moisture	Yes
$S_{\mathrm{frost\ budbreak\ to\ harv}}$	Frost suitability score	Frost damage	Yes
S_{chill}	Chill suitability score	Inadequate winter chill	Already done
$S_{\mathrm{warmth\ q4y1\ to\ q1y2}}$	Warmth suitability score	Excessive warmth above 17°C	Yes
$\mathrm{rain}_{\mathrm{q3y1\ to\ harv}}$	Rain from spring till harvest	Fungal and other disease	No
$\mathrm{Days}_{\mathrm{1Mar\ to\ harv}}$	Days of harvest	A commercial decision	No
Year	Harvest year	No risk; reflects vine age effect	No

The predictors from the kiwifruit DM model and their associated risks are presented in Table 15 along with whether it was decided to model adaptation of the risks. Two key risk factors for DM, insufficient accumulation of GDD and high soil moisture can have positive impacts for yield. For example, the warmth suitability score for kiwifruit operated in the region of optimal to excessive temperatures, and an adaptation to reduce excessive temperatures would have the effect of reducing GDD accumulation and hence DM. Similarly, irrigating to increase soil moisture would boost yield, at the expense of DM.

Table 15. Predictors used in the kiwifruit dry matter content (DM) prediction model and associated risks, and decision on which adaptations will be modelled.

Variable name	Predictor	Risk	Model adaptation?
$\mathrm{GDD}_{\mathrm{q4y1\ to\ harv}}$	Growing degree days	Inadequate warmth	Impact of yield adaptations
$\mathrm{ETa}_{\mathrm{q4y1\ to\ harv}}$	Crop evapotranspiration	High soil moisture lowers DM	Impact of yield adaptations
$\mathrm{Days}_{\mathrm{1Mar\ to\ harv}}$	Days of harvest	A commercial decision	No
Y	Yield	Increased yield reduces DM	No
$\mathrm{rain}_{\mathrm{1\ Apr\ to\ harv}}$	Rain	Dilution of DM	No

11.3 Adaptations to specific risks for avocado and kiwifruit

11.3.1 Insufficient soil moisture

Adaptations were identified that could be used to ameliorate the effect of low crop evapotranspiration resulting from low soil moisture. Irrigation schemes vary in terms of application method, with effectiveness dependent on timing, availability of water (which may require detention storage) and tree/vine maturity, and may also be limited by government regulations. Alternatives include covering crops, which entail a number of interactions for which there is little available data, mulching and/or increasing organic matter to improve soil moisture retention, and tactical thinning.

Given the complexity of options and lack of data, it was decided to model adaptation by modifying actual crop evapotranspiration (ETa) without identifying the adaptation method.

For both avocado and kiwifruit, it was assumed that the chosen adaptation would be used to increase ETa to the 75th percentile of ETa across all orchards. For kiwifruit, the change in ET was also included in the DM calculation to gauge the secondary impact of the adaptation.

11.3.2 Frost damage

Ameliorating the threat from frost can be achieve in a number of ways, including frost fans, irrigation, overhead sprinklers, managing air flows through appropriate positioning and/or shelterbelts and the use of covers depending on the maturity of the trees/vines.

Minimum temperatures below frost protection covers were the same or lower than ambient temperatures and did not prevent frost damage in cherry (Blanke & Balmer 2005) and could even increase the likelihood of damage in blueberry (Ogden et al. 2009). Silver shade covers in avocado were suggested to reduce cold stress by reducing photosynthesis, but also reduced flowering (Chernoivanov et al. 2022) and no evidence of frost protection was demonstrated. Shelterbelts were not shown to be effective in increasing minimum temperature (McAneney et al. 1990). Thus we focused on frost fans and irrigation systems for preventing frost damage.

Published studies have reported the effectiveness of irrigation and fans for preventing frost damage. Over-tree irrigation of 2.5–3.5 mm/h provided a temperature increase of 2°C and significantly greater fruit set in peach trees compared with under-tree irrigation, which provided an increase of only 0.5°C and no effective protection (Rieger 1993). Rieger & Myers (1990) found that micro-sprinkler applications of 27, 36, 44 L/h per tree (effecting an application rate of 2.5–5 mm/h at the level of fruiting wood) maintained average bud temperature above −2°C and by 2 to 5°C above those of non-irrigated trees under calm conditions but provided no protection under windy conditions. In this study, there was little difference in effective temperature between the 36 and 44 L/h application rates and was only slightly higher than that achieved by the 27 L/h application rate, identifying that considerable savings in water and energy costs can be obtained by judicious irrigation.

The effect of horizontal frost fans is not homogenous: airflow predominately occurs along rows, with flow across rows decreasing with foliage density and canopy height (Bar-Noy et al. 2019); effective increases in temperature depend on fan height, tilt, power and the temperature inversion (Ribeiro et al. 2006; Heusinkveld et al. 2020).

Protection also falls with distance from the fan, with corners of blocks often being less protection (Nanos et al. 1995). Fan density affects the effective temperature increase, with trials finding

temperature elevations of 4.2°C, 1.9°C and 1.2°C, respectively, over influenced areas of 0.8, 2.1 and 3.4 ha, and effectiveness decreased with linearly with increasing wind speed up to 2 m/s (Hu et al. 2018).

We side-stepped this complexity by modelling how an increased temperature would protect against frost events, without modelling the adaptation directly. We assumed the adaptation would come into play only when the minimum temperature was below 0°C, and modelled the effect of minimum temperature being elevated by 1, 2 or 4°C in this scenario.

11.3.3 Inadequate temperature profile during the year

Tunnel house cover for citrus increased maximum temperatures during the growing season (November to May in New Zealand) by 4–12°C and minimum temperatures by 1–2°C (Richardson et al. 1997). Chiabrando & Giacalone (2018) found that permanent covers for kiwifruit elevated the effective annual temperature differentially between two commercial orchards in the same region, with an average increase of 1.4°C at one orchard and 0.6°C at another.

Photo-selective nets offer the opportunity to control the environmental conditions for kiwifruit (Moura et al. 2022) and some combinations have been found to lower effective temperatures by 0.5 to 1.0°C (Basile et al. 2012).

To model the impact of using covers to increase mean temperature for avocado and kiwifruit, we assumed that mean temperatures would be increased by up to a maximum of 1.5°C but not above the optimal temperature (17.5°C for avocado and 17°C for kiwifruit).

To model the impact of photo-selective nets in reducing heat stress for kiwifruit, we assumed the mean temperatures would be decreased by 0.75°C but not below 17°C.

For kiwifruit, if an adaptation to reduce or increase mean temperature was modelled for a location, then we also calculated the corresponding increase or decrease in GDD, which was then used in the DM model to calculate the secondary impact of the adaptation.

11.3.4 Disease

We did not model adaptations to combat disease increase due to rain or humidity/temperature combinations. This is being considered in a current Our Land and Water (OLW) project “Horticultural Disease Risk in a Changing Climate” that aims to identify climate change impacts on horticultural diseases at a national and regional scale and develop adaptation strategies enabling pre-emptive actions by industry organisations. Modelling adaptations for disease in this project would duplicate the effort in the OLW project.

11.3.5 Wind damage in avocado

The daily data gives average wind speed at a 2-m elevation, and this was used in the model with the assumption that higher average speeds would be correlated with stronger wind gusts.

The effectiveness of windbreaks depends on the density, which can be defined by three classes: Open (about 30% density); Medium (40–80% density); and Dense (100% density), with medium density being the most effective (Gloyne 1955). A medium-density barrier of height h can reduce wind speed by up to 80% of free wind speed at 3–5h from the barrier (Gloyne 1955), although Řeháček et

al. (2017) found medium-density trees provided only a 25–50% at $3h$ and $6h$. The distance of protection is proportional to barrier height and is about $25h$ (Bird et al. 1993), and wind speed as generally recovered to 100% $40h$ from the barrier.

Considering the large variability depending on a number of factors, we modelled the possible effect of barriers to counter wind damage in avocado by simulating wind speed reductions of 25% and 50%.

11.3.6 Non-climate-risk predictors

Irregular bearing in avocado

Although irregular bearing contributes to variation in year-to-year yield and can be exacerbated by weather events such as frost, it is also responsive to management practices. We did not regard irregular bearing as a purely climate-related predictor.

Harvest year for 'Zesy002' kiwifruit

This is not a climate risk but reflects the impact of changes in the industry with new plantings of 'Zesy002' and some growers converting from 'Hayward' orchards to 'Zesy002'. Since production is higher in mature vines than young vines, this resulted in an apparent year effect.

Day of harvest

The day of harvest determines the period over which several other climate risks are calculated. However, since it is a commercial decision, we have not considered modifying harvest day as an adaptation. The industry could change this by changing their payment system.

11.4 Simulated impact of adaptations

The impacts of adaptations were simulated by modifying predictor variables described in Section 11.3 by modulating the relevant climate data inputs. Results for avocado for the historical period, and the mid- and late-century periods under RCP 6.0 and 8.5, are shown in Table 16. Results for avocado under RCP 4.5 are shown in Appendix C1. Results for conventional 'Zesy002' are shown for the historical period in Table 17 for the mid-century under RCP 6.0 in Table 18 and results for both cultivars and growing methods for all periods and RCP 4.5 6.0 and 8.5 are shown in Appendix C2 to C5.

11.4.1 Avocado: impacts of adaptations

For avocado, adaptations to increase low soil moisture in the historical period resulted in a 2.3 t/ha increase for the Far North, but only 0.6–0.8 tonnes/ha for other regions, which indicates a much larger water deficit in the Far North. VaR was increased for all regions but not proportionally to production increase. This can be due to differences in volatility of soil moisture deficit between regions, different base yields, and different relative risks from other unameliorated risks. For the Bay of Plenty and Far North under both RCP 6.0 and 9.5, adaptations for low soil moisture in the mid- and late-century periods were projected to give similar increases in yield as for the historical period; however while VaR for the Far North was slightly elevated, VaR for the Bay of Plenty declined with increasingly warming temperatures. This reduction in VaR while production is increased over unadapted production indicates that the relative risk from soil moisture deficit would be increasingly dominant without the adaptation (Table 16).

Frost protection is projected to provide no benefit in the Far North, and only very marginal benefit in Whangarei in the historical period (Table 16). By contrast, frost protection in the Bay of Plenty during the historical period is projected to give considerable benefits in both increased yield and decreased VaR, with benefit increasing with the degree of protection (raising effective temperatures by 1°C vs 2°C vs 4°C). The decrease in VaR in this situation is consistent with frost damage making a large relative contribution to risk. The benefit of frost protection is projected to decrease by the mid-century and further by the late century under RCP 6.0 and more so under RCP 8.5. The impact of frost protection for the Rest of NZ follows a similar pattern to that of the Bay of Plenty, but with increases in yield being approximately 70–80% lower. The end three columns of Table 16 gives the minimum and maximum number of frosts in a year in an orchard, and the mean number of frosts per year across an orchard. In this context, a 'frost' event was assumed to occur if the minimum temperature dropped below 0°C, which would the initiate application of the frost protection method.

Increasing temperature towards optimum in the historical period was predicted to provide an improvement of almost 20 t/h for the Bay of Plenty, 8 t/ha for Whangarei and the Rest of NZ, but only 2 t/ha for the Far North. While VaR was increased for the Far North (1.5 t/ha), Rest of NZ (4.5 t/ha) and Whangarei (2.4 t/ha), it was decreased by 2.9 t/ha for the Bay of Plenty, reflecting the strong contribution that lack of warmth to the risk profile for that region. As would be expected, the benefit of adaptations to increase temperature were projected to progressively decline in the mid-century and the late century, more so under RP 8.5 than 6.0. However, it was still projected to improve production in the Bay of Plenty by 8–11 t/ha in the mid-century and 0.8–4 t/ha in the late century, depending on RCP, and in Whangarei and the Rest of NZ by 2–3.5 t/h in the mid-century, depending on RCP adaptation (Table 16).

For the Bay of Plenty, the use of barriers to reduce wind speeds by 25% or 50% were predicted to increase mean yield for avocado by, respectively, 22 t/ha and 25 t/ha in the historical period, while reducing VaR by 2.6 and 2.4 t/ha. The impacts of these adaptations in Whangarei and the Rest of NZ were increases in yield of approximately 10 t/ha for a 25% reduction and 11 t/ha for a 50% reduction, with VaR also being increased, more so for the Rest of NZ. For both future periods under both RCP 6.0 and 8.5, barriers were projected to provide a significant saving in production in all areas, although the amount of production saved is projected to decrease for each over time and with increasing RCP number.

Table 16. Projected impact of adaptations in terms of change to mean yield and Value at Risk (VaR), for different supply regions and different time periods under representative concentration pathways (RCP) 6.0 and 8.5. Also shown are the minimum and maximum number of frosts in a year across orchards in each supply region and mean frosts per year per supply region.

Impact of adaptations on avocado																	
	Change in yield and VaR (tonnes/ha)																
Historical period																	
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		25% wind reduction		50% wind reduction		Yearly frost events		
Supply region	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean
Bay of Plenty	0.6	0.9	2.3	-1.6	3.2	-2.2	3.5	-2.5	19.9	-2.9	1.6	1.2	3.4	2.5	0	47	10.0
Far North	2.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.5	2.2	0.6	4.6	1.3	0	1	0.0
Rest of NZ	0.8	0.1	0.6	0.3	0.8	0.6	0.9	0.7	8.3	4.5	0.8	0.5	1.7	0.9	0	26	3.4
Whangarei	0.6	0.3	0.1	0.1	0.1	0.1	0.1	0.1	8.4	2.4	0.7	0.2	1.5	0.5	0	5	0.5
RCP 6.0 mid-century																	
Bay of Plenty	0.6	0.1	1.8	-0.7	2.4	-0.9	2.6	-1.0	11.2	2.7	2.5	0.2	5.0	0.4	0	32	4.5
Far North	2.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	2.3	0.7	4.8	1.4	0	1	0.0
Rest of NZ	1.1	-0.4	0.5	-0.4	0.7	-0.3	0.7	-0.3	3.5	1.2	1.3	0.4	2.6	0.7	0	19	1.6
Whangarei	0.9	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	3.1	2.2	1.1	0.3	2.3	0.6	0	4	0.2
RCP 6.0 late century																	
Bay of Plenty	0.5	-0.3	0.6	-0.2	0.8	-0.3	0.8	-0.3	4.3	2.0	2.7	0.1	5.6	0.2	0	22	1.7
Far North	2.4	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	2.1	0.8	4.4	1.6	0	1	0.0
Rest of NZ	1.2	-0.5	0.2	-0.2	0.3	-0.1	0.3	-0.1	1.2	0.5	1.3	0.4	2.6	0.7	0	15	0.5
Whangarei	0.9	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.9	1.1	0.4	2.4	0.9	0	3	0.1
RCP 8.5 mid-century																	
Bay of Plenty	0.6	-0.1	1.3	-0.5	1.7	-0.7	1.9	-0.7	8.3	2.9	2.6	0.1	5.3	0.2	0	30	3.3
Far North	2.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	2.3	0.7	4.8	1.4	0	1	0.0
Rest of NZ	1.3	-0.5	0.3	-0.3	0.4	-0.3	0.5	-0.2	2.6	0.9	1.4	0.3	2.8	0.6	0	16	0.8
Whangarei	1.0	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.7	1.2	0.4	2.4	0.7	0	3	0.1
RCP 8.5 late century																	
Bay of Plenty	0.5	-0.4	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.8	0.4	2.8	0.1	5.7	0.2	0	14	0.3
Far North	2.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	1.9	0.8	4.1	1.7	0	0	0.0
Rest of NZ	1.3	-0.5	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	1.3	0.4	2.6	0.8	0	6	0.1
Whangarei	0.9	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.1	0.5	2.3	1.0	0	1	0.0

11.4.2 Conventional 'Zesy002': impact of adaptations

The large number of kiwifruit supply areas, along with the four alternative cultivar × growing methods, requires many tables to present the simulation results from modelling the adaptations. Thus, for brevity, we discuss only the results for conventional 'Zesy002' for the historical period and the mid-century under RCP 6.0.

Adaptations to alleviate low soil moisture in the historical period were predicted to have the most impact on yield in Hawke's Bay (8000 tray/ha), with Poverty Bay and Auckland predicted to have increases of over 6000 trays/ha. All areas were predicted to have improved production under this adaptation, with the lowest predicted increase in yield being 1300 trays/ha for Horowhenua. In most cases, VaR was increased, sometimes significantly as for Hawke's Bay, which was predicted to have an increase in VaR of 3800 tray/ha. Small, predicted declines in VaR for some supply areas indicate that soil moisture deficit was a significant contributor to risk in those areas (see Table 17).

Projections for the mid-century under RCP 6.0 in Table 18 show that while the benefit of maintaining soil moisture decreased slightly for some areas such as Auckland and Kerikeri, when compared with the historical period, for other areas this adaptation provided an increased benefit. For example, yield was projected to increase by 9500 trays compared with no adaptation. The change in risk profile varied across supply areas, as for the historical period, with Hawke's Bay projected to have the largest increase in VaR of 2600 trays/ha.

Frost protection of even a 1°C increase in minimum temperature was predicted to increase mean yield by 2200 trays/ha in Nelson, and from 900 to 1300 trays/ha in Hawke's Bay, Motueka, Opotiki, Waikato and Wanganui. In all of these areas, VaR was reduced, sometimes to a larger magnitude than the gain in production, reflecting the prominence of frost risk for these areas. In colder areas, the benefit of frost protection increased as the effective temperature was raised. A 4°C protection against frosts was predicted to increase mean yield in Nelson by 4500 trays/ha while decreasing VaR by 2800 trays, and by 2300 to 2700 trays/ha in Opotiki, Wanganui and Waikato with VaR decreases of 1600 to 3100 trays/ha (see Table 17). With the warmer climates in the mid-century under RCP 6.0, the severity of frost damage is projected to decrease, but frost protection is still important in many areas and has the potential to improve yield, for example by up to 3400 trays/ha in Nelson, which is also projected to have a decline in risk of 3200 trays/ha (Table 18).

The frost statistics columns in Table 17 and Table 18 show a decline in the mean number of frosts per year for each supply area. Interestingly, the maximum number of frosts that could be experienced by an orchard in 1 year in the Waikato was projected to increase from an expectation of 8.5 to 10.1. This could be due to warmer climates bringing forward flowering times, which in some years would increase frost exposure. The maximum values for frost events are not whole numbers because frost events were weighted by the probability of the growing season having started.

Controlling temperature towards an optimal 17°C was not predicted to have a significant effect in the historical periods, with the highest benefits being increases in yield of 500 and 600 trays/ha in Motueka and Nelson, which were below optimum (Table 17). Under the warmer climate in the mid-century under RCP 6.0, the benefit of increasing temperature control had decreased (Table 18). However, because of warming temperatures, in Auckland the benefit of adaptation to control temperature would be modestly greater in the mid-century under RCP 6.0 than in the historical period. Such trends would be expected to increase in warmer areas under RCP 8.5 and later in the century.

Table 17. Projected impact of adaptations on conventional *Actinidia chinensis* var. *chinensis* 'Zesy002' for the historical period, in terms of change to mean and Value at Risk (VaR) for yield and dry matter content (DM). Also shown are the expected minimum and maximum number of frosts in a year across orchards in each supply region and mean frosts per year per supply area.

Impact of adaptations for Conventionally grown 'Zesy002' for the historical period																	
	Impact on yield and VaR (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Mean**	**VaR**	**Min**	**Max**	**Mean**	**Mean**	**VaR**	**Mean**	**VaR**
Auckland	6.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0	0.0	0.0	-0.5	-0.2	-0.1	-0.1
Coromandel	3.4	0.5	0.2	-0.1	0.3	-0.1	0.4	-0.1	0.1	0.0	0	1.8	0.2	-0.4	-0.2	0.0	-0.1
Franklin	4.0	-0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0	1.2	0.0	-0.4	-0.2	0.0	-0.1
Golden Bay	2.1	0.8	0.3	-0.5	0.4	-0.6	0.5	-0.7	0.6	0.2	0	2.4	0.2	-0.3	-0.2	0.5	0.0
Hawke's Bay	8.2	3.8	0.9	-1.0	1.4	-1.7	1.8	-2.0	0.1	0.0	0	7.5	1.1	-0.7	-0.3	0.1	-0.1
Horowhenua	1.3	0.3	0.6	-0.5	0.9	-0.8	1.1	-0.9	0.2	0.1	0	2.9	0.9	-0.4	-0.2	0.5	-0.1
Katikati	1.4	0.3	0.3	-0.4	0.4	-0.5	0.5	-0.5	0.1	0.1	0	4.2	0.2	-0.2	-0.3	0.0	-0.1
Kerikeri	2.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0	0.0	0.0	-0.3	-0.3	-0.1	-0.1
Maketu	4.4	0.0	0.2	-0.3	0.2	-0.4	0.3	-0.4	0.1	0.0	0	1.2	0.1	-0.4	-0.3	-0.1	-0.1
Maniatutu	1.9	-0.1	0.3	-0.6	0.5	-0.8	0.6	-0.9	0.1	0.0	0	7.3	0.3	-0.3	-0.3	0.0	-0.1
Motueka	5.1	1.6	0.9	-1.1	1.4	-1.5	1.7	-1.7	0.6	0.2	0	8.8	0.6	-0.5	-0.3	0.5	0.0
Nelson	5.2	1.4	2.2	-1.6	3.5	-2.6	4.5	-2.8	0.5	0.2	0	7.6	1.4	-0.5	-0.3	0.5	0.0
Opotiki	3.5	1.4	1.1	-1.6	1.8	-2.4	2.3	-2.9	0.1	0.0	0	8.2	0.7	-0.4	-0.2	0.2	-0.1
Paengaroa	2.1	-0.1	0.3	-0.5	0.4	-0.6	0.5	-0.7	0.1	0.0	0	6.7	0.2	-0.3	-0.3	0.0	-0.1
Poverty Bay	6.5	-0.8	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.0	0	2.4	0.1	-0.5	-0.3	0.0	-0.2
Pukehina	4.0	0.2	0.3	-0.6	0.5	-0.9	0.6	-1.0	0.1	0.0	0	6.7	0.3	-0.4	-0.3	0.0	-0.1
Tauranga	1.7	0.2	0.2	-0.3	0.3	-0.4	0.3	-0.4	0.1	0.0	0	4.0	0.2	-0.3	-0.3	0.1	-0.1
Te Puke	1.8	0.3	0.3	-0.6	0.5	-0.8	0.6	-0.9	0.1	0.0	0	7.3	0.3	-0.2	-0.3	0.1	-0.1
Waihi	1.3	0.3	0.4	-0.6	0.6	-0.7	0.7	-0.8	0.1	0.0	0	3.0	0.4	-0.3	-0.3	0.1	-0.1
Waikato	2.7	1.6	1.3	-1.5	2.1	-2.6	2.7	-3.1	0.1	0.0	0	8.5	1.1	-0.4	-0.3	0.2	-0.1
Wanganui	4.4	2.2	1.3	-1.0	2.1	-1.5	2.6	-1.6	0.4	0.2	0	6.2	1.1	-0.5	-0.3	0.5	-0.1
Whakatane	3.4	1.0	0.8	-0.9	1.3	-1.3	1.5	-1.5	0.1	0.0	0	7.7	0.8	-0.4	-0.2	0.0	-0.1
Whangarei	2.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0	0.1	0.0	-0.4	-0.3	0.0	-0.1

Table 18. Projected impact of adaptations on conventional *Actinidia chinensis* var. *chinensis* 'Zesy002' for the mid-century period under RCP 6.0, in terms of change to mean and Value at Risk (VaR) for yield and dry matter content (DM). Also shown are the expected minimum and maximum number of frosts in a year across orchards in each supply region and mean frosts per year per supply region.

Impact of adaptations for Conventionally grown 'Zesy002' for the mid-century period under RCP 6.0																	
	Impact on yield and VaR (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.5	0.3	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0	1.0	0.0	-0.4	-0.2	-0.2	0.0
Franklin	3.9	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0	4.0	0.0	-0.4	-0.2	-0.2	-0.1
Golden Bay	2.2	0.9	0.1	-0.2	0.2	-0.2	0.2	-0.3	0.3	0.1	0	1.8	0.1	-0.3	-0.2	0.4	-0.1
Hawke's Bay	9.5	2.6	0.6	-0.9	0.9	-1.3	1.1	-1.5	0.1	0.1	0	6.2	0.6	-0.7	-0.3	-0.1	-0.1
Horowhenua	1.6	0.1	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0	1.9	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.5	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0	2.0	0.0	-0.2	-0.3	-0.2	0.0
Kerikeri	2.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.5	-0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0	0.3	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.3	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.2	0.1	0	6.7	0.1	-0.3	-0.3	-0.2	-0.1
Motueka	5.8	1.4	0.5	-0.5	0.7	-0.6	0.9	-0.6	0.3	0.1	0	3.9	0.3	-0.4	-0.3	0.3	0.0
Nelson	5.6	1.5	1.7	-1.8	2.7	-2.8	3.4	-3.2	0.2	0.1	0	6.2	0.9	-0.5	-0.3	0.2	0.0
Opotiki	4.0	0.9	0.7	-1.2	1.1	-1.6	1.4	-1.8	0.1	0.1	0	4.9	0.4	-0.4	-0.2	-0.1	-0.1
Paengaroa	2.3	-0.3	0.1	0.0	0.1	-0.1	0.1	-0.1	0.2	0.1	0	1.5	0.0	-0.3	-0.3	-0.2	-0.1
Poverty Bay	6.9	-1.2	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0	2.1	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.2	-0.2	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0	2.2	0.1	-0.4	-0.2	-0.2	-0.1
Tauranga	1.7	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0	2.1	0.1	-0.3	-0.3	-0.2	-0.1
Te Puke	1.9	0.1	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.2	0.1	0	4.0	0.1	-0.2	-0.3	-0.1	-0.1
Waihi	1.4	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.2	0.1	0	2.2	0.1	-0.3	-0.3	-0.2	-0.1
Waikato	3.3	1.0	0.8	-1.3	1.3	-1.9	1.6	-2.2	0.1	0.1	0	10.1	0.5	-0.4	-0.3	-0.1	-0.1
Wanganui	5.4	1.1	0.7	-0.6	1.1	-0.9	1.3	-0.9	0.2	0.0	0	3.8	0.5	-0.5	-0.3	0.3	-0.1
Whakatane	3.8	0.4	0.4	-0.5	0.6	-0.7	0.7	-0.8	0.2	0.1	0	6.0	0.3	-0.4	-0.2	-0.2	-0.1
Whangarei	2.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0	0.0	0.0	-0.4	-0.3	-0.3	-0.1

The effect of increasing soil moisture to improve yield had the effect of reducing DM, generally by 0.3 to 0.3 to 0.5%. However, Hawke's Bay was expected to experience a decline of 0.7%. All supply areas were calculated to have a decline in VaR for DM in both periods. There was no significant difference between the historical and mid-century RCP 6.0 periods in terms of impact (see Table 17 and Table 18).

Controlling for temperature had a negative impact on DM when mean October–March temperature was above 17°C, for example in Auckland, Kerikeri and Maketu in the historical period, and a positive impact when temperature was low, notably in Golden Bay, Horowhenua, Motueka, Nelson and Wanganui, which were predicted to have DM increases of 0.5% (Table 17). In the mid-century period under RCP 6.0, the elevation of mean temperature resulted in larger decreases and smaller increases in DM, although relativity between supply areas was more or less preserved (Table 18).

12 Discussion

We note that a climate effect may have a negligible contribution to VaR while having a big impact on yield. Risk, as reflected in the definition of VaR, is associated with uncertainty. In this framework, a consistently deleterious effect is not a risk but a certainty. This is reflected in some of our simulations where VaR was decreased in response to the adaptation, which indicates that the corresponding unadapted climate effect contributed significantly to the variability in production. However, in other cases both VaR and VaR increased due to the adaptation, suggesting that the deleterious climate effect was relatively constant across years and that other climate effects were contributing significantly to the variability in production. Thus, while the adaptation increased yield, the increased yield had significant risk exposure, and additional adaptations would be beneficial.

Our approach to predicting VaR from crop production models and decomposing VaR based on predictor variables provides a promising tool for investigating the contribution that different variables can make to production risk, whether they be climate or management related, reflect intrinsic biology (such as irregular bearing) or a combination of all. By quantifying the individual contributions to risk, we can identify the most pressing risks, and by modelling the effect of adaptations, we can identify the sensitivity of production to different adaptations under different conditions.

The focus of the project is of course on climate change. Using climate model projection data, we have modelled expected production and VaR and VaR decomposition for future periods (mid- and late century) under different RCPs. We performed parallel calculations for a historical period. This allowed us to project the evolution of key risk factors and their influence on both production and risk. Our modelling of adaptations to risks showed how benefits would vary with location and over time, as climates changed. Projections of how risks would evolve were generally in line with trends of warming temperature and declining wind speed, and also showed the effect of different rainfall patterns.

This could provide guidance for considering climate change risks and adaptations, by providing an insight into the more pressing risks, thus identifying which adaptations are most likely to be required in the future. By modelling the effect that an adaptation would have, rather than the adaptation itself, we provided a more general assessment that allows a range of different adaptations to be considered.

Calculations were performed at the level of individual orchards, but to protect grower confidentiality and for ease of presentation, we aggregated results at the level of avocado supply regions or kiwifruit supply areas. Thus, this insight is available from the individual orchard through to national level. Based on the potential benefits of an adaptation in terms of production saved, growers can decide on whether to implement that adaptation or to choose an alternative strategy. The greater the response to the adaptation, the greater the unadapted climate effect.

A key step in decomposing VaR is separating the contributing variances which, for non-linear models, requires approximation to first order, and this will lead to some numerical inaccuracies, especially with our further assumption that predictor variables have zero covariance. The problem of estimating variance in yield for avocado was made more difficult by the predictor variables including non-linear functions of previous years' yields. We have improved on our previous approach and found an iterative approximation that allows quantification of the impact of irregular bearing on the mean and variance of yield to be modelled in the absence of actual data.

The quality of the predictions is dependent on the production models, which themselves are dependent on the quality of the calibration data. For both avocado and kiwifruit, management information that would have a strong bearing on production outcomes was not available, and this can

introduce systematic errors in the calibrated production models. Additionally, there are uncertainties in the climate projection data that extend past the variation between different model runs within an RCP. Thus, the projections should be interpreted as qualitative rather than quantitative.

For kiwifruit, we had information on cultivars and on organic versus conventional growing systems at the orchard block level, thus fitted the chill parameter separately for cultivars and growing method. The rationale was that budbreak enhancers such as Hi-Cane would be used only in conventional growing systems, and we assumed with 100% uptake and optimal application. In principle, the separately fitted chill parameters would give the differential sensitivity between the cultivars, and also reflect the impact of bud-break enhancers.

As we discussed, the chill parameters reflected a much smaller impact than expected, and thus the model simulations likely under-estimated the impact of lack of chill on an organic kiwifruit. However, the patterns of response fit with our understanding of the effect of chilling and HiCane on productivity. Adjusting the chill parameter values for organic kiwifruit based on expert opinion and scant research data may be considered before presenting results to industry.

The methodology to be developed would also have potential to be utilised for other horticultural industries in the future, to assist them in planning for climate-change resilience.

12.1 Addressing social, economic and equity issues

While we have not directly modelled social and equity issues, the outcomes from our modelling identify where social, economic and equity issues might arise. Regions in which the production of a crop is projected to improve could expect an increase in plantings of that crop, and this would highlight the benefit of studying potential changes to financial streams and pressures on infrastructure and natural resources. The impact of the land-use change could affect employment opportunities either negatively or positively, depending on the crop ecology, and thus implications for the local economy and society. Differences in the ability to obtain financial resources between stakeholders would determine their ability to invest in the new opportunities, and our results identify opportunities for research into avenues on how to assist disadvantaged stakeholders. Similarly, considerations apply if the production of a crop is projected to decrease in the future.

In areas where a warming climate reduces suitability for kiwifruit cultivation while facilitating an increase in avocado production, there would be an opportunity for the two industries to work together to aid the transition of growers from one crop to the other, and our projections can signal where and to what extent these opportunities could arise.

Modelling the impact of adaptations on production and risk provides guidance on the benefit of applying each adaptation on a location basis. Areas where resource-hungry adaptations (like irrigation) are likely to provide the most benefit are more likely to experience an increase in pressure on natural resources. Our projections have identified the current growing regions where this is most likely to occur, thus providing forewarning of increased competition for those resources, which could be exacerbated by parallel increases in non-horticultural demands. In these areas, stakeholders who are currently disadvantaged by lack of equity or resource rights could be further disadvantaged.

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Appendix A Sub-models in production models

A1 Sub-models for modelling avocado yield

A1.1 Evapotranspiration and soil moisture

Actual crop evapotranspiration ($\mathrm{ET_a}$) was calculated using the single-crop approach (Allen et al. 1998):

$$\mathrm{ET_a} = K_s K_c \, \mathrm{ET_O} \tag{12}$$

where K_s describes the effect of water stress on crop transpiration and is a dimensionless transpiration reduction factor dependent on the available soil water and is calculated as in Allen et al. (1998):

$$K_s = \begin{cases} 1, & D_r \leq \mathrm{RAW} \\ \dfrac{\mathrm{TAW} - D_r}{\mathrm{TAW} - \mathrm{RAW}}, & D_r > \mathrm{RAW} \end{cases} \tag{13}$$

where TAW (mm) is total available water in the root zone, D_r (mm) is the root zone depletion, and RAW (mm) is readily available water, where $\mathrm{RAW} = p\,\mathrm{TAW}$, and p is a crop-dependent depletion factor that governs the fraction of TAW that can be removed before moisture stress occurs (Allen et al. 1998). For avocado, $p = 0.7$ (Allen et al. 1998). TAW depends on soil type and the rooting depth, and RAW depends on the crop (Allen et al. 1998). We used TAW values from the soil database.

The parameter K_c is the crop coefficient. For avocado, Allen et al. (1998) suggest that K_c takes values of 0.6, 0.7 and 0.8 at, respectively, the early, mid and late season stages, but can vary with wetting intervals, evaporative power and importance of wetting events. Singh (2020) gives a range of values for K_c for avocado that depend on both month and location in Australia, which is not suitable for our needs. Erazo-Mesa et al. (2021) indicated that a constant value of $K_c = 0.75$ has been used in studies of avocado irrigation requirements, and we have adopted this. We note that the value of K_c depends on crop spacing and canopy structure; however, we did not have this information.

$\mathrm{ET_0}$ is the reference evapotranspiration, and is calculated by the Food and Agriculture Organisation of the United Nations (FAO) Penman-Monteith equation, which is given by Green et al. (2008):

$$\mathrm{ET_0} = \frac{\dfrac{s}{\lambda(R_N - G)} + \dfrac{900\gamma u_2 (e_s - e_a)}{T + 273.2}}{s + \gamma(1 + 0.34u_2)} \tag{14}$$

where R_N (MJ m^{-2} d^{-1}) is net solar radiation, G (MJ m^{-2} d^{-1}) is ground heat flux, T (C) is mean air temperature, e_s (kPa) is saturation vapour pressure at mean air temperature, e_a (kPa) is mean actual vapour pressure of the air, u_2 (m s^{-1}) is mean wind speed at an elevation of 2 m, s (Pa C^{-1}) is the slope of the saturation vapour-pressure versus temperature curve, γ (66.1 Pa) is the psychrometric constant, and λ (2.45 MJ kg^{-1}) is the latent heat of vaporisation of water (Green et al. 2008).

A1.2 Frost risk

Following the approach described by (Vetharaniam et al. 2022a), we modelled the daily-frost suitability-score for avocado as a sigmoidal function of temperature to predict the loss of plant tissue, but using data on avocado (Malo et al. 1977; Dubrovina & Bautista 2014) to specify constants:

$$S_{\text{frost } i} = 1 - \frac{1}{1 + \exp\left(-1.3(-3 - T_{\min i})\right)} \quad (15)$$

where $T_{\min i}$ is the minimum temperature (°C) of day *i* of the frost risk period, and $S_{\text{frost i}}$ is the fraction of yield surviving that minimum temperature. The overall proportion of yield surviving frosts over a period is obtained by taking the product of daily survivals over that period:

$$S_{\text{frost}} = \prod_i v_i S_{\text{frost } i} \quad (16)$$

A1.3 Disease suitability score

We used the generic disease risk function described by Vetharaniam et al. (2021) which has inputs of relative humidity as a proxy for leaf wetness (moisture) and temperature:

$$S_{\text{disease}} = 1 - \frac{\exp\left(-\left(\frac{T_{ave} - 20}{13}\right)^4\right)}{1 + \exp\left(-0.3(\text{RH} - 85)\right)} \quad (17)$$

where T_{ave} and is mean daily temperature and daily RH is a percentage. The threshold value of 85% for relative humidity in the denominator is an intermediate to the risk values of 90% used by Wilks & Shen (1991) and 81% used by Beresford et al. (2016). The numerator reflects the assumption that while there will be a microbial threat over a band of temperatures the temperature range 15–25°C will suit most microbes if RH is optimal for microbial attack (Nick Waipara, pers. comm., 13 July 2019).

A1.4 Wind damage

Wind can cause damage to plants throughout the year. We used the root mean squared (RMS) wind speed over a period as a predictor, rather than mean wind speed, to add more weight to days with high wind speeds, where v_i is mean daily wind speed over a period of i days:

$$v_{\text{RMS}} = \sqrt{\sum_{\text{i}} v_i^2} \quad (18)$$

A2 Sub-models for kiwifruit yield and dry matter content

A2.5 Winter chill

The sufficiency of winter chill was modelled using a sigmoidal chill suitability function that expressed the fraction of cultivars expected to receive adequate chill for a given climate:

$$S_{\text{chill}} = \frac{1}{1 + \exp\left(1.2 * (T_{\text{ave}} - 12.2)\right)} \quad (19)$$

where T_{ave} is the average May to July temperature (°C). This model was based on work that identified that the best model for expressing chill requirements to obtain at least one king flower per winter bud under New Zealand conditions is average May to July temperatures (Snelgar et al. 2008; Hall &

Snelgar 2014). Under the average May to July temperature model, chill requirements are considered met if the average May to July temperature is less than 11.7°C for 'Hayward' (Hall et al. 2018) and 12.7°C for 'Zesy002' (Snelgar et al. 2008; Hall & Snelgar 2014).

A2.6 Absence of frost risk

We used the frost suitability model for kiwifruit described by (Vetharaniam et al. 2022a). The specified daily damage as a function of minimum temperature based on the data of Hewett & Young (1981) who found that, dormant buds are generally frost tolerant while, in newly formed kiwifruit vine shoots, 95% of buds were killed at −3°C, slight damage occurred at −2°C, and no damage occurred at −1°C. In the absence of other data, this temperature sensitivity was assumed for all stages from flowering to harvest, and for all cultivars. The following function was used:

$$S_{\text{frost } i} = 1 - \frac{1}{1 + \exp(-2 - T_{\min i})} \quad (20)$$

where $T_{\min i}$ is the minimum temperature (°C) of day *i* of the frost risk period, and $S_{\text{frost } i}$ is the fraction of yield surviving that minimum temperature. As for avocado, the overall proportion of yield surviving frosts over a period is obtained by taking the product of daily survivals over that period, although multiplied by a daily weight v_i that modifies risk based on phenology stage:

$$S_{\text{frost}} = \prod_i v_i S_{\text{frost } i} \quad (21)$$

The calculation in Equation (*21*) was carried out for each orchard block from an estimated day of bud-break to the recorded harvest date (the frost risk period). The weight v_i was gradually increased from 0 to 1 at the start of the nominal frost risk period to reflect variation in the development time of individual vines, and was set to 0.5 for autumn frosts to reflect the protection provided by the canopy.

We note a key difference from the implementation of Vetharaniam et al. (2022a) who estimated the frost-related suitability of GIS grids containing unknown orchards with unknown harvest dates. Those authors used a curve that decreased from a value of 1 on 1 March to a value of 0 on 30 June specify the probability an orchard had *not* yet being harvested. This curve was used to down-weight the daily frost damage calculations in Equation (*21*) which was calculated to 30 June for all locations.

A2.7 Warmth suitability

The optimal temperature for fruit growth in kiwifruit is 17°C (Snelgar et al. 2005), and we formulated the warmth suitability score to have the value 1 at 17°C and to decline to zero as mean temperature deviated from 17°C in either direction. This function is expressed below in terms of mean temperature, T (°C), where the choice of the coefficient gave a suitability of 0.85 for temperatures of 14 and 20:

$$S_{\text{warmth}} = \exp\left(-0.018(T - 17)^2\right) \quad (22)$$

A2.8 Evapotranspiration and soil moisture

ET_a for kiwifruit is calculated using the same approach as for avocado using Equations (*12*), (*13*) and (*14*), with different values for the depletion factor, p and crop coefficient K_c. For kiwifruit, $p = 0.35$ and K_c can takes values of 0.4 in early in the season, and 1.05 and both the mid- and late-season stages,

but varies with wetting intervals, evaporative power and importance of wetting events (Allen et al. 1998), as is the case for other crops. Green et al. (2021) found that K_c for 'Zesy002' kiwifruit in Italy showed considerable variability during the season and was on average lower that the suggestion by Allen et al. (1998). For 'Hayward', Ferreira et al. (2008) found that K_c was in the range 0.9 to 1.0 during the mid and late season, based on data collected in Portugal.

We calculated $\mathrm{ET_a}$ with K_c varying with the stage of the growing season but found using a constant $K_c = 1$ produced more satisfactory results. This result is unexpected since $K_c$is known to vary, and our result may be due to unknown irrigation events in many orchards along with variation in tree spacing and canopy structure.

Appendix B Discussion notes on risks and adaptations

These notes are from discussions the project team had with Phillip West (NZ Avocado), Octavio Perez-Garcia, Jayson Benge and William Max (all from Zespri), and subsequent comments from Warrick Nelson (Plant & Food Research).

B1 Avocado

B1.1 Crop evapotranspiration – risk of insufficient rain

Adaptations

Irrigation

- There is policy-related risk that regulations may not allow irrigation.
- Drip irrigation from microspinklers would improve water-use efficiency, but is less practical on larger trees.
- Detention storage from excess flows as an adaptation – cost of land will be shared.

Covered Crops

- Cost/benefit unknown, ongoing costs – risks around pollination, and change to pest and disease risk.
- Hard plastic vs rain-permeable fabric, and everything in between. Do not know if there will be a yield risk… data needed.

Tactical pruning

- Sacrifice some or all of crop to save tree. Removing fruit as well as leaf. Judge how much fruit to remove.
- Recent PhD research has shown evapotranspiration drops significantly with harvest so harvesting fruit early would help.

Mulching

- Mulching to a depth of 10 cm should maximise moisture retention while allowing rainfall and irrigation to still penetrate into soil. Avocado trees naturally mulch themselves but additional mulch may be needed to get to 10 cm.
- May have effects on nutrient management.

Modelling possibilities and considerations

- Yield saved as a function of irrigation (mm) and time period for irrigation.
- How big a dam (retention volume) do you need per ha of avocado?
- There is not enough information and experience to model covered crops.
- Tactical pruning – micrometeorology considerations on vapour pressure deficit (VPD) and radiant energy. Yield loss for 2–3 years potentially, depending on when pruning takes place and severity.

- Separate model for likelihood of tree death not necessary.
- Monthly crop factors could be used to estimate water use and soil moisture deficit under different ET_0 scenarios.

B1.2 Risk of frost damage

Adaptations

Irrigation

- Information on this may be available for cherries on overhead sprinklers and under canopy sprinklers from data on impact.

Use of fans

- Fans are effective over a limited area if an inversion layer is present. Water is a more reliable method but ice will break branches if frost continues for a long period.

Covers and shelters

- Frost cloth on young trees.
- Covers for adult trees – look at other crops for a guide.
- Covers are not used on large trees. A couple of orchards trialling growing under cover but not financially viable with current frost risk.
- Shelterbelts and airflows.

Foliar sprays

- Foliar sprays are available, such as ThermoMax, but there are insufficient data to model effectiveness.

B1.3 Modelling possibilities and considerations

- Effective temperature increase from different methods.
- Yield saved from different methods at different temperatures.

B1.4 Risk of insufficient warmth during the growing year

Adaptations

Covers

- These have little effect on night temperature and night temperature might be more important.

Location selection

- Move orchards – transformational adaptation.

New cultivars

- Breeding is an option: There are avocado varieties with greater cold tolerance than others and a breeding programme might allow translation of this trait.

B1.5 Modelling possibilities and considerations

- Model effect of covers on temperature and yield some data on this is available.
- Look at extreme heat risks under covers.

  Shade net research from South Africa (Blakey et al. 2016) showed some but limited effect on temperature.

B1.6 Risk of non-optimal combination of temperature and humidity bands

Poor suitability for high humidity >≈80% and temperatures in the ≈15–25°C band.

Adaptations

Postharvest strategies

- There is ongoing research on post-harvest strategies to avoid disease and on understanding infection conditions of main postharvest fungal pathogens.
- Strategies to indicate if there are latent infections that are not picked up at the pack house – post-harvest impacts right to the consumer.

Chemical and canopy management

- Research on chemical and canopy density management to reduce risk of rot in fruit is not going well to date.

Modelling possibilities and considerations

- Model fruit yield saved by adaptations.
- Also model waterlogging events – phytophthora?
- There are other research projects in Our Land and Water (OLW) looking at disease in fruit trees, so we should avoid duplication.

B1.7 Risk of rain causing fungal and other disease

Adaptations

- Mounding rows with inter-row hollows is used as an adaptation in some orchards.
- Avocado are very prone to water logging (Ploetz & Schaffer 1987). Phytophthora infected trees much more susceptible to flooding as well.

Subsequent thoughts

- Canopy covers might reduce risk.

- Different tree structure (e.g. planar canopy) might reduce effect of rain by reducing water on plant and increasing speed of drying from more open canopy.
- Wind machines or using a sprayer to blow water off trees might help.

Modelling possibilities and considerations

As noted above, we will be working on modelling fruit tree diseases in an OWL project, so should avoid reinventing the wheel.

B1.8 Risk of wind damage

The weather data give average daily wind speed, whereas potentially wind damage is correlated with the strongest gusts. Is this a fruit damage issue or fruit being blown off? Could be that RMS speed is correlated with high gusts.

The main issue is physical damage to skin that downgrades the fruit. Flesh is often not affected. Trees can blow over though and limbs break off. Leaves get shredded in very strong wind.

Adaptations

Shelters belts and site selection

- More closely spaced shelter or additional shelter may be required if prevailing wind direction or intensity changes.

Modelling possibilities and considerations

- Model the effectiveness of shelter belts.

B1.9 Risk of yield loss from irregular bearing

Irregular bearing can be triggered by weather. Improved management can ameliorate. triggers can be frosts in spring or a very favourable spring leading to heavy fruit set.

Adaptations

- Improved management can ameliorate.

Modelling possibilities and considerations

- Do not model since not it is controllable and difficult to pin to a single climate factor. More extreme climates will likely make management more challenging.

B2 Kiwifruit yield

B2.10 Crop evapotranspiration – risk of insufficient rain

Adaptations

Irrigation

- There is risk that regulations may not allow irrigation. Zespri feedback supported this adaptation.

Water storage

- Detention storage from excess flows as an adaptation – cost of land will be shared.

  Zespri feedback supported this adaptation but noted that this should be covered under the irrigation bullet point above.

Covered crops

- Cost/benefit unknown, ongoing costs – risks around pollination, change pest and disease risk. Hard plastic vs rain-permeable fabric and everything in between. It is unclear if there will be a yield risk, for example if there is a flowering issue for covered crops. Bill Snelgar and Kris Kramer-Walter researched the use of covers for kiwifruit, and some data from this work may be useful here.

  Glasshouse growing is an option as an adaptation, but indoor growing or controlled environment systems are out of scope as are semi-open systems.

  Zespri supported this adaptation but considered that the influence might be minor and suggested:

  - Increasing the water retention capability of the soil by adding organic matter.
  - Increasing the water retention capability of the soil by covering soil.
  - Netting and/or retractable netting.

Tactical pruning

- Sacrifice some or the entire crop to save the vine. Removing fruit as well as leaves Judge how much fruit to remove.

  Zespri generally supported this adaptation, and noted this should be tactical thinning rather than pruning that targeted stressed vines.

Modelling possibilities and considerations

- Yield saved as a function of irrigation (mm) and time-period for irrigation.

  Timing is a must and is especially needed for dry months such as January and February. Maybe model yield as a function of ETa instead of mm of irrigation – allows rain and irrigation to be considered on an equal footing.

- How big a dam (detention volume) do you need per ha of kiwifruit? The question could be formulated as “how much water is needed?”

- Not enough information and experience to model covered crops.

- Tactical pruning – micrometeorology considerations on VPD and radiant energy. Yield loss for 2–3 years potentially, depending on when pruning takes place and severity.

- A separate model for likelihood of tree death is not necessary and may not be as valuable in the context of the project as the impact of yield.

B2.11 Risk of frost damage

Adaptations

Irrigation

- Need to get information on overhead sprinklers and under canopy sprinklers from data on impact. Zespri supports this.

Increased air flow

- Use of fans. Zespri supports this and noted both frost fans and helicopters.

Frost cloths

- Frost cloth on young vines. Zespri feedback was only for avocado.
- Covers for adult vines – some data should be available from an MBIE programme that was run a few years ago, in which vines were grown under cover.

  Zespri does not support this and indicated this would be only for avocado, and instead suggested:

  - Hail net would protect from light frost (−2°C to 0°C) for a single night only.

Shelterbelts and airflows

- Zespri supports this and noted that orchards can be located near gullies to flush cold air. That is why Te Puke does not need frost protection.

Zespri also noted that heaters at the end of rows have been used in the past but discontinued because of low efficacy.

Modelling possibilities and considerations

- Effective temperature increase from different methods.
- Yield saved from different methods at different temperatures, but relevant data is not readily available.

B2.12 Risk of inadequate winter chill

Refer to graphs from of ‘Hayward’ with and without hydrogen cyanamide (HCN) (McPherson et al. 2001a; McPherson et al. 2001b).

Adaptations

Budbreak enhancers

- HCN or other budbreak enhancers.

  Zespri supported this but also suggested further adaptations:

  - Use of alternative budbreak enhancers.
  - Canopy management. Grow more canes.
  - Canopy management. Less shade in summer to have better quality buds.

- Girdling. Hold more carbs in your canopy and buds. Works on ‘Hayward’ only.
- Stringing. Reduce king flower numbers.

Modelling possibilities and considerations

- We have modelled the effectiveness of HCN for ‘Zesy002’ vs ‘Hayward’ from fitting to data, based on no and optimal use of HCN on organic and conventional orchards.

- Insufficient data to model other budbreak enhancers.

B2.13 Risk of inadequate warmth during growing season

Consider excessive temperatures if data allow – excessive temperature induces excess vigour (non-linear) around 30°C but for several degrees higher can inhibit growth.

Zespri feedback was that this risk should be “too much warmth” during the growing season rather than insufficient warmth.

Adaptations

Site selection

Perhaps no adaptation likely to be practical.

- Move to different site.

Shading

- Excessive temperature can be ameliorated by overhead irrigation or shading in grapes.

  Excessive temperature at harvest can affect fruit temperature when being picked and that can have detrimental effects – a discussion point and nets can ameliorate the issue.

  Zespri supported this and noted that excessive temperatures can also be dealt with by:

  - Use of Hi-Cane® at different time to change budbreak dates.
  - Potentially the use of leaf drop sprays to force dormancy.

Modelling possibilities and considerations

Discuss excessive heat which, during fruit starch accumulation, can cause a major shift in partitioning towards vegetative growth at the expense of reduced fruit carbohydrate and vitamin C, and reduce growth and flowering in the following season (Richardson et al. 2004).

Heat stress was found to be a useful predictor yield but not DM in the calibration process. Risk of humidity-related disease.

Although this was not a factor identified as an important predictor of yield in the model, maybe it could still be considered at a high level.

It is necessary to specify which diseases the model applies to – for high humidity and optimal temperatures of 15–25°C. This would help identify appropriate agrichemical remedies.

Zespri was interested in similarities between our model and the Psa risk model of Linda Peacock.

B2.14 Harvest year is a model predictor

Not a risk – it is an artefact of cultivar change and relative skill of orchardists switching cultivar.

Zespri noted:

- Vine age. Changes of yield as the vine matures. The vine age effect might be masked by grower's experience to grow the cultivar.
- Younger vines (<5 years old) are more vulnerable to climate change impacts.
- Grafted plants might be more resistant to climate change.

B2.15 Risk of rain being detrimental to fruit

Combination of fungal and other disease. Maybe sclerotinia or Psa. Kiwifruit is extremely susceptible to waterlogging and any duration of wet soils can be detrimental.

Adaptations

Disease management

- Spray for sclerotinia.
- Canopy management for fruit diseases.
- Change cultivar for Psa (transformation adaptation).

Drainage

- Waterlogging – improve drainage or new tolerant rootstocks.

  For phytophthora risk, one may be able to recover the plant with adequate management.

  Zespri noted that:

  - Long rainy seasons might affect the ability to do optimal spraying during winter.
  - Long rainy seasons might affect pollination times and trigger to do artificial pollination.

Modelling possibilities and considerations

- The issue of individual diseases is being looked at in an OLW project, so do not duplicate but rather model generically, so the combined effect of all diseases is reflected in the model response.

An aside with respect to the absence of wind effect being detected: pergola structure more effective than older T-bar structure in protecting fruit from wind, and crop is lower than avocado, and flatter surfaces result in less turbulence than tall avocado trees providing 'rough' profile – laminar flow vs turbulent flow.

B2.16 Risk to yield from early harvest

Earlier harvest gives smaller fruit, and delaying harvest increases fruit size. No real risk since this is a management decision. Therefore, there are no adaptations.

Zespri noted that:

- Shorter harvest window can trigger fruit quality issues.
- The longer fruit is on the vine the greater the exposure risk to hail, frost and extreme weather events. Particularly in autumn.

Modelling possibilities and considerations

- Model increased frost risk due to delayed harvest and surrounding trade-offs.
  This relationship is already implicit in the model, and the impact can be obtained by running different scenarios for harvest times.

- Model trade-off between longer harvest delay and more cumulative rain from 1 October, which could be detrimental (see above).
  The trade-off is implicit in the model and can be modelled by running different scenarios for harvest times.

B3 Kiwifruit dry matter

B3.17 Risk of inadequate warmth from October to harvest

Adaptations

Crop management

- An extra girdling application.
- Thin the crop (depends on payment structure).
- Delay harvest – leave fruit on longer (increased frost risk and the post-harvest chain can be affected – a spill-over from losses in fruit and fruit volumes).
- Withhold water to increase DM (depends on pay structure).
- Root pruning is not effective.

Modelling possibilities and considerations

- What is the relationship between girdling and DM? A potential model is to represent growth rate switching between girdled and non-girdled rates and therefore switching between girdled and non-girdled sugar accumulation).

- Model calibration gives relationship between crop load and DM.

- Relationship in model calibration for DM vs day of harvest.

- Withholding water only works if irrigation is being used and there is no rainfall, or potentially if there are covers – VPD considerations. Will decrease yield. Will not work if DM is low because of low radiation and high rain, but could work if only radiation has been low. Too complicated to model because there are too many possible scenarios.

- Root pruning: do not model.

B3.18 Crop evapotranspiration – risk that high soil moisture lowers DM

Adaptations

Crop management

- An extra girdling application.
- Thin the crop (depends on payment structure).
- Delay harvest – leave fruit on longer (increased frost risk and the post-harvest chain can be affected – spill-over from losses in fruit and fruit volumes).
- Withhold water to increase DM (depends on pay structure).
- Root pruning is not effective.

Modelling possibilities and considerations

- Model the relationship between girdling and DM from GDD, and similarly model that growth rate varies between girdled and non-girdled rates and therefore switching between girdled and non-girdled states gives different sugar accumulation rates.
- Model calibration gives relationship between crop load and DM.
- Relationship in model calibration for DM vs day of harvest.
- Withholding water only works if there is irrigation being used and there is no rainfall – VPD considerations. Will decrease yield. Will not work if DM is low because of low radiation and high rain, but could work if only radiation has been low. Too complicated to model because there are too many possible scenarios.
- Root pruning: do not model.

B3.19 Day of harvest impacts

Earlier harvest gives a lower DM, and delaying harvest increases DM. This is not a risk, but rather a management decision.

Adaptations

- This is a tool to optimise payment due to payment structure and to trade low DM for other risks.

Modelling possibilities and considerations

- Model increased DM due to each day delayed and increased frost risk due to delayed harvest.
- Do not model surrounding trade-offs like payments?

Note that leaving fruit on longer incurs increased risk of post-harvest disorders.

B3.20 Increased yield gives decreased DM

DM is decreased with increased yield because there is less carbohydrate per fruit.

Adaptations

Management practices

- An extra girdling application.
- Thin the crop (depends on payment structure).
- Delay harvest – leave fruit on longer (increased frost risk and post-harvest chain can be affected – fall over).

- Root pruning is not effective.
- Withhold water UNLESS yield is high and fruit are small as well as low DM.
- Growers optimise between DM and weight of fruit based on payments. Threshold size and DM before harvest can occur.

Modelling possibilities and considerations

- Model the relationship between girdling and DM from GDD, and similarly model that growth rate varies between girdled and non-girdled rates and therefore switching between girdled and non-girdled states gives different sugar accumulation rates.
- Model calibration gives relationship between crop load and DM.
- Model calibration gives relationship between crop load and DM.
- Relationship in model calibration for DM vs day of harvest.
- Withholding water only works if there is irrigation being used and there is no rainfall – VPD considerations. Will decrease yield. Will not work if DM is low because of low radiation and high rain, but could work if only radiation has been low. Too complicated to model because there are too many possible scenarios.
- Root pruning: do not model.
- Do not model threshold size and DM.

B3.21 Rain from 1 April to harvest decrease DM

Increased water uptake through roots dilutes DM.

Adaptations

- Delaying harvest is possibly the only adaptation to allow DM to recover as water is lost from fruit via transpiration and exits via vasculature.
- Too late to girdle.

Modelling possibilities and considerations

- Too complicated to model since success depends on rainfall patterns, which cannot be predicted, especially from year to year.

Appendix C Impact of adaptation under climate change

C1 Avocado

Historical and RCP 4.5 mid- and late centuries

Impact of adaptations on avocado yield

Historical period

	Change in yield (tonnes/ha)																
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		25% wind reduction		50% wind reduction		Yearly frost events		
Supply area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean
Bay of Plenty	0.6	0.9	2.3	-1.6	3.2	-2.2	3.5	-2.5	19.9	-2.9	22.4	-2.6	25.1	-2.4	0	47	10.0
Far North	2.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.5	4.4	2.2	7.1	2.8	0	1	0.0
Rest of NZ	0.8	0.1	0.6	0.3	0.8	0.6	0.9	0.7	8.3	4.5	9.7	4.8	11.2	5.1	0	26	3.4
Whangarei	0.6	0.3	0.1	0.1	0.1	0.1	0.1	0.1	8.4	2.4	9.7	2.8	11.0	3.2	0	5	0.5
RCP 4.5 mid-century																	
Bay of Plenty	0.6	0.1	1.9	-0.7	2.5	-0.8	2.7	-0.9	10.5	2.7	13.3	2.8	16.1	2.9	0	31	4.6
Far North	2.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	2.7	1.1	5.3	1.8	0	1	0.0
Rest of NZ	1.2	-0.4	0.5	-0.5	0.7	-0.5	0.8	-0.4	3.3	1.3	4.7	1.6	6.2	1.9	0	19	1.7
Whangarei	0.9	-0.3	0.0	0.0	0.1	0.0	0.1	0.0	2.9	2.1	4.2	2.6	5.6	3.0	0	4	0.2
RCP 4.5 late century																	
Bay of Plenty	0.6	-0.2	1.2	-0.4	1.6	-0.5	1.8	-0.6	7.4	2.9	10.3	3.0	13.2	3.0	0	29	3.2
Far North	2.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	2.4	1.0	4.9	1.7	0	1	0.0
Rest of NZ	1.3	-0.5	0.3	-0.3	0.4	-0.3	0.5	-0.3	2.1	0.9	3.5	1.2	4.9	1.6	0	17	1.0
Whangarei	0.9	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.6	3.0	2.1	4.3	2.5	0	3	0.1

RCP 6.0 and 8.5, mid- and late centuries

Impact of adaptations on avocado yield

RCP 6.0 mid-century	Change in yield (tonnes/ha)																
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		25% wind reduction		50% wind reduction		Yearly frost events		
Supply area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean
Bay of Plenty	0.6	0.1	1.8	-0.7	2.4	-0.9	2.6	-1.0	11.2	2.7	14.0	2.8	16.9	2.8	0	32	4.5
Far North	2.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	2.7	1.2	5.3	1.9	0	1	0.0
Rest of NZ	1.1	-0.4	0.5	-0.4	0.7	-0.3	0.7	-0.3	3.5	1.2	5.0	1.6	6.5	1.9	0	19	1.6
Whangarei	0.9	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	3.1	2.2	4.4	2.7	5.7	3.1	0	4	0.2
RCP 6.0 late century																	
Bay of Plenty	0.5	-0.3	0.6	-0.2	0.8	-0.3	0.8	-0.3	4.3	2.0	7.1	2.1	10.1	2.2	0	22	1.7
Far North	2.4	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	2.2	0.9	4.5	1.7	0	1	0.0
Rest of NZ	1.2	-0.5	0.2	-0.2	0.3	-0.1	0.3	-0.1	1.2	0.5	2.5	0.8	3.9	1.2	0	15	0.5
Whangarei	0.9	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.9	2.0	1.4	3.3	1.9	0	3	0.1
RCP 8.5 mid-century																	
Bay of Plenty	0.6	-0.1	1.3	-0.5	1.7	-0.7	1.9	-0.7	8.3	2.9	11.2	2.9	14.1	3.0	0	30	3.3
Far North	2.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	2.5	1.0	5.0	1.7	0	1	0.0
Rest of NZ	1.3	-0.5	0.3	-0.3	0.4	-0.3	0.5	-0.2	2.6	0.9	4.1	1.2	5.6	1.5	0	16	0.8
Whangarei	1.0	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.7	3.4	2.2	4.8	2.6	0	3	0.1
RCP 8.5 late century																	
Bay of Plenty	0.5	-0.4	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.8	0.4	3.6	0.5	6.6	0.6	0	14	0.3
Far North	2.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	2.0	0.8	4.2	1.6	0	0	0.0
Rest of NZ	1.3	-0.5	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	1.6	0.5	2.9	0.9	0	6	0.1
Whangarei	0.9	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.2	0.6	2.5	1.1	0	1	0.0

C2 Conventional 'Hayward'

Historical

Yield Conventional 'Hayward' Historic period

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.5	-0.1	-0.1	-0.1
Coromandel	2.4	0.4	0.3	-0.2	0.4	-0.2	0.4	-0.2	0.0	0.0	0.0	6.2	0.4	-0.4	-0.1	0.0	-0.1
Franklin	2.6	0.0	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.0	0.0	9.0	0.2	-0.5	-0.1	0.0	-0.1
Golden Bay	1.5	0.5	0.4	-0.7	0.6	-0.9	0.7	-1.0	0.5	0.1	0.0	5.1	0.6	-0.3	-0.2	0.5	0.0
Hawke's Bay	4.8	2.9	0.9	-0.7	1.4	-1.2	1.8	-1.5	0.0	0.0	0.0	16.6	1.9	-0.7	-0.2	0.1	-0.1
Horowhenua	0.9	0.5	0.6	-0.4	0.9	-0.5	1.1	-0.6	0.1	0.1	0.0	6.6	1.7	-0.5	-0.1	0.5	-0.1
Katikati	1.0	0.2	0.4	-0.5	0.5	-0.6	0.6	-0.6	0.1	0.0	0.0	14.0	0.5	-0.2	-0.2	0.0	-0.2
Kerikeri	1.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.3	-0.2	-0.1	-0.1
Maketu	3.0	0.0	0.2	-0.2	0.3	-0.3	0.3	-0.3	0.1	0.1	0.0	5.1	0.2	-0.4	-0.2	-0.1	-0.1
Maniatutu	1.3	-0.1	0.4	-0.5	0.5	-0.7	0.6	-0.7	0.1	0.0	0.0	9.5	0.5	-0.3	-0.2	0.0	-0.1
Motueka	3.2	1.7	1.1	-1.3	1.8	-1.9	2.2	-2.2	0.4	0.2	0.0	14.2	1.7	-0.5	-0.2	0.5	0.0
Nelson	3.1	1.6	1.9	-1.3	3.2	-2.4	4.2	-2.9	0.3	0.2	0.0	21.6	2.6	-0.6	-0.2	0.5	0.0
Opotiki	2.3	0.9	1.1	-1.2	1.7	-1.9	2.2	-2.2	0.1	0.0	0.0	14.2	1.2	-0.4	-0.2	0.2	-0.1
Paengaroa	1.5	0.0	0.3	-0.4	0.5	-0.5	0.5	-0.6	0.1	0.0	0.0	9.1	0.4	-0.3	-0.2	0.0	-0.1
Poverty Bay	4.4	-0.7	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.1	0.0	0.0	3.2	0.1	-0.5	-0.2	0.0	-0.2
Pukehina	2.7	0.1	0.3	-0.5	0.5	-0.6	0.6	-0.7	0.1	0.0	0.0	7.2	0.5	-0.4	-0.2	0.0	-0.1
Tauranga	1.2	0.1	0.2	-0.2	0.4	-0.3	0.4	-0.3	0.1	0.0	0.0	13.0	0.3	-0.3	-0.2	0.1	-0.2
Te Puke	1.3	0.2	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0.0	15.1	0.5	-0.3	-0.2	0.1	-0.1
Waihi	0.9	0.2	0.5	-0.5	0.7	-0.7	0.8	-0.7	0.0	0.0	0.0	9.2	0.7	-0.3	-0.2	0.1	-0.1
Waikato	1.6	1.3	1.3	-1.0	2.3	-1.9	3.1	-2.3	0.1	0.0	0.0	13.1	2.3	-0.5	-0.2	0.2	-0.1
Wanganui	2.9	1.6	1.1	-0.7	1.8	-1.0	2.2	-1.1	0.3	0.1	0.0	11.7	1.7	-0.6	-0.2	0.5	-0.1
Whakatane	2.2	0.8	0.8	-0.8	1.2	-1.2	1.5	-1.3	0.0	0.0	0.0	12.5	1.3	-0.4	-0.1	0.0	-0.1
Whangarei	1.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	-0.4	-0.2	0.0	-0.1

RCP 4.5 Mid-century

Yield Conventional 'Hayward' RCP 4.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	3.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	2.2	0.3	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	6.0	0.1	-0.4	-0.1	-0.3	0.0
Franklin	2.4	0.3	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	4.0	0.1	-0.5	-0.1	-0.3	-0.1
Golden Bay	1.6	0.3	0.2	-0.5	0.3	-0.7	0.4	-0.8	0.2	0.0	0.0	6.0	0.3	-0.3	-0.2	0.4	-0.1
Hawke's Bay	5.8	2.1	0.6	-0.7	1.0	-1.0	1.2	-1.1	0.1	0.1	0.0	13.4	1.2	-0.7	-0.2	-0.2	-0.1
Horowhenua	1.1	0.2	0.4	-0.4	0.6	-0.5	0.7	-0.6	0.1	0.0	0.0	4.5	0.9	-0.5	-0.2	0.3	-0.1
Katikati	1.0	-0.2	0.1	0.0	0.1	0.0	0.2	0.1	0.2	0.1	0.0	9.0	0.1	-0.3	-0.2	-0.3	0.0
Kerikeri	1.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	3.1	-0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.5	-0.3	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.2	0.1	0.0	7.7	0.2	-0.3	-0.2	-0.2	-0.1
Motueka	3.8	1.3	0.7	-0.8	1.1	-1.2	1.3	-1.2	0.2	0.1	0.0	13.1	0.9	-0.5	-0.2	0.3	0.0
Nelson	3.3	1.4	1.7	-1.4	2.8	-2.2	3.5	-2.6	0.1	0.0	0.0	14.2	1.9	-0.5	-0.3	0.2	0.0
Opotiki	2.8	0.4	0.7	-0.9	1.0	-1.2	1.2	-1.4	0.1	0.1	0.0	8.2	0.6	-0.4	-0.1	-0.1	-0.1
Paengaroa	1.6	-0.3	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.0	2.0	0.1	-0.3	-0.2	-0.3	-0.1
Poverty Bay	4.7	-0.9	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	5.4	0.1	-0.6	-0.2	-0.2	-0.1
Pukehina	2.9	-0.3	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.0	3.0	0.1	-0.4	-0.1	-0.3	0.0
Tauranga	1.1	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	10.0	0.1	-0.3	-0.2	-0.2	-0.1
Te Puke	1.4	-0.1	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.1	0.0	10.1	0.2	-0.3	-0.2	-0.2	-0.1
Waihi	1.0	-0.1	0.1	0.0	0.2	0.0	0.2	0.0	0.1	0.1	0.0	6.2	0.2	-0.3	-0.2	-0.2	-0.1
Waikato	2.0	0.9	1.0	-1.1	1.5	-1.6	1.9	-1.8	0.1	0.1	0.0	12.1	1.2	-0.5	-0.2	-0.1	-0.1
Wanganui	3.5	0.9	0.7	-0.5	1.1	-0.6	1.3	-0.7	0.1	0.0	0.0	7.4	0.8	-0.5	-0.2	0.3	-0.1
Whakatane	2.6	0.2	0.4	-0.4	0.6	-0.5	0.7	-0.6	0.2	0.1	0.0	8.2	0.5	-0.4	-0.1	-0.3	-0.1
Whangarei	1.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

RCP 4.5 Late century

Yield Conventional 'Hayward' RCP 4.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	2.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	2.1	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.3	0.1	-0.4	-0.1	-0.3	0.0
Franklin	2.4	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	6.0	0.1	-0.5	-0.1	-0.3	0.0
Golden Bay	1.7	0.1	0.1	-0.3	0.2	-0.4	0.2	-0.4	0.2	0.0	0.0	7.0	0.2	-0.3	-0.2	0.3	-0.1
Hawke's Bay	6.3	1.7	0.5	-0.6	0.8	-0.8	0.9	-0.9	0.1	0.1	0.0	10.4	0.9	-0.7	-0.2	-0.2	-0.1
Horowhenua	1.1	0.1	0.4	-0.3	0.5	-0.4	0.6	-0.4	0.0	0.0	0.0	3.8	0.8	-0.5	-0.1	0.2	-0.1
Katikati	1.0	-0.2	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.0	8.0	0.1	-0.3	-0.2	-0.3	0.0
Kerikeri	1.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.4	-0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	6.5	0.1	-0.3	-0.2	-0.3	0.0
Motueka	4.3	1.1	0.5	-0.7	0.8	-1.0	0.9	-1.0	0.1	0.0	0.0	10.0	0.6	-0.5	-0.2	0.2	0.0
Nelson	3.8	1.5	1.4	-1.4	2.3	-2.3	3.0	-2.7	0.1	0.0	0.0	13.2	1.6	-0.5	-0.3	0.1	0.0
Opotiki	2.6	0.2	0.6	-0.7	0.8	-1.0	1.0	-1.1	0.1	0.1	0.0	8.2	0.5	-0.4	-0.1	-0.2	-0.1
Paengaroa	1.6	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.1	0.1	-0.3	-0.2	-0.3	0.0
Poverty Bay	4.5	-0.9	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	2.2	0.0	-0.5	-0.2	-0.3	-0.1
Pukehina	2.8	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	5.0	0.1	-0.4	-0.1	-0.3	0.0
Tauranga	1.2	-0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.0	0.0	9.0	0.1	-0.3	-0.2	-0.2	-0.1
Te Puke	1.4	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	7.0	0.1	-0.3	-0.2	-0.2	-0.1
Waihi	1.0	-0.2	0.1	0.0	0.2	0.0	0.2	0.1	0.2	0.1	0.0	7.0	0.2	-0.3	-0.2	-0.3	0.0
Waikato	2.2	0.8	0.8	-0.9	1.3	-1.3	1.6	-1.4	0.1	0.1	0.0	9.2	1.0	-0.5	-0.2	-0.2	-0.1
Wanganui	3.9	0.7	0.5	-0.4	0.8	-0.5	0.9	-0.5	0.1	0.0	0.0	5.1	0.6	-0.6	-0.2	0.2	-0.1
Whakatane	2.5	0.2	0.3	-0.3	0.4	-0.4	0.5	-0.4	0.2	0.1	0.0	7.6	0.4	-0.4	-0.1	-0.3	0.0
Whangarei	1.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

RCP6.0 Mid-century

Yield Conventional 'Hayward' RCP 6.0 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	2.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	2.3	0.4	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.0	0.0	3.0	0.1	-0.4	-0.1	-0.2	0.0
Franklin	2.4	0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	5.0	0.1	-0.5	-0.1	-0.2	-0.1
Golden Bay	1.7	0.5	0.2	-0.5	0.3	-0.6	0.3	-0.7	0.2	0.0	0.0	5.1	0.3	-0.3	-0.2	0.4	-0.1
Hawke's Bay	6.0	1.9	0.6	-0.6	0.9	-0.9	1.1	-1.1	0.1	0.1	0.0	11.4	1.0	-0.7	-0.2	-0.1	-0.1
Horowhenua	1.1	0.2	0.4	-0.4	0.6	-0.5	0.7	-0.5	0.1	0.0	0.0	4.1	0.9	-0.5	-0.1	0.3	-0.1
Katikati	1.0	-0.2	0.1	0.0	0.1	0.1	0.2	0.1	0.2	0.1	0.0	9.0	0.1	-0.3	-0.2	-0.2	-0.1
Kerikeri	1.4	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.9	-0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.4	-0.2	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.2	0.1	0.0	8.7	0.1	-0.3	-0.2	-0.2	-0.1
Motueka	3.9	1.3	0.7	-0.9	1.1	-1.2	1.4	-1.3	0.2	0.1	0.0	14.1	0.9	-0.5	-0.2	0.3	0.0
Nelson	3.7	1.6	1.7	-1.6	2.7	-2.5	3.4	-2.9	0.1	0.0	0.0	14.0	1.8	-0.5	-0.2	0.2	0.0
Opotiki	2.7	0.5	0.7	-0.9	1.1	-1.3	1.3	-1.4	0.1	0.1	0.0	11.6	0.6	-0.4	-0.1	-0.1	-0.1
Paengaroa	1.5	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	3.2	0.1	-0.3	-0.2	-0.2	-0.1
Poverty Bay	4.5	-0.9	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	2.2	0.1	-0.6	-0.2	-0.2	-0.1
Pukehina	2.8	-0.1	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.2	0.1	0.0	6.2	0.2	-0.4	-0.2	-0.2	-0.1
Tauranga	1.2	-0.1	0.1	0.0	0.1	0.0	0.2	0.0	0.1	0.0	0.0	9.0	0.1	-0.3	-0.2	-0.2	-0.1
Te Puke	1.3	0.0	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.1	0.0	7.1	0.2	-0.3	-0.2	-0.1	-0.1
Waihi	1.0	-0.1	0.2	0.0	0.2	0.0	0.3	0.0	0.1	0.1	0.0	5.3	0.2	-0.3	-0.2	-0.2	-0.1
Waikato	2.1	1.1	1.0	-1.1	1.6	-1.7	2.0	-1.9	0.1	0.1	0.0	9.4	1.2	-0.5	-0.2	-0.1	-0.1
Wanganui	3.7	0.9	0.6	-0.4	1.0	-0.5	1.1	-0.5	0.1	0.0	0.0	5.7	0.7	-0.5	-0.2	0.3	-0.1
Whakatane	2.5	0.3	0.4	-0.4	0.6	-0.6	0.7	-0.6	0.1	0.1	0.0	11.0	0.6	-0.4	-0.1	-0.2	-0.1
Whangarei	1.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.4	-0.2	-0.3	-0.1

RCP6.0 Late century

Yield Conventional 'Hayward' RCP 6.0 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	2.3	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	2.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	2.0	0.0	-0.4	-0.1	-0.3	0.0
Franklin	2.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	5.0	0.1	-0.5	-0.1	-0.3	0.0
Golden Bay	1.8	0.1	0.1	-0.3	0.2	-0.4	0.2	-0.4	0.1	0.0	0.0	4.1	0.2	-0.3	-0.2	0.2	-0.1
Hawke's Bay	6.5	1.6	0.4	-0.5	0.6	-0.6	0.8	-0.7	0.1	0.1	0.0	8.4	0.7	-0.7	-0.2	-0.3	-0.1
Horowhenua	1.2	0.0	0.3	-0.2	0.4	-0.3	0.5	-0.3	0.0	0.0	0.0	4.5	0.6	-0.5	-0.1	0.1	-0.1
Katikati	0.9	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.2	0.0	-0.3	-0.2	-0.3	0.0
Kerikeri	1.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.1	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.3	-0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.0	3.6	0.0	-0.3	-0.2	-0.3	0.0
Motueka	4.5	0.8	0.4	-0.5	0.6	-0.7	0.7	-0.7	0.1	0.0	0.0	10.2	0.4	-0.5	-0.2	0.1	0.0
Nelson	4.2	1.0	1.2	-1.4	1.9	-2.1	2.4	-2.3	0.0	0.0	0.0	10.2	1.2	-0.5	-0.3	0.0	0.0
Opotiki	2.8	0.2	0.4	-0.5	0.6	-0.7	0.7	-0.7	0.2	0.1	0.0	6.9	0.3	-0.4	-0.1	-0.2	0.0
Paengaroa	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	2.0	0.0	-0.3	-0.2	-0.3	0.0
Poverty Bay	4.6	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	2.2	0.0	-0.6	-0.2	-0.3	0.0
Pukehina	2.6	0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	3.0	0.1	-0.4	-0.1	-0.3	0.0
Tauranga	1.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	9.0	0.0	-0.3	-0.2	-0.3	0.0
Te Puke	1.3	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	4.0	0.0	-0.3	-0.2	-0.3	0.0
Waihi	0.9	-0.2	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	3.0	0.1	-0.3	-0.2	-0.3	0.0
Waikato	2.3	0.5	0.6	-0.6	0.9	-0.8	1.1	-0.8	0.2	0.1	0.0	15.1	0.7	-0.5	-0.2	-0.3	0.0
Wanganui	4.3	0.4	0.4	-0.3	0.5	-0.4	0.6	-0.5	0.1	0.0	0.0	5.5	0.4	-0.6	-0.1	0.1	-0.1
Whakatane	2.6	0.2	0.2	-0.1	0.2	-0.2	0.3	-0.2	0.3	0.1	0.0	7.9	0.2	-0.4	-0.1	-0.3	0.0
Whangarei	1.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

RCP 8.5 Mid-century

Yield Conventional 'Hayward' RCP 8.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	2.7	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	2.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	3.0	0.0	-0.4	-0.1	-0.3	0.0
Franklin	2.3	0.4	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	5.0	0.1	-0.5	-0.1	-0.3	0.0
Golden Bay	1.8	0.1	0.2	-0.4	0.2	-0.5	0.3	-0.6	0.2	0.0	0.0	4.1	0.2	-0.3	-0.2	0.3	-0.1
Hawke's Bay	6.2	1.7	0.5	-0.5	0.8	-0.7	1.0	-0.8	0.1	0.1	0.0	9.2	1.0	-0.7	-0.2	-0.2	-0.1
Horowhenua	1.1	0.0	0.3	-0.4	0.5	-0.6	0.6	-0.6	0.1	0.0	0.0	5.5	0.7	-0.5	-0.2	0.2	-0.1
Katikati	0.9	-0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	7.2	0.1	-0.3	-0.2	-0.3	0.0
Kerikeri	1.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.4	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	6.5	0.1	-0.3	-0.2	-0.3	0.0
Motueka	4.3	1.2	0.6	-0.8	0.9	-1.1	1.1	-1.2	0.1	0.0	0.0	10.0	0.7	-0.5	-0.2	0.2	0.0
Nelson	3.9	1.8	1.5	-1.5	2.4	-2.5	3.1	-3.0	0.1	0.0	0.0	10.2	1.6	-0.6	-0.3	0.1	0.0
Opotiki	2.8	0.3	0.6	-0.8	0.8	-1.0	1.0	-1.1	0.1	0.1	0.0	7.2	0.5	-0.4	-0.1	-0.2	-0.1
Paengaroa	1.5	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	4.0	0.1	-0.3	-0.2	-0.3	0.0
Poverty Bay	4.6	-0.9	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.2	0.0	-0.6	-0.2	-0.2	-0.1
Pukehina	2.7	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	4.1	0.1	-0.4	-0.1	-0.3	0.0
Tauranga	1.2	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	10.0	0.1	-0.3	-0.2	-0.2	-0.1
Te Puke	1.3	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.0	7.1	0.1	-0.3	-0.2	-0.2	-0.1
Waihi	0.9	-0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.2	0.1	0.0	7.0	0.2	-0.3	-0.2	-0.3	0.0
Waikato	2.1	0.8	0.9	-1.0	1.4	-1.4	1.7	-1.6	0.1	0.1	0.0	15.1	1.0	-0.5	-0.2	-0.2	-0.1
Wanganui	3.8	0.8	0.6	-0.3	0.9	-0.4	1.0	-0.4	0.1	0.0	0.0	4.3	0.7	-0.6	-0.2	0.2	-0.1
Whakatane	2.6	0.2	0.3	-0.3	0.5	-0.3	0.5	-0.3	0.2	0.1	0.0	10.6	0.4	-0.4	-0.1	-0.3	0.0
Whangarei	1.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

RCP 8.5 late century

Conventional 'Hayward' RCP 8.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	1.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	1.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.4	0.0	-0.3	0.0
Franklin	1.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.5	-0.1	-0.3	0.0
Golden Bay	1.7	-0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.0	0.0	-0.3	-0.2	0.0	-0.1
Hawke's Bay	6.5	0.6	0.2	-0.2	0.4	-0.2	0.4	-0.3	0.2	0.1	0.0	8.3	0.4	-0.8	-0.2	-0.3	0.0
Horowhenua	1.2	-0.3	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.0	0.0	0.0	1.0	0.2	-0.5	0.0	-0.1	-0.1
Katikati	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.0	0.0	-0.3	-0.2	-0.3	0.0
Kerikeri	0.8	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0
Maniatutu	1.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.2	0.0	-0.3	-0.2	-0.3	0.0
Motueka	4.4	0.1	0.2	-0.2	0.3	-0.3	0.4	-0.3	0.1	0.0	0.0	10.0	0.2	-0.5	-0.2	-0.1	-0.1
Nelson	4.2	0.7	0.8	-1.2	1.3	-1.8	1.5	-2.0	0.1	0.1	0.0	13.2	0.8	-0.5	-0.3	-0.2	0.0
Opotiki	2.7	0.2	0.2	-0.1	0.3	-0.1	0.3	-0.1	0.4	0.1	0.0	4.0	0.2	-0.4	-0.1	-0.3	0.0
Paengaroa	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0	0.0	-0.3	-0.2	-0.3	0.0
Poverty Bay	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.2	0.0	-0.6	-0.2	-0.3	0.0
Pukehina	2.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0	0.0	-0.4	-0.1	-0.3	0.0
Tauranga	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	2.0	0.0	-0.3	-0.2	-0.3	0.0
Te Puke	1.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	2.0	0.0	-0.3	-0.2	-0.3	0.0
Waihi	0.7	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.1	-0.3	0.0
Waikato	2.3	0.2	0.3	-0.2	0.4	-0.2	0.5	-0.2	0.3	0.1	0.0	9.0	0.4	-0.5	-0.1	-0.3	0.0
Wanganui	4.1	-0.4	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.0	0.0	2.3	0.2	-0.6	-0.1	-0.2	-0.1
Whakatane	2.4	0.4	0.1	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	5.1	0.1	-0.4	-0.1	-0.3	0.0
Whangarei	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

C3 Organic 'Hayward'

Historical

Yield Organic 'Hayward' Historical period

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	3.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.5	-0.1	-0.1	-0.1
Coromandel	2.4	0.5	0.2	-0.1	0.4	-0.1	0.4	-0.1	0.0	0.0	0.0	6.2	0.4	-0.4	-0.1	0.0	-0.1
Franklin	2.5	0.1	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.0	0.0	9.0	0.2	-0.5	-0.1	0.0	-0.1
Golden Bay	1.5	0.5	0.4	-0.7	0.6	-0.9	0.7	-1.0	0.5	0.1	0.0	5.1	0.6	-0.3	-0.2	0.5	0.0
Hawke's Bay	4.8	2.9	0.9	-0.7	1.4	-1.2	1.8	-1.5	0.0	0.0	0.0	16.6	1.9	-0.7	-0.2	0.1	-0.1
Horowhenua	0.9	0.5	0.6	-0.4	0.9	-0.5	1.1	-0.6	0.1	0.1	0.0	6.6	1.7	-0.5	-0.1	0.5	-0.1
Katikati	0.9	0.1	0.3	-0.4	0.5	-0.5	0.6	-0.6	0.1	0.0	0.0	14.0	0.5	-0.2	-0.2	0.0	-0.2
Kerikeri	1.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.3	-0.2	-0.1	-0.1
Maketu	2.9	0.0	0.2	-0.2	0.3	-0.2	0.3	-0.3	0.1	0.0	0.0	5.1	0.2	-0.4	-0.2	-0.1	-0.1
Maniatutu	1.3	0.0	0.4	-0.5	0.5	-0.6	0.6	-0.7	0.1	0.0	0.0	9.5	0.5	-0.3	-0.2	0.0	-0.1
Motueka	3.2	1.7	1.1	-1.3	1.8	-1.9	2.2	-2.2	0.4	0.2	0.0	14.2	1.7	-0.5	-0.2	0.5	0.0
Nelson	3.1	1.6	1.9	-1.3	3.2	-2.4	4.2	-2.9	0.3	0.2	0.0	21.6	2.6	-0.6	-0.2	0.5	0.0
Opotiki	2.3	0.9	1.1	-1.1	1.7	-1.8	2.1	-2.2	0.1	0.0	0.0	14.2	1.2	-0.4	-0.2	0.2	-0.1
Paengaroa	1.4	0.0	0.3	-0.4	0.5	-0.5	0.5	-0.6	0.1	0.0	0.0	9.1	0.4	-0.3	-0.2	0.0	-0.1
Poverty Bay	4.3	-0.7	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.1	0.0	0.0	3.2	0.1	-0.5	-0.2	0.0	-0.2
Pukehina	2.7	0.1	0.3	-0.5	0.5	-0.6	0.6	-0.7	0.1	0.0	0.0	7.2	0.5	-0.4	-0.2	0.0	-0.1
Tauranga	1.2	0.1	0.2	-0.2	0.3	-0.3	0.4	-0.3	0.1	0.0	0.0	13.0	0.3	-0.3	-0.2	0.1	-0.2
Te Puke	1.3	0.2	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0.0	15.1	0.5	-0.3	-0.2	0.1	-0.1
Waihi	0.9	0.2	0.5	-0.5	0.7	-0.7	0.8	-0.7	0.0	0.0	0.0	9.2	0.7	-0.3	-0.2	0.1	-0.1
Waikato	1.6	1.3	1.3	-1.0	2.3	-1.8	3.1	-2.3	0.1	0.0	0.0	13.1	2.3	-0.5	-0.2	0.2	-0.1
Wanganui	2.9	1.6	1.1	-0.7	1.8	-1.0	2.2	-1.1	0.3	0.1	0.0	11.7	1.7	-0.6	-0.2	0.5	-0.1
Whakatane	2.2	0.8	0.8	-0.8	1.2	-1.2	1.5	-1.3	0.0	0.0	0.0	12.5	1.3	-0.4	-0.1	0.0	-0.1
Whangarei	1.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	-0.4	-0.2	0.0	-0.1

RCP 4.5 Mid-century

Yield Organic 'Hayward' RCP 4.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	2.6	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	2.1	0.4	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.0	6.0	0.1	-0.4	-0.1	-0.3	0.0
Franklin	2.2	0.6	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	4.0	0.1	-0.5	-0.1	-0.3	-0.1
Golden Bay	1.5	0.3	0.2	-0.5	0.3	-0.7	0.4	-0.7	0.2	0.0	0.0	6.0	0.3	-0.3	-0.2	0.4	-0.1
Hawke's Bay	5.7	2.1	0.6	-0.6	0.9	-0.9	1.2	-1.1	0.1	0.1	0.0	13.4	1.2	-0.7	-0.2	-0.2	-0.1
Horowhenua	1.0	0.2	0.4	-0.4	0.6	-0.6	0.7	-0.6	0.1	0.0	0.0	4.5	0.9	-0.5	-0.2	0.3	-0.1
Katikati	0.9	-0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.2	0.1	0.0	9.0	0.1	-0.3	-0.2	-0.3	0.0
Kerikeri	1.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.9	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.4	-0.2	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.2	0.1	0.0	7.7	0.2	-0.3	-0.2	-0.2	-0.1
Motueka	3.8	1.3	0.7	-0.8	1.1	-1.1	1.3	-1.2	0.2	0.1	0.0	13.1	0.9	-0.5	-0.2	0.3	0.0
Nelson	3.3	1.4	1.7	-1.4	2.8	-2.2	3.5	-2.6	0.1	0.0	0.0	14.2	1.9	-0.5	-0.3	0.2	0.0
Opotiki	2.7	0.4	0.6	-0.9	1.0	-1.2	1.2	-1.3	0.1	0.1	0.0	8.2	0.6	-0.4	-0.1	-0.1	-0.1
Paengaroa	1.6	-0.2	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.0	2.0	0.1	-0.3	-0.2	-0.3	-0.1
Poverty Bay	4.6	-0.6	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	5.4	0.1	-0.6	-0.2	-0.2	-0.1
Pukehina	2.8	-0.1	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.0	3.0	0.1	-0.4	-0.1	-0.3	0.0
Tauranga	1.1	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	10.0	0.1	-0.3	-0.2	-0.2	-0.1
Te Puke	1.3	0.0	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.1	0.0	10.1	0.2	-0.3	-0.2	-0.2	-0.1
Waihi	0.9	-0.1	0.1	0.0	0.2	0.0	0.2	0.0	0.1	0.1	0.0	6.2	0.2	-0.3	-0.2	-0.2	-0.1
Waikato	2.0	0.9	0.9	-1.1	1.5	-1.6	1.9	-1.8	0.1	0.1	0.0	12.1	1.2	-0.5	-0.2	-0.1	-0.1
Wanganui	3.5	0.9	0.7	-0.5	1.1	-0.6	1.3	-0.7	0.1	0.0	0.0	7.4	0.8	-0.5	-0.2	0.3	-0.1
Whakatane	2.5	0.3	0.4	-0.4	0.5	-0.5	0.6	-0.5	0.2	0.1	0.0	8.2	0.5	-0.4	-0.1	-0.3	-0.1
Whangarei	1.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

RCP 4.5 Late century

Yield Organic 'Hayward' RCP 4.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	2.3	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	1.9	0.7	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.3	0.1	-0.4	-0.1	-0.3	0.0
Franklin	2.2	0.7	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	6.0	0.1	-0.5	-0.1	-0.3	0.0
Golden Bay	1.7	0.2	0.1	-0.3	0.2	-0.4	0.2	-0.4	0.2	0.0	0.0	7.0	0.2	-0.3	-0.2	0.3	-0.1
Hawke's Bay	6.2	1.7	0.5	-0.6	0.7	-0.8	0.9	-0.9	0.1	0.1	0.0	10.4	0.9	-0.7	-0.2	-0.2	-0.1
Horowhenua	1.1	0.1	0.4	-0.3	0.5	-0.4	0.6	-0.4	0.0	0.0	0.0	3.8	0.8	-0.5	-0.1	0.2	-0.1
Katikati	0.9	-0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.0	8.0	0.1	-0.3	-0.2	-0.3	0.0
Kerikeri	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.4	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	6.5	0.1	-0.3	-0.2	-0.3	0.0
Motueka	4.3	1.1	0.5	-0.7	0.8	-1.0	0.9	-1.0	0.1	0.0	0.0	10.0	0.6	-0.5	-0.2	0.2	0.0
Nelson	3.8	1.5	1.4	-1.4	2.3	-2.3	2.9	-2.7	0.1	0.0	0.0	13.2	1.6	-0.5	-0.3	0.1	0.0
Opotiki	2.5	0.3	0.5	-0.7	0.8	-0.9	1.0	-1.0	0.1	0.1	0.0	8.2	0.5	-0.4	-0.1	-0.2	-0.1
Paengaroa	1.5	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.1	-0.3	-0.2	-0.3	0.0
Poverty Bay	4.3	-0.6	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	2.2	0.0	-0.5	-0.2	-0.3	-0.1
Pukehina	2.7	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	5.0	0.1	-0.4	-0.1	-0.3	0.0
Tauranga	1.1	-0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.0	0.0	9.0	0.1	-0.3	-0.2	-0.2	-0.1
Te Puke	1.3	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	7.0	0.1	-0.3	-0.2	-0.2	-0.1
Waihi	0.9	-0.1	0.1	0.0	0.1	0.0	0.2	0.1	0.1	0.1	0.0	7.0	0.2	-0.3	-0.2	-0.3	0.0
Waikato	2.2	0.9	0.8	-0.9	1.2	-1.2	1.5	-1.3	0.1	0.1	0.0	9.2	1.0	-0.5	-0.2	-0.2	-0.1
Wanganui	3.8	0.7	0.5	-0.3	0.8	-0.4	0.9	-0.5	0.1	0.0	0.0	5.1	0.6	-0.6	-0.2	0.2	-0.1
Whakatane	2.4	0.2	0.3	-0.3	0.4	-0.3	0.5	-0.4	0.2	0.1	0.0	7.6	0.4	-0.4	-0.1	-0.3	0.0
Whangarei	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

RCP6.0 Mid-century

Yield Organic 'Hayward' RCP 6.0 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	2.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	2.1	0.6	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.1	0.0	3.0	0.1	-0.4	-0.1	-0.2	0.0
Franklin	2.2	0.5	0.1	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	5.0	0.1	-0.5	-0.1	-0.2	-0.1
Golden Bay	1.7	0.5	0.2	-0.5	0.3	-0.6	0.3	-0.7	0.2	0.0	0.0	5.1	0.3	-0.3	-0.2	0.4	-0.1
Hawke's Bay	5.9	1.9	0.6	-0.6	0.9	-0.9	1.1	-1.0	0.1	0.1	0.0	11.4	1.0	-0.7	-0.2	-0.1	-0.1
Horowhenua	1.0	0.2	0.4	-0.4	0.6	-0.5	0.7	-0.5	0.1	0.0	0.0	4.1	0.9	-0.5	-0.1	0.3	-0.1
Katikati	0.9	-0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.2	0.1	0.0	9.0	0.1	-0.3	-0.2	-0.2	-0.1
Kerikeri	1.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.8	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.3	-0.1	0.1	0.0	0.1	-0.1	0.2	-0.1	0.2	0.1	0.0	8.7	0.1	-0.3	-0.2	-0.2	-0.1
Motueka	3.9	1.3	0.7	-0.9	1.1	-1.2	1.4	-1.3	0.2	0.1	0.0	14.1	0.9	-0.5	-0.2	0.3	0.0
Nelson	3.7	1.5	1.7	-1.5	2.7	-2.5	3.4	-2.9	0.1	0.0	0.0	14.0	1.8	-0.5	-0.2	0.2	0.0
Opotiki	2.6	0.5	0.7	-0.9	1.0	-1.3	1.3	-1.4	0.1	0.1	0.0	11.6	0.6	-0.4	-0.1	-0.1	-0.1
Paengaroa	1.5	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	3.2	0.1	-0.3	-0.2	-0.2	-0.1
Poverty Bay	4.4	-0.7	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	2.2	0.1	-0.6	-0.2	-0.2	-0.1
Pukehina	2.7	0.0	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.2	0.1	0.0	6.2	0.2	-0.4	-0.1	-0.2	-0.1
Tauranga	1.1	-0.1	0.1	0.0	0.1	0.0	0.2	0.0	0.1	0.0	0.0	9.0	0.1	-0.3	-0.2	-0.2	-0.1
Te Puke	1.3	0.1	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.0	0.0	7.1	0.2	-0.3	-0.2	-0.1	-0.1
Waihi	0.9	0.0	0.1	0.0	0.2	0.0	0.3	0.1	0.1	0.1	0.0	5.3	0.2	-0.3	-0.2	-0.2	-0.1
Waikato	2.0	1.1	1.0	-1.1	1.6	-1.6	2.0	-1.8	0.1	0.1	0.0	9.4	1.2	-0.5	-0.2	-0.1	-0.1
Wanganui	3.6	0.9	0.6	-0.4	0.9	-0.5	1.1	-0.5	0.1	0.0	0.0	5.7	0.7	-0.5	-0.2	0.3	-0.1
Whakatane	2.4	0.4	0.4	-0.4	0.6	-0.6	0.7	-0.6	0.1	0.1	0.0	11.0	0.6	-0.4	-0.1	-0.2	-0.1
Whangarei	1.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.4	-0.1	-0.3	-0.1

RCP6.0 Late century

Yield Organic 'Hayward' RCP 6.0 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	1.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	1.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	2.0	0.0	-0.4	-0.1	-0.3	0.0
Franklin	1.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	5.0	0.1	-0.5	-0.1	-0.3	0.0
Golden Bay	1.8	0.1	0.1	-0.3	0.2	-0.4	0.2	-0.4	0.1	0.0	0.0	4.1	0.2	-0.3	-0.2	0.2	-0.1
Hawke's Bay	6.3	1.6	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.1	0.0	8.4	0.7	-0.7	-0.2	-0.3	-0.1
Horowhenua	1.2	0.0	0.3	-0.2	0.4	-0.3	0.5	-0.3	0.0	0.0	0.0	4.5	0.6	-0.5	-0.1	0.1	-0.1
Katikati	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.2	0.0	-0.3	-0.2	-0.3	0.0
Kerikeri	0.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.1	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.3	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.0	3.6	0.0	-0.3	-0.2	-0.3	0.0
Motueka	4.5	0.8	0.4	-0.5	0.6	-0.7	0.7	-0.7	0.1	0.0	0.0	10.2	0.4	-0.5	-0.2	0.1	0.0
Nelson	4.2	1.0	1.2	-1.4	1.9	-2.1	2.4	-2.3	0.0	0.0	0.0	10.2	1.2	-0.5	-0.3	0.0	0.0
Opotiki	2.7	0.3	0.4	-0.5	0.6	-0.6	0.7	-0.6	0.2	0.1	0.0	6.9	0.3	-0.4	-0.1	-0.2	0.0
Paengaroa	1.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.2	-0.3	0.0
Poverty Bay	4.4	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	2.2	0.0	-0.6	-0.2	-0.3	0.0
Pukehina	2.5	0.4	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	3.0	0.1	-0.4	-0.1	-0.3	0.0
Tauranga	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	9.0	0.0	-0.3	-0.2	-0.3	0.0
Te Puke	1.2	0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	4.0	0.0	-0.3	-0.2	-0.3	0.0
Waihi	0.8	-0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	3.0	0.1	-0.3	-0.2	-0.3	0.0
Waikato	2.2	0.6	0.6	-0.6	0.9	-0.7	1.0	-0.8	0.2	0.1	0.0	15.1	0.7	-0.5	-0.2	-0.3	0.0
Wanganui	4.2	0.4	0.3	-0.3	0.5	-0.4	0.6	-0.5	0.1	0.0	0.0	5.5	0.4	-0.6	-0.1	0.1	-0.1
Whakatane	2.5	0.3	0.1	-0.1	0.2	-0.2	0.3	-0.2	0.3	0.1	0.0	7.9	0.2	-0.4	-0.1	-0.3	0.0
Whangarei	1.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

RCP 8.5 Mid-century

Yield Organic 'Hayward' RCP 8.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	2.3	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	2.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	3.0	0.0	-0.4	-0.1	-0.3	0.0
Franklin	2.1	0.6	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	5.0	0.1	-0.5	-0.1	-0.3	0.0
Golden Bay	1.8	0.2	0.2	-0.4	0.2	-0.5	0.3	-0.6	0.2	0.0	0.0	4.1	0.2	-0.3	-0.2	0.3	-0.1
Hawke's Bay	6.1	1.7	0.5	-0.5	0.8	-0.7	1.0	-0.7	0.1	0.1	0.0	9.2	1.0	-0.7	-0.2	-0.2	-0.1
Horowhenua	1.1	0.0	0.3	-0.4	0.5	-0.6	0.6	-0.6	0.1	0.0	0.0	5.5	0.7	-0.5	-0.2	0.2	-0.1
Katikati	0.9	-0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	7.2	0.1	-0.3	-0.2	-0.3	0.0
Kerikeri	1.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	2.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.3	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	6.5	0.1	-0.3	-0.2	-0.3	0.0
Motueka	4.3	1.2	0.6	-0.8	0.9	-1.1	1.1	-1.2	0.1	0.0	0.0	10.0	0.7	-0.5	-0.2	0.2	0.0
Nelson	3.9	1.8	1.5	-1.5	2.4	-2.5	3.1	-3.0	0.1	0.0	0.0	10.2	1.6	-0.6	-0.3	0.1	0.0
Opotiki	2.7	0.4	0.5	-0.7	0.8	-1.0	1.0	-1.1	0.1	0.1	0.0	7.2	0.5	-0.4	-0.1	-0.2	-0.1
Paengaroa	1.4	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	4.0	0.1	-0.3	-0.2	-0.3	0.0
Poverty Bay	4.5	-0.7	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	2.2	0.0	-0.6	-0.2	-0.2	-0.1
Pukehina	2.6	0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	4.1	0.1	-0.4	-0.1	-0.3	0.0
Tauranga	1.1	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.0	10.0	0.1	-0.3	-0.2	-0.2	-0.1
Te Puke	1.3	0.1	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.0	0.0	7.1	0.1	-0.3	-0.2	-0.2	-0.1
Waihi	0.9	-0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.1	0.0	7.0	0.2	-0.3	-0.2	-0.3	0.0
Waikato	2.1	0.8	0.8	-1.0	1.3	-1.4	1.6	-1.5	0.1	0.1	0.0	15.1	1.0	-0.5	-0.2	-0.2	-0.1
Wanganui	3.8	0.8	0.6	-0.3	0.9	-0.4	1.0	-0.4	0.1	0.0	0.0	4.3	0.7	-0.6	-0.2	0.2	-0.1
Whakatane	2.5	0.3	0.3	-0.2	0.4	-0.3	0.5	-0.3	0.2	0.1	0.0	10.6	0.4	-0.4	-0.1	-0.3	0.0
Whangarei	1.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

RCP 8.5 late century

Yield Organic 'Hayward' RCP 8.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	1.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.5	0.0	-0.3	0.0
Coromandel	1.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	1.0	0.0	-0.4	0.0	-0.3	0.0
Franklin	1.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	1.0	0.0	-0.5	-0.1	-0.3	0.0
Golden Bay	1.6	-0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.0	0.0	-0.3	-0.2	0.0	-0.1
Hawke's Bay	6.3	0.8	0.2	-0.2	0.3	-0.2	0.4	-0.2	0.2	0.1	0.0	8.3	0.4	-0.8	-0.2	-0.3	0.0
Horowhenua	1.2	-0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	1.0	0.2	-0.5	0.0	-0.1	-0.1
Katikati	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.3	-0.2	-0.3	0.0
Kerikeri	0.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.3	-0.1	-0.3	0.0
Maketu	1.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0
Maniatutu	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.2	0.0	-0.3	-0.2	-0.3	0.0
Motueka	4.4	0.2	0.2	-0.2	0.3	-0.3	0.4	-0.3	0.1	0.0	0.0	10.0	0.2	-0.5	-0.2	-0.1	-0.1
Nelson	4.2	0.7	0.8	-1.2	1.2	-1.8	1.5	-2.0	0.1	0.1	0.0	13.2	0.8	-0.5	-0.3	-0.2	0.0
Opotiki	2.5	0.4	0.2	-0.1	0.3	-0.1	0.3	-0.1	0.3	0.1	0.0	4.0	0.2	-0.4	-0.1	-0.3	0.0
Paengaroa	1.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.0	0.0	-0.3	-0.1	-0.3	0.0
Poverty Bay	4.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.2	0.0	-0.6	-0.2	-0.3	0.0
Pukehina	2.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.0	0.0	-0.4	-0.1	-0.3	0.0
Tauranga	0.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.2	-0.3	0.0
Te Puke	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	2.0	0.0	-0.3	-0.2	-0.3	0.0
Waihi	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.1	-0.3	0.0
Waikato	2.1	0.4	0.3	-0.2	0.4	-0.2	0.5	-0.1	0.3	0.1	0.0	9.0	0.4	-0.5	-0.1	-0.3	0.0
Wanganui	4.0	-0.2	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.0	0.0	2.3	0.2	-0.6	-0.1	-0.2	-0.1
Whakatane	2.2	0.6	0.1	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	5.1	0.1	-0.4	-0.1	-0.3	0.0
Whangarei	0.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	-0.4	-0.1	-0.3	0.0

C4 Conventional 'Zesy002'

Historical

Yield Conventional 'Zesy002' Historical period

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	6.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.5	-0.2	-0.1	-0.1
Coromandel	3.4	0.5	0.2	-0.1	0.3	-0.1	0.4	-0.1	0.1	0.0	0.0	1.8	0.2	-0.4	-0.2	0.0	-0.1
Franklin	4.0	-0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	1.2	0.0	-0.4	-0.2	0.0	-0.1
Golden Bay	2.1	0.8	0.3	-0.5	0.4	-0.6	0.5	-0.7	0.6	0.2	0.0	2.4	0.2	-0.3	-0.2	0.5	0.0
Hawke's Bay	8.2	3.8	0.9	-1.0	1.4	-1.7	1.8	-2.0	0.1	0.0	0.0	7.5	1.1	-0.7	-0.3	0.1	-0.1
Horowhenua	1.3	0.3	0.6	-0.5	0.9	-0.8	1.1	-0.9	0.2	0.1	0.0	2.9	0.9	-0.4	-0.2	0.5	-0.1
Katikati	1.4	0.3	0.3	-0.4	0.4	-0.5	0.5	-0.5	0.1	0.1	0.0	4.2	0.2	-0.2	-0.3	0.0	-0.1
Kerikeri	2.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.1	-0.1
Maketu	4.4	0.0	0.2	-0.3	0.2	-0.4	0.3	-0.4	0.1	0.0	0.0	1.2	0.1	-0.4	-0.3	-0.1	-0.1
Maniatutu	1.9	-0.1	0.3	-0.6	0.5	-0.8	0.6	-0.9	0.1	0.0	0.0	7.3	0.3	-0.3	-0.3	0.0	-0.1
Motueka	5.1	1.6	0.9	-1.1	1.4	-1.5	1.7	-1.7	0.6	0.2	0.0	8.8	0.6	-0.5	-0.3	0.5	0.0
Nelson	5.2	1.4	2.2	-1.6	3.5	-2.6	4.5	-2.8	0.5	0.2	0.0	7.6	1.4	-0.5	-0.3	0.5	0.0
Opotiki	3.5	1.4	1.1	-1.6	1.8	-2.4	2.3	-2.9	0.1	0.0	0.0	8.2	0.7	-0.4	-0.2	0.2	-0.1
Paengaroa	2.1	-0.1	0.3	-0.5	0.4	-0.6	0.5	-0.7	0.1	0.0	0.0	6.7	0.2	-0.3	-0.3	0.0	-0.1
Poverty Bay	6.5	-0.8	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.0	0.0	2.4	0.1	-0.5	-0.3	0.0	-0.2
Pukehina	4.0	0.2	0.3	-0.6	0.5	-0.9	0.6	-1.0	0.1	0.0	0.0	6.7	0.3	-0.4	-0.3	0.0	-0.1
Tauranga	1.7	0.2	0.2	-0.3	0.3	-0.4	0.3	-0.4	0.1	0.0	0.0	4.0	0.2	-0.3	-0.3	0.1	-0.1
Te Puke	1.8	0.3	0.3	-0.6	0.5	-0.8	0.6	-0.9	0.1	0.0	0.0	7.3	0.3	-0.2	-0.3	0.1	-0.1
Waihi	1.3	0.3	0.4	-0.6	0.6	-0.7	0.7	-0.8	0.1	0.0	0.0	3.0	0.4	-0.3	-0.3	0.1	-0.1
Waikato	2.7	1.6	1.3	-1.5	2.1	-2.6	2.7	-3.1	0.1	0.0	0.0	8.5	1.1	-0.4	-0.3	0.2	-0.1
Wanganui	4.4	2.2	1.3	-1.0	2.1	-1.5	2.6	-1.6	0.4	0.2	0.0	6.2	1.1	-0.5	-0.3	0.5	-0.1
Whakatane	3.4	1.0	0.8	-0.9	1.3	-1.3	1.5	-1.5	0.1	0.0	0.0	7.7	0.8	-0.4	-0.2	0.0	-0.1
Whangarei	2.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	-0.4	-0.3	0.0	-0.1

RCP 4.5 Mid-century

Yield Conventional 'Zesy002' RCP 4.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.4	0.2	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.9	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.9	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.0	0.0	-0.4	-0.2	-0.3	-0.1
Golden Bay	2.1	0.6	0.1	-0.2	0.2	-0.2	0.2	-0.2	0.3	0.1	0.0	1.8	0.1	-0.2	-0.3	0.4	-0.1
Hawke's Bay	9.5	2.6	0.6	-0.8	0.9	-1.2	1.1	-1.4	0.1	0.1	0.0	6.2	0.6	-0.6	-0.3	-0.2	-0.1
Horowhenua	1.5	-0.1	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0.0	1.9	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.4	-0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.6	-0.6	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.0	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.2	-0.5	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.3	0.1	0.0	6.7	0.1	-0.3	-0.3	-0.2	-0.1
Motueka	5.6	1.1	0.5	-0.5	0.7	-0.5	0.9	-0.5	0.2	0.1	0.0	6.3	0.3	-0.4	-0.3	0.3	0.0
Nelson	5.4	1.1	1.6	-1.6	2.5	-2.3	3.1	-2.6	0.1	0.1	0.0	4.5	0.8	-0.4	-0.3	0.2	0.0
Opotiki	4.2	0.7	0.7	-1.2	1.1	-1.7	1.4	-1.8	0.2	0.1	0.0	4.6	0.4	-0.4	-0.2	-0.1	-0.1
Paengaroa	2.4	-0.4	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.3	0.1	0.0	1.8	0.1	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.2	-1.1	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.4	-0.4	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	2.4	0.1	-0.4	-0.3	-0.3	0.0
Tauranga	1.7	-0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	2.0	0.0	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.2	0.1	0.0	4.0	0.1	-0.3	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.2	0.0	0.2	0.0	0.2	0.1	0.0	2.0	0.1	-0.3	-0.3	-0.2	0.0
Waikato	3.2	0.9	0.9	-1.4	1.3	-2.0	1.6	-2.3	0.1	0.1	0.0	5.6	0.6	-0.4	-0.3	-0.1	-0.1
Wanganui	5.2	1.3	0.8	-0.7	1.2	-0.9	1.5	-1.0	0.2	0.0	0.0	4.8	0.6	-0.5	-0.2	0.3	-0.1
Whakatane	3.9	0.2	0.4	-0.4	0.6	-0.6	0.7	-0.6	0.2	0.1	0.0	6.3	0.3	-0.4	-0.2	-0.2	0.0
Whangarei	2.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0

RCP 4.5 Late century

Yield Conventional 'Zesy002' RCP 4.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	3.4	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.6	0.0	-0.4	-0.2	-0.3	0.0
Franklin	4.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.0	0.0	-0.5	-0.2	-0.3	0.0
Golden Bay	2.4	0.7	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.2	0.0	0.0	0.9	0.1	-0.3	-0.2	0.3	-0.1
Hawke's Bay	10.1	1.8	0.5	-0.7	0.7	-1.0	0.9	-1.2	0.1	0.1	0.0	5.8	0.5	-0.7	-0.3	-0.2	-0.1
Horowhenua	1.6	-0.1	0.3	-0.4	0.5	-0.6	0.5	-0.6	0.1	0.0	0.0	1.8	0.4	-0.4	-0.2	0.2	-0.1
Katikati	1.5	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.5	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.2	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.1	-0.3	0.1	0.0	0.1	0.0	0.1	-0.1	0.3	0.1	0.0	6.5	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.3	1.0	0.3	-0.2	0.4	-0.2	0.5	-0.2	0.2	0.1	0.0	5.0	0.1	-0.4	-0.3	0.2	0.0
Nelson	6.0	1.1	1.4	-1.5	2.1	-2.1	2.5	-2.2	0.1	0.0	0.0	5.9	0.7	-0.5	-0.3	0.1	0.0
Opotiki	4.0	0.6	0.6	-0.9	0.9	-1.2	1.0	-1.3	0.2	0.1	0.0	3.1	0.3	-0.4	-0.2	-0.2	-0.1
Paengaroa	2.3	-0.3	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	6.9	-1.4	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.0	0.0	-0.5	-0.3	-0.3	-0.1
Pukehina	4.2	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	2.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.8	-0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	2.0	0.0	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	2.4	0.1	-0.2	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	1.6	0.1	-0.3	-0.3	-0.3	0.0
Waikato	3.5	0.6	0.6	-1.0	1.0	-1.4	1.2	-1.5	0.2	0.1	0.0	4.1	0.4	-0.4	-0.3	-0.2	-0.1
Wanganui	5.6	0.9	0.6	-0.5	0.9	-0.7	1.1	-0.7	0.1	0.0	0.0	3.3	0.4	-0.5	-0.2	0.2	-0.1
Whakatane	3.8	0.2	0.3	-0.3	0.4	-0.4	0.5	-0.4	0.3	0.1	0.0	5.0	0.2	-0.4	-0.2	-0.3	0.0
Whangarei	2.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	0.0

RCP6.0 Mid-century

Yield Conventional 'Zesy002' RCP 6.0 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.5	0.3	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.2	0.0
Franklin	3.9	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	4.0	0.0	-0.4	-0.2	-0.2	-0.1
Golden Bay	2.2	0.9	0.1	-0.2	0.2	-0.2	0.2	-0.3	0.3	0.1	0.0	1.8	0.1	-0.3	-0.2	0.4	-0.1
Hawke's Bay	9.5	2.6	0.6	-0.9	0.9	-1.3	1.1	-1.5	0.1	0.1	0.0	6.2	0.6	-0.7	-0.3	-0.1	-0.1
Horowhenua	1.6	0.1	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0.0	1.9	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.5	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.2	0.0
Kerikeri	2.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.5	-0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	0.3	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.3	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.2	0.1	0.0	6.7	0.1	-0.3	-0.3	-0.2	-0.1
Motueka	5.8	1.4	0.5	-0.5	0.7	-0.6	0.9	-0.6	0.3	0.1	0.0	3.9	0.3	-0.4	-0.3	0.3	0.0
Nelson	5.6	1.5	1.7	-1.8	2.7	-2.8	3.4	-3.2	0.2	0.1	0.0	6.2	0.9	-0.5	-0.3	0.2	0.0
Opotiki	4.0	0.9	0.7	-1.2	1.1	-1.6	1.4	-1.8	0.1	0.1	0.0	4.9	0.4	-0.4	-0.2	-0.1	-0.1
Paengaroa	2.3	-0.3	0.1	0.0	0.1	-0.1	0.1	-0.1	0.2	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.2	-0.1
Poverty Bay	6.9	-1.2	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	2.1	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.2	-0.2	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	2.2	0.1	-0.4	-0.2	-0.2	-0.1
Tauranga	1.7	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.1	-0.3	-0.3	-0.2	-0.1
Te Puke	1.9	0.1	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.2	0.1	0.0	4.0	0.1	-0.2	-0.3	-0.1	-0.1
Waihi	1.4	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.2	0.1	0.0	2.2	0.1	-0.3	-0.3	-0.2	-0.1
Waikato	3.3	1.0	0.8	-1.3	1.3	-1.9	1.6	-2.2	0.1	0.1	0.0	10.1	0.5	-0.4	-0.3	-0.1	-0.1
Wanganui	5.4	1.1	0.7	-0.6	1.1	-0.9	1.3	-0.9	0.2	0.0	0.0	3.8	0.5	-0.5	-0.3	0.3	-0.1
Whakatane	3.8	0.4	0.4	-0.5	0.6	-0.7	0.7	-0.8	0.2	0.1	0.0	6.0	0.3	-0.4	-0.2	-0.2	-0.1
Whangarei	2.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	-0.1

RCP6.0 Late century

Yield Conventional 'Zesy002' RCP 6.0 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.2	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.4	0.6	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.1	0.0	0.0	0.8	0.0	-0.3	-0.3	0.2	-0.1
Hawke's Bay	10.6	1.1	0.3	-0.5	0.5	-0.7	0.6	-0.8	0.2	0.1	0.0	4.5	0.3	-0.7	-0.3	-0.3	-0.1
Horowhenua	1.8	-0.2	0.2	-0.1	0.3	-0.1	0.4	-0.1	0.0	0.0	0.0	2.5	0.2	-0.4	-0.2	0.1	-0.1
Katikati	1.4	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.2	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.1	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.1	0.0	3.6	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.6	1.0	0.3	-0.2	0.4	-0.2	0.5	-0.2	0.1	0.0	0.0	3.9	0.1	-0.4	-0.3	0.1	-0.1
Nelson	6.4	1.1	1.1	-1.3	1.7	-1.8	2.1	-1.9	0.1	0.0	0.0	3.6	0.5	-0.5	-0.3	0.0	0.0
Opotiki	4.3	0.5	0.4	-0.6	0.6	-0.8	0.8	-0.9	0.3	0.1	0.0	2.9	0.2	-0.4	-0.2	-0.2	0.0
Paengaroa	2.2	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.4	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.2	-1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.5	-0.3	-0.3	0.0
Pukehina	4.1	-0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.1	0.0	1.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.7	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.2	0.0	-0.3	-0.3	-0.3	0.0
Te Puke	1.9	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.2	0.0	-0.2	-0.2	-0.3	0.0
Waihi	1.4	-0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	1.1	0.0	-0.3	-0.3	-0.3	0.0
Waikato	3.6	0.3	0.4	-0.6	0.6	-0.8	0.7	-0.8	0.3	0.1	0.0	3.4	0.2	-0.4	-0.3	-0.3	0.0
Wanganui	6.3	0.4	0.4	-0.4	0.6	-0.5	0.6	-0.6	0.1	0.0	0.0	2.7	0.2	-0.5	-0.2	0.1	-0.1
Whakatane	4.0	0.1	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.4	0.1	0.0	4.1	0.1	-0.4	-0.2	-0.3	0.0
Whangarei	2.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0

RCP 8.5 Mid-century

Yield Conventional 'Zesy002' RCP 8.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.3	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.7	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	3.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.4	0.9	0.1	-0.1	0.1	-0.2	0.2	-0.2	0.2	0.0	0.0	0.9	0.1	-0.3	-0.2	0.3	-0.1
Hawke's Bay	10.1	2.0	0.5	-0.7	0.7	-1.0	0.9	-1.2	0.1	0.1	0.0	6.0	0.5	-0.7	-0.3	-0.2	-0.1
Horowhenua	1.6	-0.1	0.4	-0.4	0.5	-0.5	0.6	-0.6	0.1	0.0	0.0	1.8	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.4	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.4	-0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.1	0.0	0.2	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.2	0.1	0.0	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	6.5	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.3	1.2	0.4	-0.4	0.5	-0.4	0.6	-0.4	0.2	0.1	0.0	3.4	0.2	-0.5	-0.3	0.2	0.0
Nelson	6.2	1.5	1.5	-1.5	2.2	-2.0	2.7	-2.2	0.1	0.0	0.0	3.6	0.7	-0.5	-0.3	0.1	0.0
Opotiki	4.2	0.6	0.6	-0.9	0.9	-1.2	1.1	-1.3	0.2	0.1	0.0	4.7	0.3	-0.4	-0.2	-0.2	-0.1
Paengaroa	2.2	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.2	-1.3	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	1.2	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.1	-0.1	0.1	0.0	0.1	-0.1	0.1	-0.1	0.4	0.1	0.0	2.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.8	-0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	1.9	0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.2	0.1	0.0	2.5	0.1	-0.2	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	5.0	0.1	-0.3	-0.3	-0.3	0.0
Waikato	3.4	0.7	0.7	-1.1	1.0	-1.5	1.2	-1.7	0.2	0.1	0.0	4.6	0.4	-0.4	-0.3	-0.2	-0.1
Wanganui	5.6	1.0	0.7	-0.6	1.0	-0.7	1.1	-0.8	0.2	0.0	0.0	3.4	0.5	-0.5	-0.2	0.2	-0.1
Whakatane	3.9	0.2	0.3	-0.3	0.4	-0.4	0.5	-0.4	0.3	0.1	0.0	5.6	0.2	-0.4	-0.2	-0.3	0.0
Whangarei	2.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	0.0

RCP 8.5 late century

Yield Conventional 'Zesy002' RCP 8.5 late century

	Impact on yield (1000 trays/ha)										Expected Frost Statistics			Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control					Irrigation		Temperature control	
Supply Area	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	2.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.8	0.0	-0.3	-0.3	0.0	-0.1
Hawke's Bay	10.8	0.2	0.2	-0.3	0.3	-0.4	0.4	-0.5	0.4	0.2	0.0	2.7	0.2	-0.7	-0.3	-0.3	0.0
Horowhenua	1.8	-0.6	0.1	0.0	0.1	0.0	0.2	0.1	0.1	0.0	0.0	1.0	0.1	-0.5	-0.2	-0.1	-0.1
Katikati	1.2	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.2	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.3	-0.2	-0.3	0.0
Maketu	3.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	1.2	0.0	-0.3	-0.2	-0.3	0.0
Motueka	6.3	0.9	0.1	-0.1	0.2	-0.1	0.2	0.0	0.1	0.0	0.0	1.9	0.1	-0.4	-0.3	-0.1	-0.1
Nelson	6.4	1.0	0.7	-0.9	1.0	-1.2	1.2	-1.2	0.2	0.1	0.0	2.4	0.3	-0.5	-0.3	-0.2	0.0
Opotiki	4.4	0.3	0.2	-0.1	0.3	-0.2	0.4	-0.2	0.5	0.1	0.0	2.3	0.1	-0.4	-0.2	-0.3	0.0
Paengaroa	2.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.2	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.1	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.1	0.0	-0.6	-0.2	-0.3	0.0
Pukehina	3.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.7	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	1.0	0.0	-0.3	-0.3	-0.3	0.0
Te Puke	1.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	1.0	0.0	-0.2	-0.2	-0.3	0.0
Waihi	1.2	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0	0.0	-0.3	-0.3	-0.3	0.0
Waikato	3.7	-0.1	0.2	-0.2	0.3	-0.3	0.4	-0.3	0.5	0.1	0.0	6.1	0.1	-0.4	-0.2	-0.3	0.0
Wanganui	6.3	-0.6	0.2	-0.1	0.2	-0.2	0.3	-0.2	0.2	0.0	0.0	1.5	0.1	-0.5	-0.2	-0.2	-0.1
Whakatane	3.9	0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.6	0.1	0.0	1.1	0.0	-0.4	-0.2	-0.3	0.0
Whangarei	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0

Historical

Yield Conventional 'Zesy002' Historical period

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	6.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.5	-0.2	-0.1	-0.1
Coromandel	3.4	0.5	0.2	-0.1	0.3	-0.1	0.4	-0.1	0.1	0.0	0.0	1.8	0.2	-0.4	-0.2	0.0	-0.1
Franklin	4.0	-0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	1.2	0.0	-0.4	-0.2	0.0	-0.1
Golden Bay	2.1	0.8	0.3	-0.5	0.4	-0.6	0.5	-0.7	0.6	0.2	0.0	2.4	0.2	-0.3	-0.2	0.5	0.0
Hawke's Bay	8.2	3.8	0.9	-1.0	1.4	-1.7	1.8	-2.0	0.1	0.0	0.0	7.5	1.1	-0.7	-0.3	0.1	-0.1
Horowhenua	1.3	0.3	0.6	-0.5	0.9	-0.8	1.1	-0.9	0.2	0.1	0.0	2.9	0.9	-0.4	-0.2	0.5	-0.1
Katikati	1.4	0.3	0.3	-0.4	0.4	-0.5	0.5	-0.5	0.1	0.1	0.0	4.2	0.2	-0.2	-0.3	0.0	-0.1
Kerikeri	2.7	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.1	-0.1
Maketu	4.4	0.0	0.2	-0.3	0.2	-0.4	0.3	-0.4	0.1	0.0	0.0	1.2	0.1	-0.4	-0.3	-0.1	-0.1
Maniatutu	1.9	-0.1	0.3	-0.6	0.5	-0.8	0.6	-0.9	0.1	0.0	0.0	7.3	0.3	-0.3	-0.3	0.0	-0.1
Motueka	5.1	1.6	0.9	-1.1	1.4	-1.5	1.7	-1.7	0.6	0.2	0.0	8.8	0.6	-0.5	-0.3	0.5	0.0
Nelson	5.2	1.4	2.2	-1.6	3.5	-2.6	4.5	-2.8	0.5	0.2	0.0	7.6	1.4	-0.5	-0.3	0.5	0.0
Opotiki	3.5	1.4	1.1	-1.6	1.8	-2.4	2.3	-2.9	0.1	0.0	0.0	8.2	0.7	-0.4	-0.2	0.2	-0.1
Paengaroa	2.1	-0.1	0.3	-0.5	0.4	-0.6	0.5	-0.7	0.1	0.0	0.0	6.7	0.2	-0.3	-0.3	0.0	-0.1
Poverty Bay	6.5	-0.8	0.1	-0.1	0.2	-0.1	0.2	-0.1	0.1	0.0	0.0	2.4	0.1	-0.5	-0.3	0.0	-0.2
Pukehina	4.0	0.2	0.3	-0.6	0.5	-0.9	0.6	-1.0	0.1	0.0	0.0	6.7	0.3	-0.4	-0.3	0.0	-0.1
Tauranga	1.7	0.2	0.2	-0.3	0.3	-0.4	0.3	-0.4	0.1	0.0	0.0	4.0	0.2	-0.3	-0.3	0.1	-0.1
Te Puke	1.8	0.3	0.3	-0.6	0.5	-0.8	0.6	-0.9	0.1	0.0	0.0	7.3	0.3	-0.2	-0.3	0.1	-0.1
Waihi	1.3	0.3	0.4	-0.6	0.6	-0.7	0.7	-0.8	0.1	0.0	0.0	3.0	0.4	-0.3	-0.3	0.1	-0.1
Waikato	2.7	1.6	1.3	-1.5	2.1	-2.6	2.7	-3.1	0.1	0.0	0.0	8.5	1.1	-0.4	-0.3	0.2	-0.1
Wanganui	4.4	2.2	1.3	-1.0	2.1	-1.5	2.6	-1.6	0.4	0.2	0.0	6.2	1.1	-0.5	-0.3	0.5	-0.1
Whakatane	3.4	1.0	0.8	-0.9	1.3	-1.3	1.5	-1.5	0.1	0.0	0.0	7.7	0.8	-0.4	-0.2	0.0	-0.1
Whangarei	2.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	-0.4	-0.3	0.0	-0.1

RCP 4.5 Mid-century

Yield Conventional 'Zesy002' RCP 4.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.4	0.2	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.9	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.9	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.0	0.0	-0.4	-0.2	-0.3	-0.1
Golden Bay	2.1	0.6	0.1	-0.2	0.2	-0.2	0.2	-0.2	0.3	0.1	0.0	1.8	0.1	-0.2	-0.3	0.4	-0.1
Hawke's Bay	9.5	2.6	0.6	-0.8	0.9	-1.2	1.1	-1.4	0.1	0.1	0.0	6.2	0.6	-0.6	-0.3	-0.2	-0.1
Horowhenua	1.5	-0.1	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0.0	1.9	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.4	-0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.6	-0.6	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.0	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.2	-0.5	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.3	0.1	0.0	6.7	0.1	-0.3	-0.3	-0.2	-0.1
Motueka	5.6	1.1	0.5	-0.5	0.7	-0.5	0.9	-0.5	0.2	0.1	0.0	6.3	0.3	-0.4	-0.3	0.3	0.0
Nelson	5.4	1.1	1.6	-1.6	2.5	-2.3	3.1	-2.6	0.1	0.1	0.0	4.5	0.8	-0.4	-0.3	0.2	0.0
Opotiki	4.2	0.7	0.7	-1.2	1.1	-1.7	1.4	-1.8	0.2	0.1	0.0	4.6	0.4	-0.4	-0.2	-0.1	-0.1
Paengaroa	2.4	-0.4	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.3	0.1	0.0	1.8	0.1	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.2	-1.1	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.4	-0.4	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	2.4	0.1	-0.4	-0.3	-0.3	0.0
Tauranga	1.7	-0.3	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	2.0	0.0	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.2	0.1	0.0	4.0	0.1	-0.3	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.2	0.0	0.2	0.0	0.2	0.1	0.0	2.0	0.1	-0.3	-0.3	-0.2	0.0
Waikato	3.2	0.9	0.9	-1.4	1.3	-2.0	1.6	-2.3	0.1	0.1	0.0	5.6	0.6	-0.4	-0.3	-0.1	-0.1
Wanganui	5.2	1.3	0.8	-0.7	1.2	-0.9	1.5	-1.0	0.2	0.0	0.0	4.8	0.6	-0.5	-0.2	0.3	-0.1
Whakatane	3.9	0.2	0.4	-0.4	0.6	-0.6	0.7	-0.6	0.2	0.1	0.0	6.3	0.3	-0.4	-0.2	-0.2	0.0
Whangarei	2.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0

RCP 4.5 Late century

Yield Conventional 'Zesy002' RCP 4.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	3.4	0.3	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.6	0.0	-0.4	-0.2	-0.3	0.0
Franklin	4.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.0	0.0	-0.5	-0.2	-0.3	0.0
Golden Bay	2.4	0.7	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.2	0.0	0.0	0.9	0.1	-0.3	-0.2	0.3	-0.1
Hawke's Bay	10.1	1.8	0.5	-0.7	0.7	-1.0	0.9	-1.2	0.1	0.1	0.0	5.8	0.5	-0.7	-0.3	-0.2	-0.1
Horowhenua	1.6	-0.1	0.3	-0.4	0.5	-0.6	0.5	-0.6	0.1	0.0	0.0	1.8	0.4	-0.4	-0.2	0.2	-0.1
Katikati	1.5	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.3	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.5	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.2	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.1	-0.3	0.1	0.0	0.1	0.0	0.1	-0.1	0.3	0.1	0.0	6.5	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.3	1.0	0.3	-0.2	0.4	-0.2	0.5	-0.2	0.2	0.1	0.0	5.0	0.1	-0.4	-0.3	0.2	0.0
Nelson	6.0	1.1	1.4	-1.5	2.1	-2.1	2.5	-2.2	0.1	0.0	0.0	5.9	0.7	-0.5	-0.3	0.1	0.0
Opotiki	4.0	0.6	0.6	-0.9	0.9	-1.2	1.0	-1.3	0.2	0.1	0.0	3.1	0.3	-0.4	-0.2	-0.2	-0.1
Paengaroa	2.3	-0.3	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	6.9	-1.4	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.0	0.0	-0.5	-0.3	-0.3	-0.1
Pukehina	4.2	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	2.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.8	-0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	2.0	0.0	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	2.4	0.1	-0.2	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	1.6	0.1	-0.3	-0.3	-0.3	0.0
Waikato	3.5	0.6	0.6	-1.0	1.0	-1.4	1.2	-1.5	0.2	0.1	0.0	4.1	0.4	-0.4	-0.3	-0.2	-0.1
Wanganui	5.6	0.9	0.6	-0.5	0.9	-0.7	1.1	-0.7	0.1	0.0	0.0	3.3	0.4	-0.5	-0.2	0.2	-0.1
Whakatane	3.8	0.2	0.3	-0.3	0.4	-0.4	0.5	-0.4	0.3	0.1	0.0	5.0	0.2	-0.4	-0.2	-0.3	0.0
Whangarei	2.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	0.0

RCP6.0 Mid-century

Yield Conventional 'Zesy002' RCP 6.0 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.4	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.5	0.3	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.2	0.0
Franklin	3.9	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	4.0	0.0	-0.4	-0.2	-0.2	-0.1
Golden Bay	2.2	0.9	0.1	-0.2	0.2	-0.2	0.2	-0.3	0.3	0.1	0.0	1.8	0.1	-0.3	-0.2	0.4	-0.1
Hawke's Bay	9.5	2.6	0.6	-0.9	0.9	-1.3	1.1	-1.5	0.1	0.1	0.0	6.2	0.6	-0.7	-0.3	-0.1	-0.1
Horowhenua	1.6	0.1	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0.0	1.9	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.5	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.2	0.0
Kerikeri	2.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.5	-0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	0.3	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.3	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.2	0.1	0.0	6.7	0.1	-0.3	-0.3	-0.2	-0.1
Motueka	5.8	1.4	0.5	-0.5	0.7	-0.6	0.9	-0.6	0.3	0.1	0.0	3.9	0.3	-0.4	-0.3	0.3	0.0
Nelson	5.6	1.5	1.7	-1.8	2.7	-2.8	3.4	-3.2	0.2	0.1	0.0	6.2	0.9	-0.5	-0.3	0.2	0.0
Opotiki	4.0	0.9	0.7	-1.2	1.1	-1.6	1.4	-1.8	0.1	0.1	0.0	4.9	0.4	-0.4	-0.2	-0.1	-0.1
Paengaroa	2.3	-0.3	0.1	0.0	0.1	-0.1	0.1	-0.1	0.2	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.2	-0.1
Poverty Bay	6.9	-1.2	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	2.1	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.2	-0.2	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	2.2	0.1	-0.4	-0.2	-0.2	-0.1
Tauranga	1.7	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.1	-0.3	-0.3	-0.2	-0.1
Te Puke	1.9	0.1	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.2	0.1	0.0	4.0	0.1	-0.2	-0.3	-0.1	-0.1
Waihi	1.4	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.2	0.1	0.0	2.2	0.1	-0.3	-0.3	-0.2	-0.1
Waikato	3.3	1.0	0.8	-1.3	1.3	-1.9	1.6	-2.2	0.1	0.1	0.0	10.1	0.5	-0.4	-0.3	-0.1	-0.1
Wanganui	5.4	1.1	0.7	-0.6	1.1	-0.9	1.3	-0.9	0.2	0.0	0.0	3.8	0.5	-0.5	-0.3	0.3	-0.1
Whakatane	3.8	0.4	0.4	-0.5	0.6	-0.7	0.7	-0.8	0.2	0.1	0.0	6.0	0.3	-0.4	-0.2	-0.2	-0.1
Whangarei	2.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	-0.1

RCP6.0 Late century

Yield Conventional 'Zesy002' RCP 6.0 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.2	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.4	0.6	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.1	0.0	0.0	0.8	0.0	-0.3	-0.3	0.2	-0.1
Hawke's Bay	10.6	1.1	0.3	-0.5	0.5	-0.7	0.6	-0.8	0.2	0.1	0.0	4.5	0.3	-0.7	-0.3	-0.3	-0.1
Horowhenua	1.8	-0.2	0.2	-0.1	0.3	-0.1	0.4	-0.1	0.0	0.0	0.0	2.5	0.2	-0.4	-0.2	0.1	-0.1
Katikati	1.4	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.2	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.1	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.1	0.0	3.6	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.6	1.0	0.3	-0.2	0.4	-0.2	0.5	-0.2	0.1	0.0	0.0	3.9	0.1	-0.4	-0.3	0.1	-0.1
Nelson	6.4	1.1	1.1	-1.3	1.7	-1.8	2.1	-1.9	0.1	0.0	0.0	3.6	0.5	-0.5	-0.3	0.0	0.0
Opotiki	4.3	0.5	0.4	-0.6	0.6	-0.8	0.8	-0.9	0.3	0.1	0.0	2.9	0.2	-0.4	-0.2	-0.2	0.0
Paengaroa	2.2	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.4	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.2	-1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.5	-0.3	-0.3	0.0
Pukehina	4.1	-0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.1	0.0	1.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.7	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.2	0.0	-0.3	-0.3	-0.3	0.0
Te Puke	1.9	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.2	0.0	-0.2	-0.2	-0.3	0.0
Waihi	1.4	-0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	1.1	0.0	-0.3	-0.3	-0.3	0.0
Waikato	3.6	0.3	0.4	-0.6	0.6	-0.8	0.7	-0.8	0.3	0.1	0.0	3.4	0.2	-0.4	-0.3	-0.3	0.0
Wanganui	6.3	0.4	0.4	-0.4	0.6	-0.5	0.6	-0.6	0.1	0.0	0.0	2.7	0.2	-0.5	-0.2	0.1	-0.1
Whakatane	4.0	0.1	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.4	0.1	0.0	4.1	0.1	-0.4	-0.2	-0.3	0.0
Whangarei	2.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0

RCP 8.5 Mid-century

Yield Conventional 'Zesy002' RCP 8.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.3	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.7	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	3.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.4	0.9	0.1	-0.1	0.1	-0.2	0.2	-0.2	0.2	0.0	0.0	0.9	0.1	-0.3	-0.2	0.3	-0.1
Hawke's Bay	10.1	2.0	0.5	-0.7	0.7	-1.0	0.9	-1.2	0.1	0.1	0.0	6.0	0.5	-0.7	-0.3	-0.2	-0.1
Horowhenua	1.6	-0.1	0.4	-0.4	0.5	-0.5	0.6	-0.6	0.1	0.0	0.0	1.8	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.4	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.4	-0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.1	0.0	0.2	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.2	0.1	0.0	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	6.5	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.3	1.2	0.4	-0.4	0.5	-0.4	0.6	-0.4	0.2	0.1	0.0	3.4	0.2	-0.5	-0.3	0.2	0.0
Nelson	6.2	1.5	1.5	-1.5	2.2	-2.0	2.7	-2.2	0.1	0.0	0.0	3.6	0.7	-0.5	-0.3	0.1	0.0
Opotiki	4.2	0.6	0.6	-0.9	0.9	-1.2	1.1	-1.3	0.2	0.1	0.0	4.7	0.3	-0.4	-0.2	-0.2	-0.1
Paengaroa	2.2	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.2	-1.3	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	1.2	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.1	-0.1	0.1	0.0	0.1	-0.1	0.1	-0.1	0.4	0.1	0.0	2.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.8	-0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	1.9	0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.2	0.1	0.0	2.5	0.1	-0.2	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	5.0	0.1	-0.3	-0.3	-0.3	0.0
Waikato	3.4	0.7	0.7	-1.1	1.0	-1.5	1.2	-1.7	0.2	0.1	0.0	4.6	0.4	-0.4	-0.3	-0.2	-0.1
Wanganui	5.6	1.0	0.7	-0.6	1.0	-0.7	1.1	-0.8	0.2	0.0	0.0	3.4	0.5	-0.5	-0.2	0.2	-0.1
Whakatane	3.9	0.2	0.3	-0.3	0.4	-0.4	0.5	-0.4	0.3	0.1	0.0	5.6	0.2	-0.4	-0.2	-0.3	0.0
Whangarei	2.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	0.0

RCP 8.5 late century

Yield Conventional 'Zesy002' RCP 8.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	2.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.8	0.0	-0.3	-0.3	0.0	-0.1
Hawke's Bay	10.8	0.2	0.2	-0.3	0.3	-0.4	0.4	-0.5	0.4	0.2	0.0	2.7	0.2	-0.7	-0.3	-0.3	0.0
Horowhenua	1.8	-0.6	0.1	0.0	0.1	0.0	0.2	0.1	0.1	0.0	0.0	1.0	0.1	-0.5	-0.2	-0.1	-0.1
Katikati	1.2	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.2	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.3	-0.2	-0.3	0.0
Maketu	3.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	1.2	0.0	-0.3	-0.2	-0.3	0.0
Motueka	6.3	0.9	0.1	-0.1	0.2	-0.1	0.2	0.0	0.1	0.0	0.0	1.9	0.1	-0.4	-0.3	-0.1	-0.1
Nelson	6.4	1.0	0.7	-0.9	1.0	-1.2	1.2	-1.2	0.2	0.1	0.0	2.4	0.3	-0.5	-0.3	-0.2	0.0
Opotiki	4.4	0.3	0.2	-0.1	0.3	-0.2	0.4	-0.2	0.5	0.1	0.0	2.3	0.1	-0.4	-0.2	-0.3	0.0
Paengaroa	2.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.2	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.1	-1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.1	0.0	-0.6	-0.2	-0.3	0.0
Pukehina	3.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.7	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	1.0	0.0	-0.3	-0.3	-0.3	0.0
Te Puke	1.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	1.0	0.0	-0.2	-0.2	-0.3	0.0
Waihi	1.2	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0	0.0	-0.3	-0.3	-0.3	0.0
Waikato	3.7	-0.1	0.2	-0.2	0.3	-0.3	0.4	-0.3	0.5	0.1	0.0	6.1	0.1	-0.4	-0.2	-0.3	0.0
Wanganui	6.3	-0.6	0.2	-0.1	0.2	-0.2	0.3	-0.2	0.2	0.0	0.0	1.5	0.1	-0.5	-0.2	-0.2	-0.1
Whakatane	3.9	0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.6	0.1	0.0	1.1	0.0	-0.4	-0.2	-0.3	0.0
Whangarei	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0

C5 Organic 'Zesy002'

Historical

Yield Organic 'Zesy002' Historical period

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	6.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.5	-0.2	-0.1	-0.1
Coromandel	3.4	0.6	0.2	-0.1	0.3	-0.1	0.4	-0.1	0.1	0.0	0.0	1.8	0.2	-0.4	-0.2	0.0	-0.1
Franklin	3.9	-0.3	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	1.2	0.0	-0.4	-0.2	0.0	-0.1
Golden Bay	2.1	0.8	0.3	-0.5	0.4	-0.6	0.5	-0.7	0.6	0.2	0.0	2.4	0.2	-0.3	-0.2	0.5	0.0
Hawke's Bay	8.2	3.7	0.9	-1.0	1.4	-1.6	1.8	-2.0	0.1	0.0	0.0	7.5	1.1	-0.7	-0.3	0.1	-0.1
Horowhenua	1.3	0.3	0.6	-0.5	0.9	-0.7	1.1	-0.9	0.2	0.1	0.0	2.9	0.9	-0.4	-0.2	0.5	-0.1
Katikati	1.3	0.3	0.3	-0.4	0.4	-0.5	0.5	-0.5	0.1	0.0	0.0	4.2	0.2	-0.2	-0.3	0.0	-0.1
Kerikeri	2.5	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.1	-0.1
Maketu	4.3	0.0	0.2	-0.3	0.2	-0.4	0.3	-0.4	0.1	0.0	0.0	1.2	0.1	-0.4	-0.3	-0.1	-0.1
Maniatutu	1.9	-0.1	0.3	-0.6	0.5	-0.8	0.6	-0.9	0.1	0.0	0.0	7.3	0.3	-0.3	-0.3	0.0	-0.1
Motueka	5.1	1.6	0.9	-1.1	1.4	-1.5	1.7	-1.6	0.6	0.2	0.0	8.8	0.6	-0.5	-0.3	0.5	0.0
Nelson	5.2	1.4	2.2	-1.6	3.5	-2.6	4.5	-2.8	0.5	0.2	0.0	7.6	1.4	-0.5	-0.3	0.5	0.0
Opotiki	3.5	1.4	1.1	-1.6	1.8	-2.4	2.2	-2.8	0.1	0.0	0.0	8.2	0.7	-0.4	-0.2	0.2	-0.1
Paengaroa	2.1	-0.1	0.3	-0.5	0.4	-0.6	0.5	-0.7	0.1	0.0	0.0	6.7	0.2	-0.3	-0.3	0.0	-0.1
Poverty Bay	6.5	-0.8	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.1	0.0	0.0	2.4	0.1	-0.5	-0.3	0.0	-0.2
Pukehina	4.0	0.2	0.3	-0.6	0.5	-0.8	0.6	-1.0	0.1	0.0	0.0	6.7	0.3	-0.4	-0.3	0.0	-0.1
Tauranga	1.7	0.2	0.2	-0.3	0.3	-0.4	0.3	-0.4	0.1	0.0	0.0	4.0	0.2	-0.3	-0.3	0.1	-0.1
Te Puke	1.8	0.3	0.3	-0.6	0.5	-0.8	0.6	-0.9	0.1	0.0	0.0	7.3	0.3	-0.2	-0.3	0.1	-0.1
Waihi	1.2	0.3	0.4	-0.5	0.6	-0.7	0.7	-0.8	0.1	0.0	0.0	3.0	0.4	-0.3	-0.3	0.1	-0.1
Waikato	2.7	1.6	1.3	-1.5	2.1	-2.5	2.7	-3.1	0.1	0.0	0.0	8.5	1.1	-0.4	-0.3	0.2	-0.1
Wanganui	4.4	2.2	1.3	-1.0	2.1	-1.5	2.6	-1.6	0.4	0.2	0.0	6.2	1.1	-0.5	-0.3	0.5	-0.1
Whakatane	3.4	1.0	0.8	-0.9	1.3	-1.3	1.5	-1.5	0.1	0.0	0.0	7.7	0.8	-0.4	-0.2	0.0	-0.1
Whangarei	2.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	-0.4	-0.3	0.0	-0.1

RCP 4.5 Mid-century

Yield Organic 'Zesy002' RCP 4.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	5.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.2	0.4	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	0.9	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	1.0	0.0	-0.4	-0.2	-0.3	-0.1
Golden Bay	2.1	0.6	0.1	-0.2	0.2	-0.2	0.2	-0.2	0.3	0.1	0.0	1.8	0.1	-0.2	-0.3	0.4	-0.1
Hawke's Bay	9.4	2.6	0.6	-0.8	0.9	-1.2	1.1	-1.4	0.1	0.1	0.0	6.2	0.6	-0.6	-0.3	-0.2	-0.1
Horowhenua	1.4	0.0	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0.0	1.9	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.4	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.5	-0.4	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.0	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.2	-0.4	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.3	0.1	0.0	6.7	0.1	-0.3	-0.3	-0.2	-0.1
Motueka	5.6	1.1	0.5	-0.5	0.7	-0.5	0.9	-0.5	0.2	0.1	0.0	6.3	0.3	-0.4	-0.3	0.3	0.0
Nelson	5.3	1.1	1.6	-1.6	2.5	-2.3	3.1	-2.6	0.1	0.1	0.0	4.5	0.8	-0.4	-0.3	0.2	0.0
Opotiki	4.1	0.7	0.7	-1.2	1.1	-1.6	1.3	-1.8	0.1	0.1	0.0	4.6	0.4	-0.4	-0.2	-0.1	-0.1
Paengaroa	2.3	-0.3	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	1.8	0.1	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.1	-1.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.3	-0.3	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	2.4	0.1	-0.4	-0.3	-0.3	0.0
Tauranga	1.6	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	1.9	0.0	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.2	0.1	0.0	4.0	0.1	-0.3	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.2	0.0	0.2	0.0	0.2	0.1	0.0	2.0	0.1	-0.3	-0.3	-0.2	0.0
Waikato	3.1	1.0	0.9	-1.3	1.3	-2.0	1.6	-2.3	0.1	0.1	0.0	5.6	0.6	-0.4	-0.3	-0.1	-0.1
Wanganui	5.2	1.3	0.8	-0.7	1.2	-0.9	1.5	-1.0	0.2	0.0	0.0	4.8	0.6	-0.5	-0.2	0.3	-0.1
Whakatane	3.8	0.3	0.4	-0.4	0.6	-0.6	0.7	-0.6	0.2	0.1	0.0	6.3	0.3	-0.4	-0.2	-0.2	0.0
Whangarei	2.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0

RCP 4.5 Late century

Yield Organic 'Zesy002' RCP 4.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	3.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.6	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	1.0	0.0	-0.5	-0.2	-0.3	0.0
Golden Bay	2.3	0.7	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.2	0.0	0.0	0.9	0.1	-0.3	-0.2	0.3	-0.1
Hawke's Bay	10.0	1.8	0.5	-0.7	0.7	-1.0	0.9	-1.1	0.1	0.1	0.0	5.8	0.5	-0.7	-0.3	-0.2	-0.1
Horowhenua	1.6	-0.1	0.3	-0.4	0.5	-0.6	0.5	-0.6	0.1	0.0	0.0	1.8	0.4	-0.4	-0.2	0.2	-0.1
Katikati	1.4	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.2	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.1	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	6.5	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.2	1.0	0.3	-0.2	0.4	-0.2	0.5	-0.2	0.2	0.1	0.0	5.0	0.1	-0.4	-0.3	0.2	0.0
Nelson	6.0	1.1	1.4	-1.5	2.1	-2.1	2.5	-2.2	0.1	0.0	0.0	5.9	0.7	-0.5	-0.3	0.1	0.0
Opotiki	3.9	0.6	0.6	-0.9	0.9	-1.2	1.0	-1.3	0.2	0.1	0.0	3.1	0.3	-0.4	-0.2	-0.2	-0.1
Paengaroa	2.3	-0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	6.7	-1.2	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	2.0	0.0	-0.5	-0.3	-0.3	-0.1
Pukehina	4.1	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	2.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.7	-0.2	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	1.9	0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.2	0.1	0.0	2.4	0.1	-0.2	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	1.6	0.1	-0.3	-0.3	-0.3	0.0
Waikato	3.5	0.7	0.6	-1.0	1.0	-1.4	1.2	-1.5	0.2	0.1	0.0	4.1	0.4	-0.4	-0.3	-0.2	-0.1
Wanganui	5.5	0.8	0.6	-0.5	0.9	-0.6	1.1	-0.7	0.1	0.0	0.0	3.3	0.4	-0.5	-0.2	0.2	-0.1
Whakatane	3.7	0.2	0.3	-0.3	0.4	-0.4	0.5	-0.4	0.3	0.1	0.0	5.0	0.2	-0.4	-0.2	-0.3	0.0
Whangarei	2.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	0.0

RCP6.0 Mid-century

Yield Organic 'Zesy002' RCP 6.0 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	3.3	0.5	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.2	0.0
Franklin	3.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	4.0	0.0	-0.4	-0.2	-0.2	-0.1
Golden Bay	2.2	0.9	0.1	-0.2	0.2	-0.2	0.2	-0.3	0.3	0.1	0.0	1.8	0.1	-0.3	-0.2	0.4	-0.1
Hawke's Bay	9.4	2.6	0.6	-0.9	0.9	-1.3	1.1	-1.4	0.1	0.1	0.0	6.2	0.6	-0.7	-0.3	-0.1	-0.1
Horowhenua	1.6	0.2	0.4	-0.5	0.6	-0.6	0.7	-0.7	0.1	0.0	0.0	1.9	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.4	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.2	0.0
Kerikeri	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.3	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	0.3	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.2	0.1	-0.1	0.1	-0.1	0.2	-0.1	0.2	0.1	0.0	6.7	0.1	-0.3	-0.3	-0.2	-0.1
Motueka	5.8	1.4	0.5	-0.5	0.7	-0.6	0.9	-0.6	0.3	0.1	0.0	3.9	0.3	-0.4	-0.3	0.3	0.0
Nelson	5.6	1.5	1.7	-1.8	2.7	-2.8	3.4	-3.2	0.2	0.1	0.0	6.2	0.9	-0.5	-0.3	0.2	0.0
Opotiki	4.0	0.9	0.7	-1.2	1.1	-1.6	1.3	-1.8	0.1	0.1	0.0	4.9	0.4	-0.4	-0.2	-0.1	-0.1
Paengaroa	2.2	-0.2	0.1	0.0	0.1	-0.1	0.1	-0.1	0.2	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.2	-0.1
Poverty Bay	6.8	-1.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.0	2.1	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.1	-0.1	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.3	0.1	0.0	2.2	0.1	-0.4	-0.2	-0.2	-0.1
Tauranga	1.7	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.2	0.1	0.0	2.1	0.1	-0.3	-0.3	-0.2	-0.1
Te Puke	1.9	0.2	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.2	0.1	0.0	4.0	0.1	-0.2	-0.3	-0.1	-0.1
Waihi	1.4	0.0	0.1	0.0	0.2	0.0	0.2	0.1	0.1	0.1	0.0	2.2	0.1	-0.3	-0.3	-0.2	-0.1
Waikato	3.3	1.1	0.8	-1.3	1.3	-1.9	1.6	-2.1	0.1	0.1	0.0	10.1	0.5	-0.4	-0.3	-0.1	-0.1
Wanganui	5.4	1.1	0.7	-0.6	1.1	-0.8	1.3	-0.9	0.2	0.0	0.0	3.8	0.5	-0.5	-0.3	0.3	-0.1
Whakatane	3.7	0.4	0.4	-0.5	0.6	-0.7	0.7	-0.7	0.2	0.1	0.0	6.0	0.3	-0.4	-0.2	-0.2	-0.1
Whangarei	2.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	-0.1

RCP 6.0 Late century

Yield Organic 'Zesy002' RCP 6.0 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.1	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	3.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.2	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.4	0.6	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.1	0.0	0.0	0.8	0.0	-0.3	-0.3	0.2	-0.1
Hawke's Bay	10.4	1.2	0.3	-0.5	0.5	-0.7	0.6	-0.8	0.2	0.1	0.0	4.5	0.3	-0.7	-0.3	-0.3	-0.1
Horowhenua	1.8	-0.2	0.2	-0.1	0.3	-0.1	0.4	-0.1	0.0	0.0	0.0	2.5	0.2	-0.4	-0.2	0.1	-0.1
Katikati	1.3	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.2	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.1	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.1	0.0	3.6	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.5	1.0	0.3	-0.2	0.4	-0.2	0.5	-0.2	0.1	0.0	0.0	3.9	0.1	-0.4	-0.3	0.1	-0.1
Nelson	6.4	1.1	1.1	-1.3	1.7	-1.8	2.1	-1.9	0.1	0.0	0.0	3.6	0.5	-0.5	-0.3	0.0	0.0
Opotiki	4.2	0.6	0.4	-0.6	0.6	-0.8	0.7	-0.8	0.3	0.1	0.0	2.9	0.2	-0.4	-0.2	-0.2	0.0
Paengaroa	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.4	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	6.9	-0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	1.0	0.0	-0.5	-0.3	-0.3	0.0
Pukehina	4.0	0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.1	0.0	1.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.6	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.2	0.0	-0.3	-0.3	-0.3	0.0
Te Puke	1.8	0.2	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.1	0.0	1.2	0.0	-0.2	-0.2	-0.3	0.0
Waihi	1.3	-0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	1.1	0.0	-0.3	-0.3	-0.3	0.0
Waikato	3.5	0.4	0.4	-0.6	0.6	-0.8	0.7	-0.8	0.3	0.1	0.0	3.4	0.2	-0.4	-0.3	-0.3	0.0
Wanganui	6.2	0.4	0.4	-0.4	0.5	-0.5	0.6	-0.5	0.1	0.0	0.0	2.7	0.2	-0.5	-0.2	0.1	-0.1
Whakatane	3.9	0.2	0.1	-0.1	0.2	-0.2	0.2	-0.2	0.4	0.1	0.0	4.1	0.1	-0.4	-0.2	-0.3	0.0
Whangarei	2.4	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0

RCP 8.5 Mid-century

Yield Organic 'Zesy002' RCP 8.5 mid-century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	4.7	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	-0.5	-0.2	-0.3	0.0
Coromandel	3.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.7	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	3.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.4	0.9	0.1	-0.1	0.1	-0.2	0.2	-0.2	0.2	0.0	0.0	0.9	0.1	-0.3	-0.2	0.3	-0.1
Hawke's Bay	9.9	2.0	0.5	-0.7	0.7	-1.0	0.9	-1.1	0.1	0.1	0.0	6.0	0.5	-0.7	-0.3	-0.2	-0.1
Horowhenua	1.6	-0.1	0.4	-0.4	0.5	-0.5	0.6	-0.6	0.1	0.0	0.0	1.8	0.5	-0.4	-0.2	0.3	-0.1
Katikati	1.4	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	2.0	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	-0.3	-0.3	-0.3	0.0
Maketu	4.2	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.1	0.0	0.2	0.0	-0.4	-0.3	-0.3	0.0
Maniatutu	2.0	-0.1	0.1	0.0	0.1	0.0	0.1	-0.1	0.3	0.1	0.0	6.5	0.0	-0.3	-0.3	-0.3	0.0
Motueka	6.3	1.2	0.4	-0.4	0.5	-0.4	0.6	-0.4	0.2	0.1	0.0	3.4	0.2	-0.5	-0.3	0.2	0.0
Nelson	6.2	1.5	1.5	-1.4	2.2	-2.0	2.7	-2.2	0.1	0.0	0.0	3.6	0.7	-0.5	-0.3	0.1	0.0
Opotiki	4.2	0.7	0.6	-0.9	0.9	-1.2	1.0	-1.3	0.2	0.1	0.0	4.7	0.3	-0.4	-0.2	-0.2	-0.1
Paengaroa	2.2	-0.1	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	1.5	0.0	-0.3	-0.3	-0.3	0.0
Poverty Bay	7.0	-1.1	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.1	0.0	1.2	0.0	-0.5	-0.3	-0.2	-0.1
Pukehina	4.0	0.0	0.1	0.0	0.1	0.0	0.1	-0.1	0.4	0.1	0.0	2.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.7	-0.1	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.0	2.0	0.0	-0.3	-0.3	-0.2	-0.1
Te Puke	1.8	0.2	0.1	-0.1	0.1	-0.1	0.1	-0.1	0.2	0.1	0.0	2.5	0.1	-0.2	-0.3	-0.2	-0.1
Waihi	1.4	-0.2	0.1	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.0	5.0	0.1	-0.3	-0.3	-0.3	0.0
Waikato	3.3	0.7	0.7	-1.1	1.0	-1.5	1.2	-1.6	0.2	0.1	0.0	4.6	0.4	-0.4	-0.3	-0.2	-0.1
Wanganui	5.6	1.0	0.7	-0.6	1.0	-0.7	1.1	-0.8	0.2	0.0	0.0	3.4	0.5	-0.5	-0.2	0.2	-0.1
Whakatane	3.8	0.3	0.3	-0.3	0.4	-0.4	0.5	-0.4	0.3	0.1	0.0	5.6	0.2	-0.4	-0.2	-0.3	0.0
Whangarei	2.6	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	-0.4	-0.3	-0.3	0.0

RCP 8.5 late century

Yield Organic 'Zesy002' RCP 8.5 late century

	Impact on yield (1000 trays/ha)													Impact on DM (%)			
	Irrigation		+1°C frost protection		+2°C frost protection		+4°C frost protection		Temperature control		Expected Frost Statistics			Irrigation		Temperature control	
Supply Area	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Mean	VaR	Min	Max	Mean	Mean	VaR	Mean	VaR
Auckland	3.2	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	-0.5	-0.1	-0.3	0.0
Coromandel	2.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0
Franklin	3.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0	0.0	-0.4	-0.2	-0.3	0.0
Golden Bay	2.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.8	0.0	-0.3	-0.3	0.0	-0.1
Hawke's Bay	10.4	0.3	0.2	-0.3	0.3	-0.4	0.4	-0.4	0.4	0.2	0.0	2.7	0.2	-0.7	-0.3	-0.3	0.0
Horowhenua	1.8	-0.5	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	1.0	0.1	-0.5	-0.2	-0.1	-0.1
Katikati	1.1	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.2	0.0	-0.2	-0.3	-0.3	0.0
Kerikeri	1.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.3	-0.2	-0.3	0.0
Maketu	3.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0
Maniatutu	1.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	1.2	0.0	-0.3	-0.2	-0.3	0.0
Motueka	6.2	0.9	0.1	-0.1	0.2	-0.1	0.2	0.0	0.1	0.0	0.0	1.9	0.1	-0.4	-0.3	-0.1	-0.1
Nelson	6.3	1.0	0.7	-0.9	1.0	-1.1	1.2	-1.2	0.2	0.1	0.0	2.4	0.3	-0.5	-0.3	-0.2	0.0
Opotiki	4.2	0.5	0.2	-0.1	0.3	-0.2	0.4	-0.1	0.5	0.1	0.0	2.3	0.1	-0.4	-0.2	-0.3	0.0
Paengaroa	1.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.2	0.0	-0.3	-0.2	-0.3	0.0
Poverty Bay	6.8	-0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.1	0.0	-0.6	-0.2	-0.3	0.0
Pukehina	3.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.2	0.0	-0.4	-0.2	-0.3	0.0
Tauranga	1.5	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0	0.0	-0.3	-0.3	-0.3	0.0
Te Puke	1.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	1.0	0.0	-0.2	-0.2	-0.3	0.0
Waihi	1.1	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	1.0	0.0	-0.3	-0.3	-0.3	0.0
Waikato	3.5	0.1	0.2	-0.2	0.3	-0.3	0.4	-0.3	0.5	0.1	0.0	6.1	0.1	-0.4	-0.2	-0.3	0.0
Wanganui	6.2	-0.5	0.2	-0.1	0.2	-0.2	0.2	-0.2	0.1	0.0	0.0	1.5	0.1	-0.5	-0.2	-0.2	-0.1
Whakatane	3.7	0.4	0.1	0.0	0.1	0.0	0.1	0.0	0.6	0.1	0.0	1.1	0.0	-0.4	-0.2	-0.3	0.0
Whangarei	2.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0	-0.4	-0.2	-0.3	0.0

A smart green future. Together.