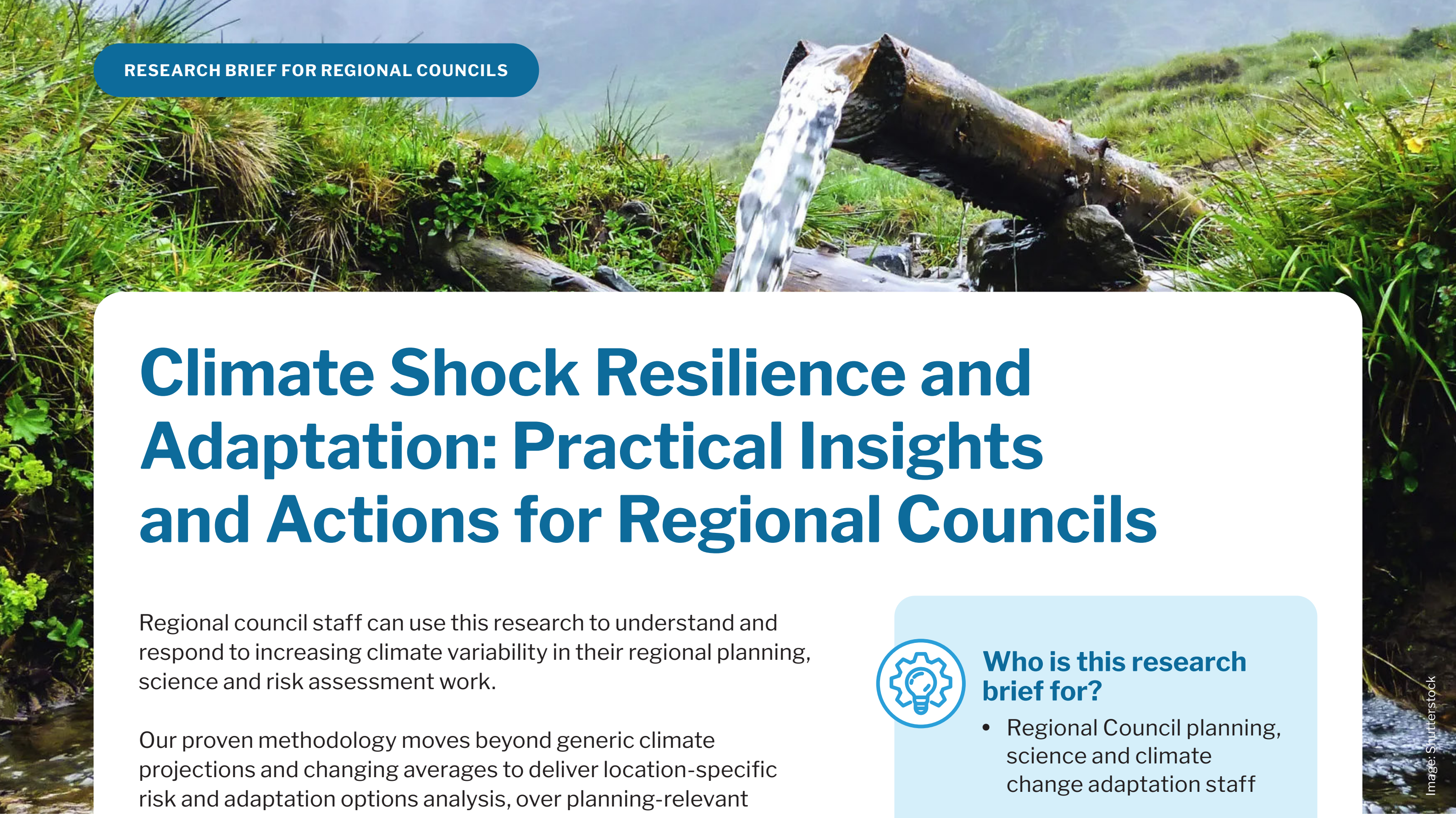
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RESEARCH BRIEF FOR REGIONAL COUNCILS

Climate Shock Resilience and Adaptation: Practical Insights and Actions for Regional Councils

Regional council staff can use this research to understand and respond to increasing climate variability in their regional planning, science and risk assessment work.

Our proven methodology moves beyond generic climate projections and changing averages to deliver location-specific risk and adaptation options analysis, over planning-relevant timeframes. This approach helps you to make robust policy decisions, avoid maladaptation, analyse trade-offs, and support more resilient communities.

Key insights

- New Zealand's climate is becoming more variable. Increasing variability and climate shocks are more important for land and water management planning than long-term average changes.
- Our research has developed a new approach that produces location-specific information about climate variability risks within timeframes that are relevant for regional land and water management.
- Our model quantifies the likelihood and consequence of adverse event sequences (like consecutive dry seasons) over five-to-ten-year timeframes, using millions of simulations. This provides unprecedented insight for regional councils, and enables proactive policy design and risk management.
- Historical climate data is becoming less relevant as climate change accelerates. Past data can overestimate water supply reliability and underestimate ecosystem stress, risking policy errors. Regional plans and long-duration consents founded on past data face increasing risks of unexpected outcomes. Our approach enables policy design and consenting decisions that account for the climate variability we're experiencing now, and will continue to experience over future policy and consent lifecycles.
- By quantifying the effects of water allocation policy on both stream health and rural economic outcomes, we found that policy choices can either strengthen farm resilience or amplify financial stress, with direct implications for community resilience and wellbeing.
- Our location-specific analysis revealed risk variations between sites just 20 km apart, confirming that generic approaches can miss critical variations. Our methodology provides the localised intelligence needed for robust plan changes and resource consenting decisions.

Who is this research brief for?

- Regional Council planning, science and climate change adaptation staff

Research team

- Zeb Etheridge
- Matthew Dumont
- Andrew Curtis
- Greg Bodeker
- Alex Schuddeboom

Research info

- October 2020 – August 2025
- Funded by the Sustainable Land Management and Climate Change Fund, Ministry for Primary Industries (SLMACC contract 406315)

Why is this research needed?

Current climate risk assessment and adaptation planning primarily focuses on extreme weather events and changes in average temperature and rainfall, projected over time horizons as distant as 2100. The distant time frames for significant average change projections do not align with typical planning decision time horizons, which limits the practical application and usefulness of these projections (*see technical addendum, 'Why we need to move beyond averages', page 8*).

While New Zealand has support mechanisms for severe weather emergencies, we are unprepared for the ongoing challenge of increasing climate variability and consecutive climate shock events.

Increasing climate variability is affecting people and ecosystems now, and has much greater consequences than changes in average climate conditions.

On top of this, the probability of consecutive adverse weather and climate sequences is also changing, with severe droughts and wet periods becoming more likely and frequent, meaning there is less time between events to recover and rebuild resilience.

For example, a second drought event in three years will have higher impact than the first if the farm system has not had sufficient time to recover. If commodity prices are depressed or if interest rates have increased during the second drought, the cumulative impact will be even greater.

Ecosystems also face repeated climate variability stress, such as variable river flows, and will be more severely affected if there are existing stressors like poor water quality.

Assessing risks and identifying effective management actions therefore requires a holistic evaluation of all system factors, not just the immediate climate event (*see technical addendum, 'Complex systems: why we need to think holistically', page 8*).

Climate variability vs average climate

Climate change is often talked about in long-term averages, which gives the impression of a slow increase in temperature over time. However, climate change is actually experienced day-to-day as an increasingly variable climate. An average 22°C summer may once have reflected days ranging from 18–26°C. Today, an average 22°C summer may include days from 14–30°C. Similarly, while average river flows may not change, increasing variability means longer periods of lower and higher flows, with implications for water supply reliability and ecological health.

Image: Anthony Pexels

Climate shocks and scares

In our case study catchment, climate shock events like an autumn drought or cold spring, can typically be recovered from in a period of 6–12 months with current farm management. Most farms are resilient to one climate shock, but events in fairly close succession can hurt a farming business.

Scare combinations are defined as three climate shock events in one year, followed by similar the following year. Scare combinations make recovery very difficult.

Our research found that flow-on effects and external pressures mean the third year following a scare combination is likely to trigger farmers to make transformational adaptation decisions, such as increasing on-farm water storage or adding storage for supplementary feed (*see 'Resilience: The three capacities' box*).

What does this research mean for regional councils?

Risk of policy error and misleading information

Historical climate information can mislead policymakers. Historical temperature and river flow records reflect a less variable climate than we are currently experiencing (*Figure 1*). This means past data can underestimate the frequency of water take restrictions, the severity of ecological stress, and the scale of cultural impacts.

The true impacts and benefits of water policy may differ significantly in an increasingly variable climate. Relying on past data can lead to incorrect assessment of trade-offs between reliability, economic costs, ecological health, and cultural values. This leads to policy error, where the goals of the policy are not achieved because the input data were incorrect.

Water take restrictions may be underestimated

Underestimating climate variability (by relying on records from the past) can drive maladaptive behaviour. Water users make investment and management decisions based on the water reliability they expect from past experience, which the near future may not support. If the projected water reliability is not available, resilience declines, exposure to climate risk increases, and community trust erodes.

The combination of maladaptive user behaviour and policy error can lock in vulnerability and reduce the effectiveness of future adaptation options.

Climate risk assessments can be improved with quantitative data

Many regional councils have provided local leadership in climate change risk assessment through regional analysis of threats and impacts, on a qualitative basis. This research can provide location-specific quantitative data on risks, resilience and adaptation thresholds over policy-relevant timeframes. This can be used to identify the range of plausible futures and create a clear pathway for adaptation planning and action.

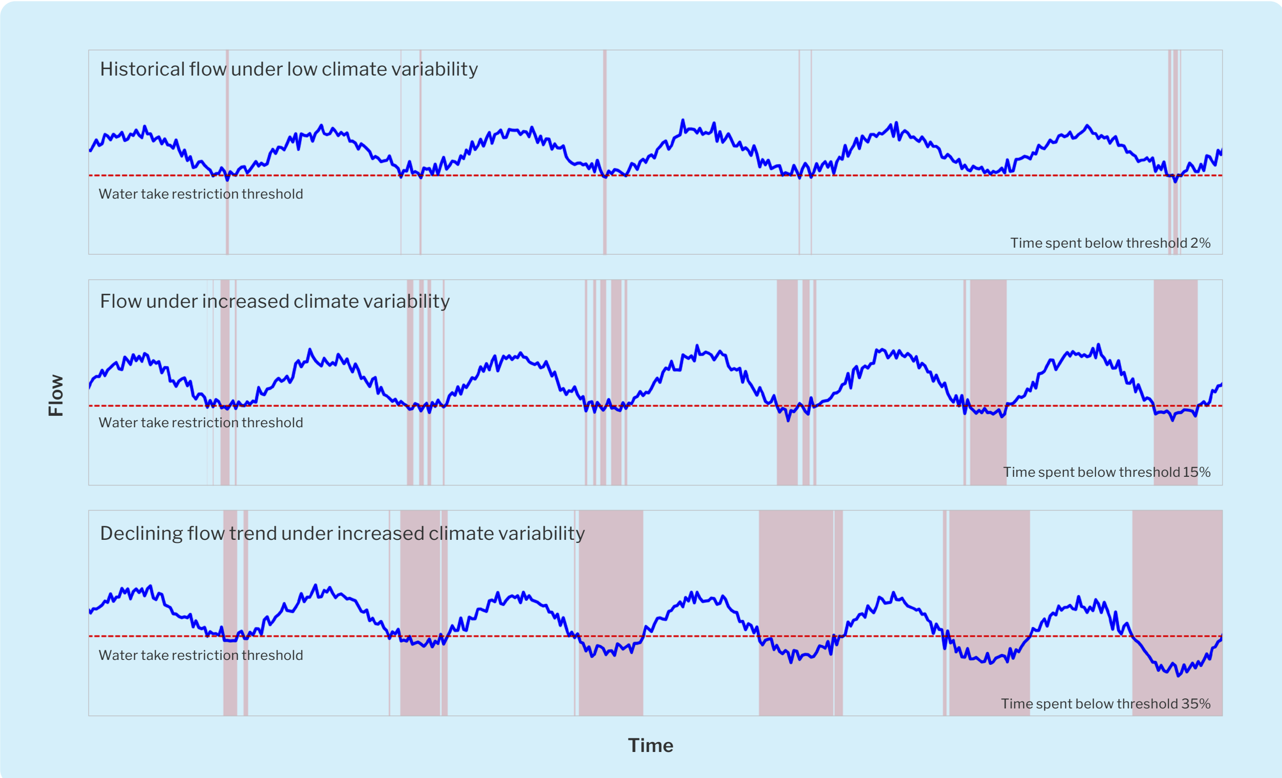


Figure 1: The proportion of time that river flow falls below a restriction threshold increases from 2% to 35% under a more variable climate, in this simplified example. This scenario would lead to extended water-take restrictions, heightened ecological stress during low flows, and increased cultural impacts.

How can this research be used?

Our five-year research programme developed a modelling framework that can identify significant risks and absorptive and adaptive capacity limits much sooner and more precisely than previously possible.

This approach allows us to quantify the likelihood of consecutive adverse weather events and increased climate variability over a range of planning horizons (e.g. the next ten years), and their location-specific impacts for farms and ecosystems.

Four-step framework to strengthen adaptation planning

Our research provides a practical four-step framework *(see 'What did we do', page 5*) to bridge the gap between average climate projections and the decision-making needs of regional council staff. It is designed to be implemented within reasonable resource constraints, identify key areas of climate-driven risk, explore adaptation options, and support the development of more resilient land and water management policy and practice.

The framework supports adaptation planning within the Dynamic Adaptive Policy Pathways (DAPP) approach embedded in New Zealand's Coastal Hazards and Climate Change Guidance, and which is increasingly being adopted internationally to develop plans under conditions of deep uncertainty (*see technical addendum, 'Triggers and signals for dynamic adaptation planning', page 11*).

Climate risk planning and management

Land and water policy operates within a broad and complex system. Our integrated modelling approach includes all relevant system variables that contribute to the overall outcome of regional council actions. We can use it to explore catchment and regional scale climate risks, policy impacts and adaptation options.
This research empowers regional council staff to move beyond generic climate risk planning and into actionable, scenario-based land and water management.

By providing locally specific, probability-driven metrics for climate event sequences and their impacts, the methodology supports robust stress-testing of policy options under a range of plausible futures, providing a foundation for constructive community conversations on climate risks and adaptation pathways.

Resilience: The three capacities

Absorptive Capacity

The ability of a system (such as a farm, business, or community) to **absorb** external shocks or stresses (such as climate variability or financial disruptions) while maintaining its structure and functions. This represents the system's capacity to "buffer" stresses without significant change.

Adaptive Capacity

The capability of a system to **adjust to** climate-related risks and changes, minimising adverse effects or taking advantage of new opportunities without major changes in function. Practices, processes, or structures may be modified to cope with changing conditions or reduce vulnerability.

Transformational Capacity

The potential of a system to **fundamentally change** its structure, function, or operating model in response to severe or persistent risks (such as those from climate change or market shifts). This may include transitioning to new production systems, markets, or institutional arrangements.

What did we do?

Focusing on a case study catchment in North Canterbury, a key component of this research was exploration of the relative costs and benefits of on-farm and water policy adaptation to climate variability driven shocks. The four main steps of our approach were:

1. Define climate variability stressors, key system elements and the planning horizon.
2. Develop variability datasets and probabilities for the chosen horizon.
3. Develop/deploy consequence models.
4. Explore adsorptive capacity limits and adaptation scenarios.

The first three steps identified climate shock events and event sequences for specified climate periods, and their probabilities and consequences under current operating systems, accounting for the absorptive capacity of the system. The fourth step explored the limits of the absorptive capacity of the system and the extent to which risks can be managed within their adaptive capacity (*see 'Resilience: The three capacities' box*).

Working with farming consultants, practitioners, DairyNZ science and economics specialists, and freshwater ecologists, we then identified the key variables and connected systems that influence dairy farm vulnerability to climate shocks. We developed models of these connected systems (*Figure 2*).

For our North Canterbury case study, the connected systems were pasture production, river flow and ecological health, water allocation policy, and feed supplement prices. Key external variables included interest rates and milk payout rates.

The climate scientists in our research team then ran 295 million simulations of 10-year weather and climate data sequences for two irrigated farm sites in Eyrewell in the Waimakariri District, Canterbury (*see technical addendum, 'Stochastic data for quantitative risk analysis and holistic policy analysis', page 9*).

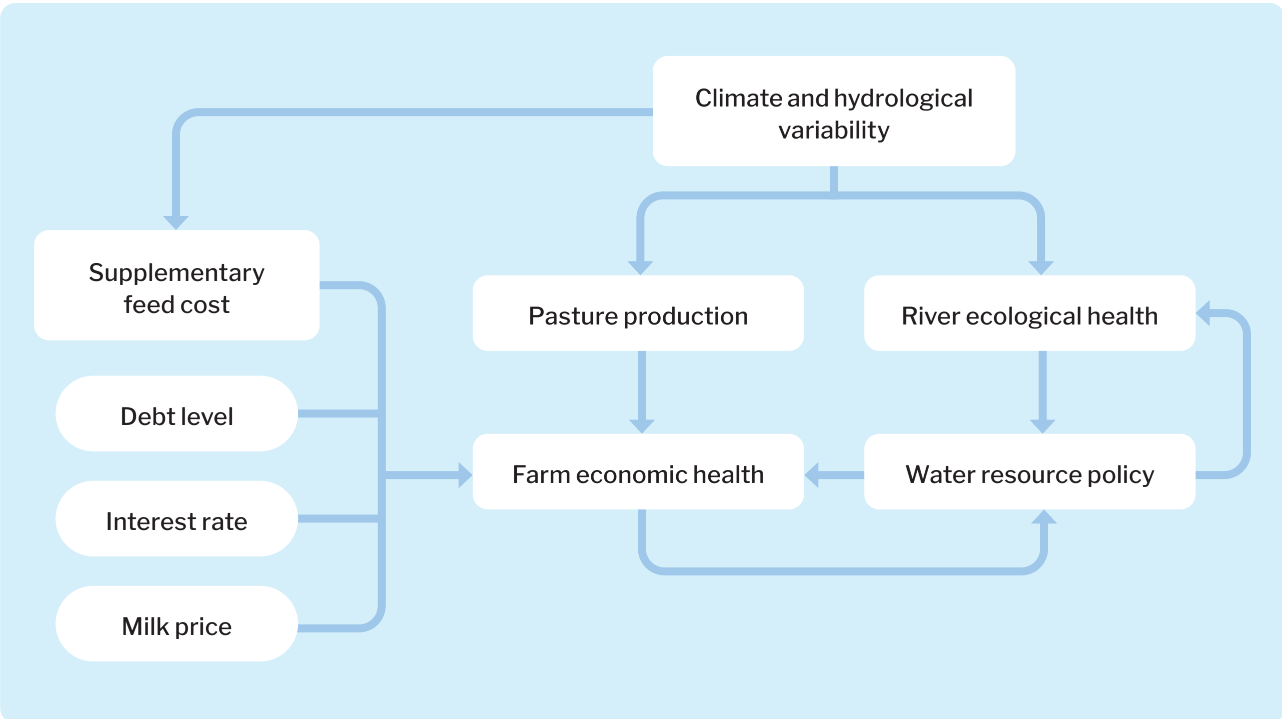


Figure 2: Causal diagram

What did we find?

Climate change is here

Climate change is already having an impact on New Zealand farms – but we have not inhabited the current climate for long enough to understand our current exposure to climate variability risk. We need to use models to understand these risks.

Location-specific, scenario-based analysis is needed

The effects of climate variability are location specific. We found significantly different risks at our two case study sites, which are just 20 km apart. One-size-fits-all approaches are unlikely to be successful, and therefore bespoke risk assessment and adaptation planning are needed.

Research has shown that climate change is likely to drive increased interest rate and price volatility. This underlines the importance of scenario-based assessment of climate variability exposure under a range of external stresses. Our models were fast enough to explore external system stresses over 295 million climate simulations within practical time and cost constraints.

Water allocation policy strongly influences rural financial resilience

Water regulations can either strengthen farm resilience or amplify financial stress.

In our case study area, current irrigation water availability has mitigated on-farm risk from hot/dry weather sequences. This means the effects of climate change to date have been net positive: increased growing seasons have supported higher pasture production. Conversely, the effects of climate change on stream health indicators shows a negative impact, equivalent to the effects of a large water abstraction from the river.

The models reveal that water allocation policy, whether adaptive or restrictive, can shift solvency risk significantly for irrigated dairy producers. This rich information gives regional council staff new insights into the consequences of land and water management decisions and provides stakeholders with the information they need to engage with regional planning processes and proactively adapt to increasing climate stress.

Figure 3 plots financial risk under a $8.13/kg milk solids payout and 6.3% interest rate scenario for: 1) the status quo water allocation policy; 2) supportive policy with more irrigation water available in years with severe pasture growth deficit; and 3) more restrictive policy to protect stream ecosystems from further decline. Risk from near-term climate variability varies significantly.

See technical addendum, 'Can adaptive water allocation mitigate climate shock risks?' (page 10) for more details of our adaptive environmental flow regime analysis.

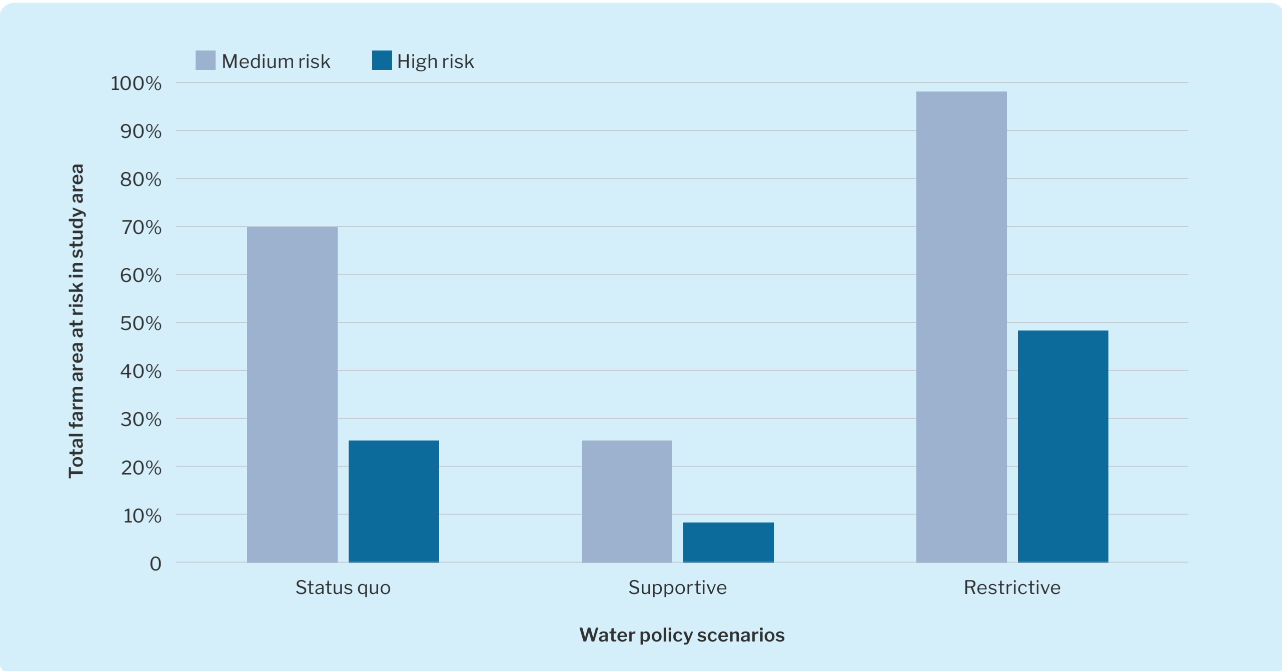
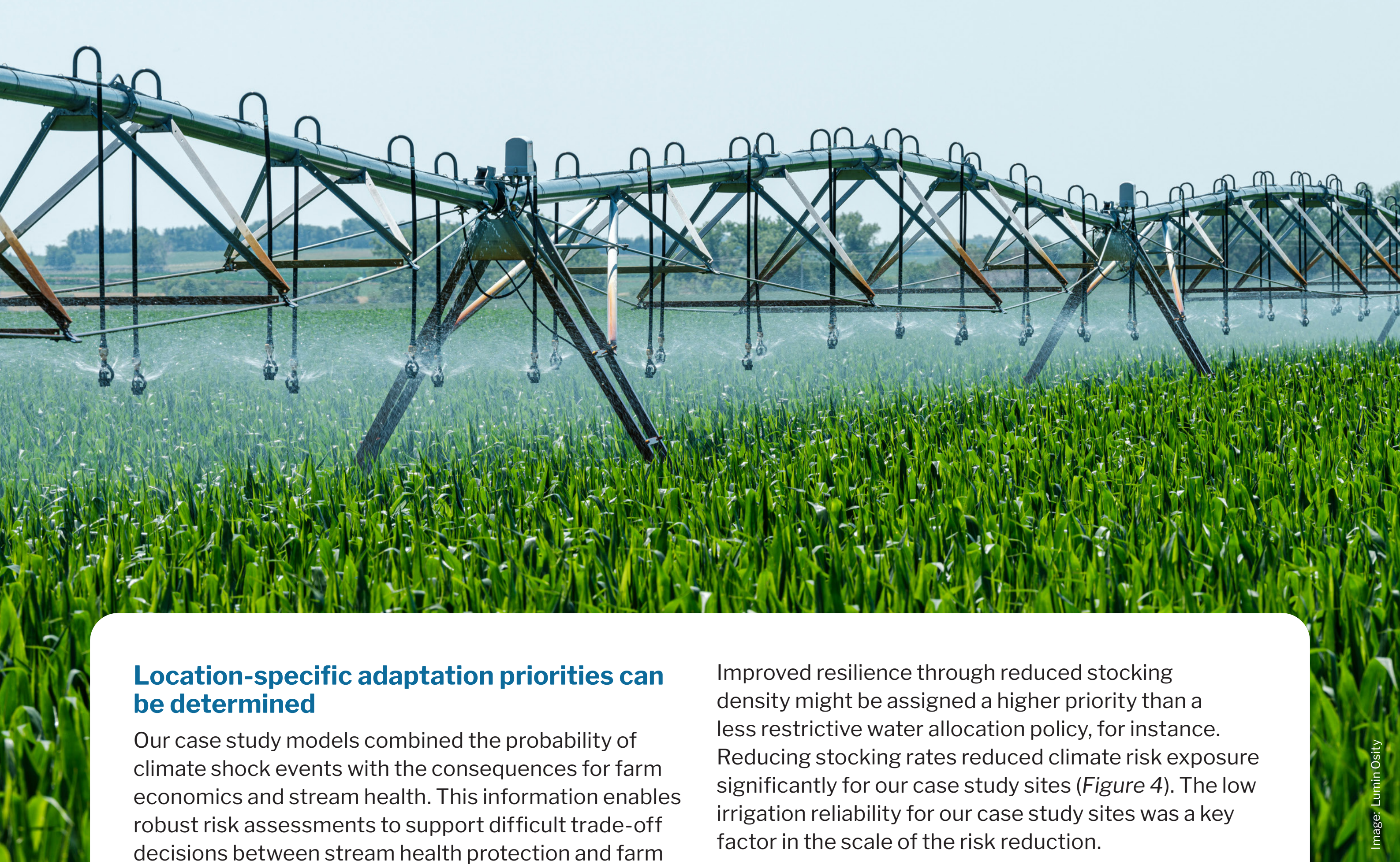


Figure 3: Farm exposure to climate variability risk — with supportive and restrictive water allocation policy



Location-specific adaptation priorities can be determined

Our case study models combined the probability of climate shock events with the consequences for farm economics and stream health. This information enables robust risk assessments to support difficult trade-off decisions between stream health protection and farm and rural economic resilience.

An adaptation priority hierarchy can be determined by including data on the relative costs and benefits of on-farm adaptations, such as reduced stocking rates and on-farm water storage, in conjunction with stream health impact modelling results for a range of supportive and restrictive water allocation policy settings.

Improved resilience through reduced stocking density might be assigned a higher priority than a less restrictive water allocation policy, for instance. Reducing stocking rates reduced climate risk exposure significantly for our case study sites (*Figure 4*). The low irrigation reliability for our case study sites was a key factor in the scale of the risk reduction.

Our industry workshop revealed that farmers are much more likely to adapt in response to experience rather than predictions. Transformational adaptation, such as farm system change, is likely to be resisted until crisis points are reached. The trigger for farm system change requires a very high probability (30–70%) of a high-impact climate shock event sequence. Outreach programmes to communicate climate risks may be required to promote a proactive approach to risk management.

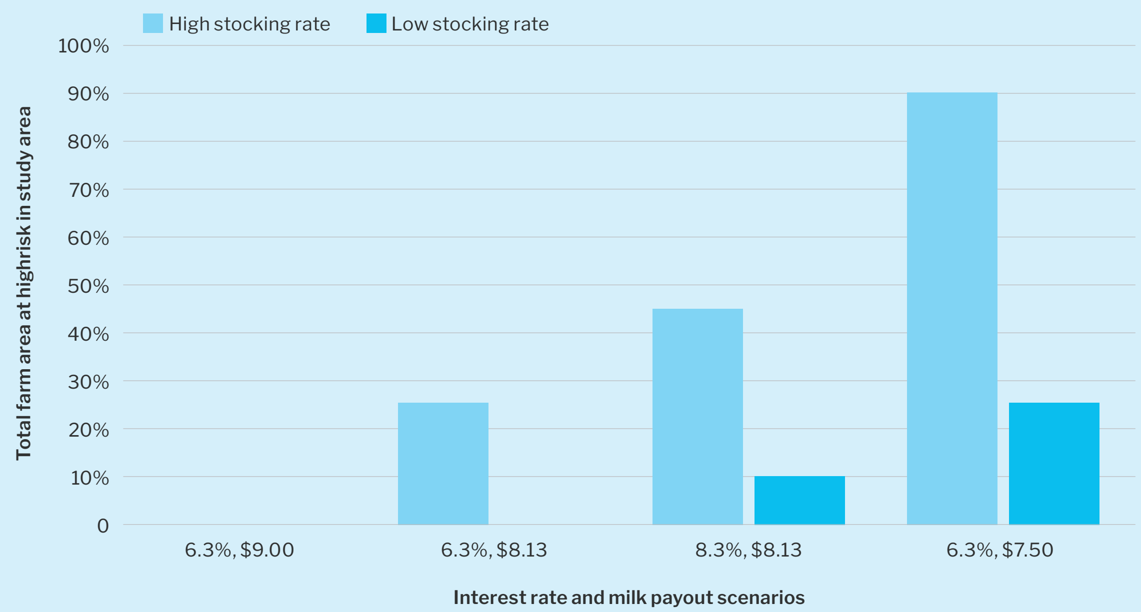


Figure 4: Farm exposure to high climate variability risk — with and without reduced stocking density

Technical addendum

Climate Shock Resilience and Adaptation: Technical Addendum for Scientists

Why we need to move beyond averages

The applicability limits of near and mid-term average change projections are illustrated in Figure 5, which shows modelled changes in average rainfall in Canterbury for the 2031–2050 period, derived from six downscaled climate models.

Model-to-model variability is so high that wetter and drier futures are shown to be almost equally likely across all seasons, with no consistent distinction between lower- and higher-forcing scenarios (RCPs). As a result, these outputs offer little actionable guidance for regional water management. Moreover, they provide little or no information on changes in climate variability, an aspect of climate change that is widely recognised as critical but remains poorly quantified.

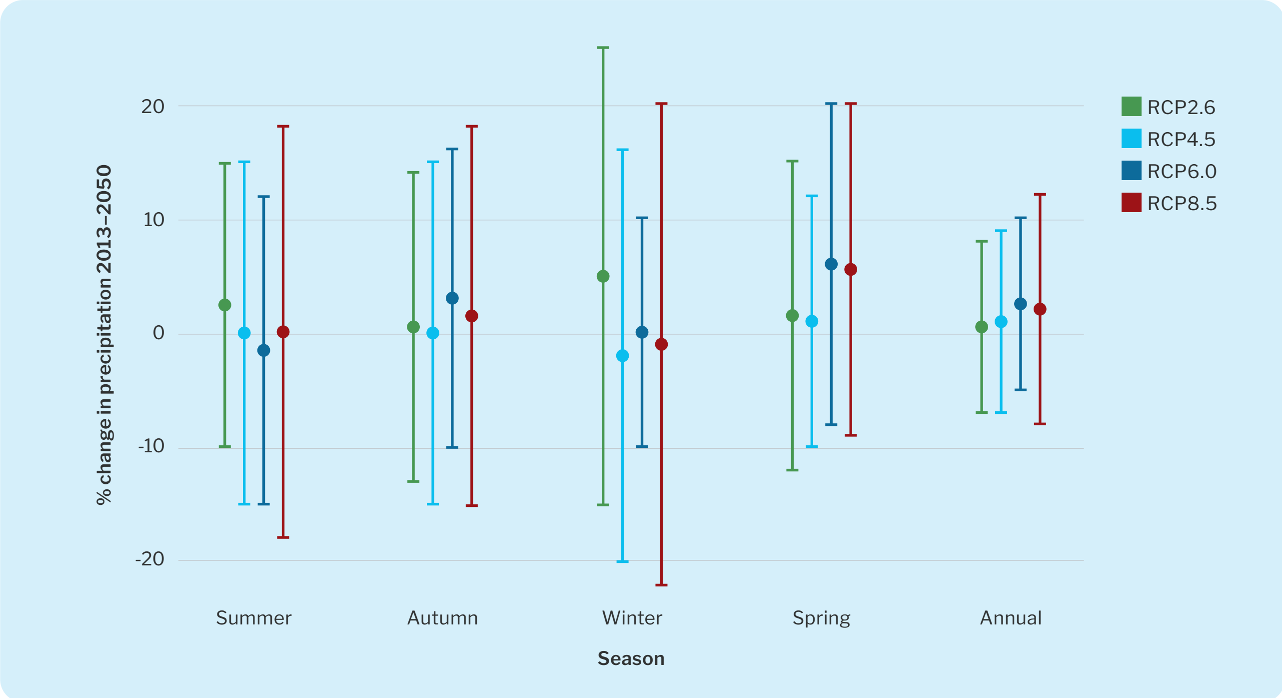


Figure 5: Modelled changes in average precipitation by 2031–2050 (adapted from Macara et al., 2020)

Complex systems: why we need to think holistically

Successful land and water management policy is founded on understanding of the connections and interactions within and between social, economic and environmental systems.

The impact of climate shocks – such as sequences of droughts and wet periods – largely depends on the starting state of the system affected. For example, if two significant droughts occur within three years, the second drought may have a much greater effect if the system has not had sufficient time to recover. These “memory” or hysteresis effects are well documented in both ecological and financial systems.

Initial conditions (soil moisture, financial reserves, or other stressors) play a major role in determining the eventual impact. For instance, if commodity prices are already low, or if interest rates have risen during a second drought, this can amplify the economic consequences.

Similarly, ecosystems facing repeated climate variability, such as variable river flows, will be more severely affected if there are existing stressors like poor water quality. Assessing risks and identifying effective management actions therefore requires a holistic evaluation of all key system factors, not just the immediate climate event.

We developed a loop diagram to explore the interactions between water allocation policy, stream ecological health, and farming systems, identifying key external stressors such as interest rates and milk payout rates (*see Figure 2*).

Models were built for the main components exposed to increased climate variability: river flow and ecological health, pasture production, farm economics, feed supplement pricing, and water allocation policy. The stream ecological health model (*see Figure 6*) was developed via a series of workshops with freshwater ecologists under a structured expert panel framework (SHELF). Models were designed to account for the influence of initial conditions and compounding impacts as far as practically possible.

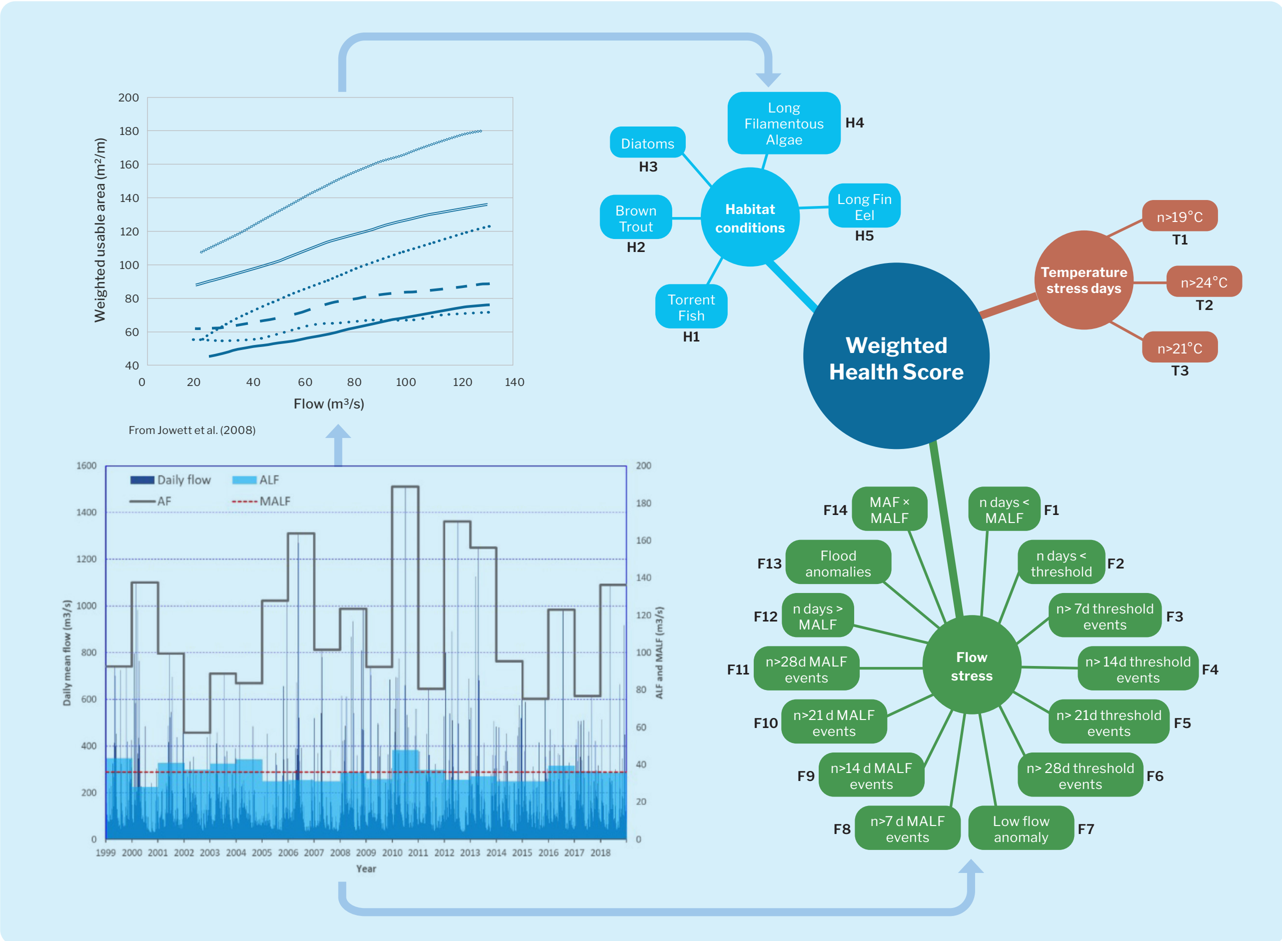


Figure 6: Stream health model

Stochastic data for quantitative risk analysis and holistic policy analysis

Weather and climate sequences were generated by combining Regional Climate Model simulations with a robust stochastic weather generator, yielding a comprehensive, multivariate, location-specific dataset of 10-year time series. These time series enabled detailed, probability-based analyses of complex climate event sequences, such as the likelihood of experiencing multiple droughts within five years or the 10th percentile annual land surface recharge rate. The resulting outputs offered unprecedented insight into both the likelihood and consequences of high-impact climate scenarios for land and water management.

A suite of 295 million location-specific 10-year weather and climate simulations was created for two irrigated farm sites in Eyrewell, Waimakariri District, Canterbury. We applied the climate time series datasets to a simple hydrology model which predicted irrigation supply availability and the hydrological determinants of stream ecology health, with and without irrigation water takes. The irrigation reliability and climate time series datasets were applied to the pasture growth model, and the pasture growth model results then applied to the farm system model. The latter accounts for the decisions and actions farmers take in response to climate variability. We refer to this aspect of farm resilience as the 'absorptive capacity' of the farm (*see 'Resilience: The three capacities' box*).

We translated the farm system model results into an economic health score to identify where the absorptive capacity of a farm is exceeded and the degree to which it is exceed, the latter relating to solvency risk. The hydrology model outputs were modified to account for irrigation abstraction under various water allocation policy options and applied to the stream health model to generate a suite of 10-year time series from which an aggregated stream health was calculated as per Figure 6.

Although the climate sequences were generated for the current climate (2015–2025) for our case study, results could equally be generated for future dates or warming increments.

The model results provided stream health model scores and key farm finance risk metrics for irrigated dairy farms under the increased level of climate variability likely to be experienced under current and near-term future climate conditions. By running the models with a range of broader system stress factors such as increased insurance costs, higher interest rates, lower commodity prices and reduced irrigation water availability due to climate change and/or water allocation policy, our models explored farm financial risks in a more volatile world. A range of static and adaptive water allocation policy options in the form of minimum flow thresholds were applied to the models and the results used to explore trade-offs between policies to protect stream health and policies to support farm resilience in the face of increasing climate variability.

Can adaptive water allocation mitigate climate shock risks?

Figure 7 plots farm financial positions for a range of adaptive water allocation policy settings under which more water is made available under times of varying levels of drought and irrigation water availability stresses. By taking the probability of these stress events, determined from the climate variability dataset, and combining it with the consequences for farm economics and stream health, decision makers are empowered with robust risk assessments to support trade-off decisions between stream health protection and farm and rural economic resilience.

The inclusion of a holistic set of data on the relative costs and benefits on-farm adaptations such as reduced stocking rates and on-farm water storage means that an adaptation priority hierarchy could be explored and adaptation investment assigned accordingly. Improved resilience through reduced stocking density (*see Figure 4*) might be assigned a higher priority than a less restrictive water allocation policy, for instance.

While the North Canterbury case study can be directly applied in the region with additional validation, the primary value lies in demonstrating a scalable, practical pathway to integrating climate risk quantification and adaptation strategy into land and water management decisions.

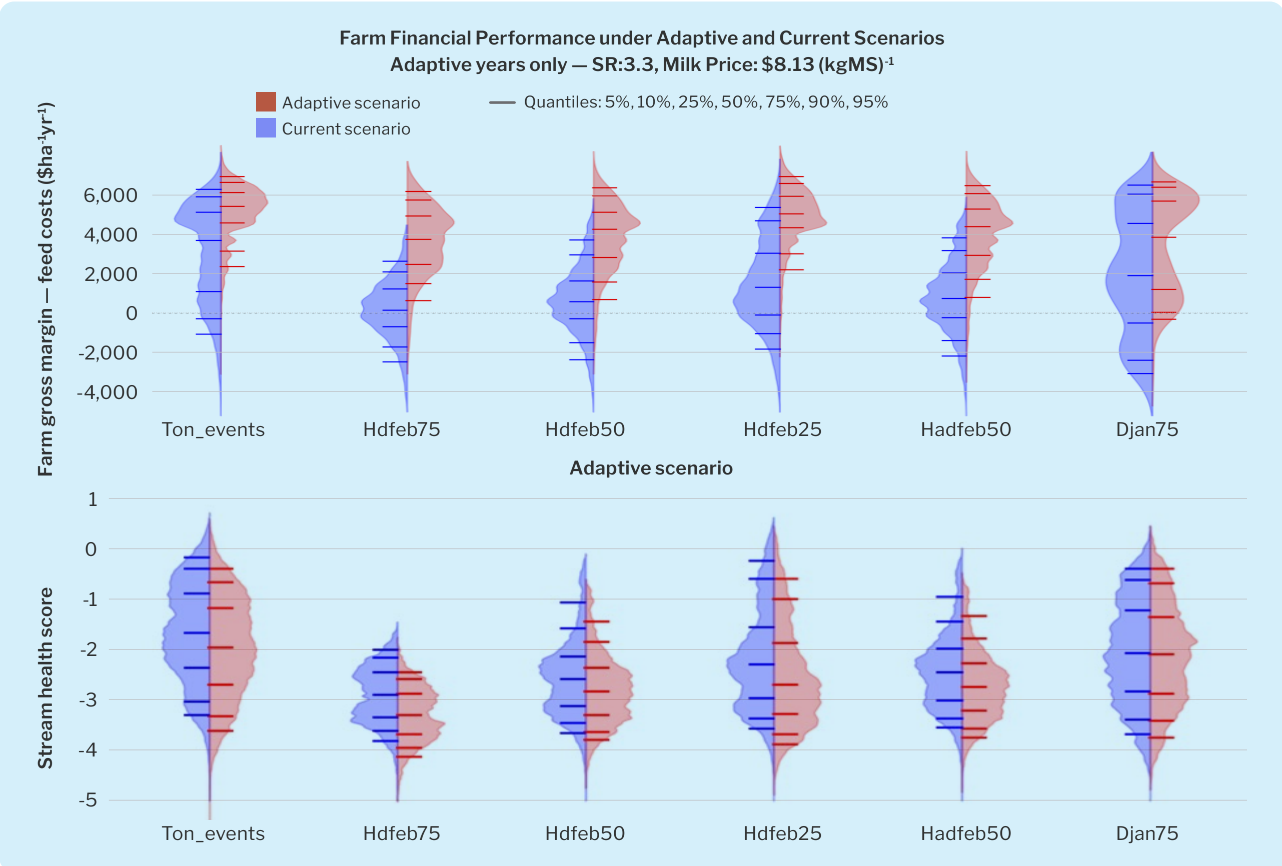


Figure 7: Farm financial position ex debt servicing costs under adaptive water allocation policy scenarios:
a) Ton_events: a 50% reduction in flow restriction during months with pasture production stress;
b) hdfeb75: water abstraction restrictions reduced from the 75th percentile to the 25th percentile for all hot and dry Februarys during which restrictions are ≥75th percentile (from approx 26 to 12 days with limited water abstraction);
c) hdfeb50: as per hdfeb75 but substituting the 75th percentile for the 50th;
d) hdfeb25: as per hdfeb75 but when restrictions are ≥25th percentile;
e) hadfeb50: abstraction restrictions reduced from the 50th percentile to the 25th percentile for all average-to-hot and dry Februarys;
f) Djan75: abstraction restrictions reduced from the 75th percentile to the 25th percentile for all dry Januarys.
The plots present model realisations only for years the specified conditions arise (e.g. the hadfeb50 scenario occurs in 14% of the 10-year storylines; the Djan75 scenario eventuates in 5%)

Triggers and signals for dynamic adaptation planning

The Dynamic Adaptation Policy Pathways (DAPP) framework is increasingly used in New Zealand to tackle the deep uncertainty challenges of climate change adaptation planning. Our method can be used to develop a set of plausible futures based on modelled probabilities, and explore the limits of the absorptive and adaptive capacity of land and water systems and when these limits are likely to be reached in relation to global temperature increase increments. Land and water management adaption signals and triggers can therefore be developed. Exploration of alternative adaptation pathways is supported by the information generated from this new method.

Key steps in the methodology are as follows:

1. Problem definition: Which aspects of land and water policy/decisions are sensitive to increasing variability and where are the risks greatest? Examples include aquifers with high paper allocations relative to actual usage, with connected surface water systems with high cultural and ecological values and surface water irrigation schemes which are sensitive to increasing climate-variability-driven take restrictions .
2. Systems analysis: Mapping of key connections and variables within the interconnected land and water system (e.g. causal diagrams). Holistic understanding the key interactions, variables and systems that need to be modelled and the nature of connections and feedbacks is essential for good decision making.
3. Generate large array of locally specific climate data for catchment(s) and for each global warming temperature increment of interest (e.g. 1.5, 2.0, 2.5°C above baseline)
4. Develop/paramaterise key systems models, connectivity and feedbacks
5. Apply weather and climate time series arrays to systems models and explore adaptive capacity and limits and adaptation options, limits and triggers.
6. Explore planning and policy options to support climate resilience and adaption.
7. Provide stakeholders and communities with locally specific data on how our increasingly variable climate effects them, how they can adapt and when they will need to take action to manage growing risks.

What else did we learn?

1. On-farm irrigation storage can reduce climate risk exposure where irrigation supply reliability is constrained, but this depends on stocking rate, carry-over feed storage capacity and debt levels. Some scenarios showing an increase in risk with on-farm storage investment due to the increased debt burden. Investment in on-farm storage can therefore be both adaptive and maladaptive, depending on the circumstances.
2. Reducing stocking rates reduced climate risk exposure significantly for our case study sites under the assumption that the pasture management system could accommodate the revised rotation schedule required for this, i.e., maintain good quality pasture feed. The low irrigation reliability for these sites was a key factor in the scale of the risk reduction. Dryland pasture systems may see a similar pattern because lower stocking rates reduce exposure to pasture production variability.
3. Farm risk profile varies significantly with interest rates and commodity prices, as expected. Research has shown that climate change is likely to drive increased interest rate and price volatility which underlines the importance of scenario-based assessment of climate variability exposure under a range of external stresses. By implementing our "everything should be made as simple as possible, but no simpler" philosophy, our models were fast enough to explore external system stresses over the large climate simulation suite within practical time and cost constraints.
4. Adaptive water allocation policy, which makes more water available during periods of severe pasture growth stress, can improve farm resilience in exchange for varying degrees of stream health impact. However, reduced irrigation water availability is a possible response to the increased level of stream ecosystem stress associated with near-term climate change, and could increase farm financial risk significantly.

Image: Bernd Dittrich

We turn climate uncertainty into insights

Our cutting-edge climate variability assessment and decision support framework delivers timely, location-specific risk intelligence that strengthens your climate adaptation planning and supports resilient policy development. You can use our insights from this approach to:

- Test policy options under realistic climate variability scenarios
- Avoid policy errors based on outdated historical assumptions
- Balance trade-offs between stream health, cultural values and economic resilience
- Strengthen plan changes with location-specific climate risk data
- Provide appropriate guidance to consent holders and applicants and assess the impact of activities for relevant climate conditions and not the past climate we have left behind.

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Our science delivers actionable intelligence at the scale and timeframes that matter for your planning cycles, from catchment-specific assessments to regional scale analysis.

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Key publications

Matt Dumont, Zeb Etheridge, Andrew Curtis, Pierre Beukes, Alex Schuddeboom. (2025a.) Current climate variability of pastoral yield: a case study in Canterbury, New Zealand. Climatic Change 178:98. https://doi.org/10.1007/s10584-025-03946-z

Matt Dumont, Zeb Etheridge, Andrew Curtis, et al. (2025b). The Current Impacts of Climate Change on Farm Systems and Preventing Maladaptation, A Case Study of the Waimakariri Zone, New Zealand. *In submission, pre-print available on request.*

Zeb Etheridge and Matt Dumont. (2025.) Navigating Climate Variability Risks: an Adaptation Decision Support Method for Land and Water Management. *In progress, abstract, method and results available on request.*

Please use the following citation:

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