National and regional economic impacts of climate-driven pasture decline

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Abstract

Declining pasture and crop harvests is increasingly evident across several New Zealand regions. Milk production per cow has continued to increase over the past two decades, driven largely through increased use of supplementary feed. This may mask the true effect of declining pasture and crop harvested, which remains fundamental to profitable dairy production. Pasture is the cheapest form of feed for a dairy farm, and relying on other feeds will erode New Zealand's competitive cost advantage. This study quantifies the national and regional economic costs of declining pasture and crop harvested and estimates the potential value of strategic investment in forage and farmsystem solutions. Using the Dairy Sector Pathways model, parameterised with DairyBase and Dairy Statistics data, four scenarios were simulated to 2064/65: a baseline holding pasture and crop harvested constant; a business-as-usual scenario with declining pasture and crop harvested; a strategic mitigation scenario slowing the decline; and an improvement scenario increasing pasture and crop harvested. Outcomes were assessed using discounted net present values of operating profit for dairy farms. Nationally, pasture decline imposes an estimated net present value cost of $10.5 billion to the 2064/65 season, relative to a Baseline net present value of $98.6 billion. Strategic investment generates positive economic returns relative to business-as-usual, valued at $0.5 billion under mitigation and $2.6 billion under improvement. Benefits depended strongly on the timing and extent of technology uptake, highlighting the importance of early and widespread investment to sustain pasturebased dairy systems.

Keywords: climate change, dairy farm economics, pasture and crop harvest, pasture persistence

Introduction

Home-grown pasture underpins the New Zealand dairy farm system, supplying most consumed feed at costs lower than purchased supplements, supporting the sector's profitability and international competitiveness as a low-cost exporter (Beca 2021). However, evidence from farm data, regional statistics, and farm system studies indicates pasture and crop harvested (PCH) has stalled or, in some cases, declined over the past 15 years (Glassey 2011; Chapman et al. 2020, 2025; Glassey et al. 2021; Mills & Neal 2021; Marmont et al. 2024) Milksolids per cow continued to increase during this time (DairyNZ and Livestock Improvement Corporation Limited 2025), implying that supplementary feed is offsetting this decline in pasture and crop harvested (Cleland and Woodward 2024; DairyNZ 2025a). A sustained shift away from home-grown feed risks eroding the low-cost advantage that New Zealand dairy relies upon (Beca 2021).

These trends are not uniform over regions. Declines are most evident in the Upper North Island, which is exposed to warmer, drier summer conditions. Mills and Neal (2021) reported a decline in median PCH in Northland and Waikato, with little evidence of improvement among higher-performing farms. Chapman et al. (2020, 2025) similarly reported limited realised gains in pasture eaten relative to technical potential, and reported declines in 5-year mean pasture eaten in all regions outside Canterbury. In contrast, Canterbury has maintained stable or improving PCH, reflecting the ability to utilise irrigation in drier months. Dumont et al. (2025) found that water storage could largely buffer climate impacts on pasture and crop grown in Canterbury, with projected changes ranging from –2 to +15%. However, increased atmospheric carbon dioxide may also inhibit the plants crude protein concentration which will influence the quality of the feed provided, creating further pressures on regions irrespective of their change in temperature and moisture (Liu et al. 2023). Overall, the results suggest that a decline, or lack of improvement in PCH over time, is already affecting the productivity base of many dairy farms.

Climate change is a plausible contributor to these trends, affecting PCH directly and indirectly. Modelling studies have mixed projections about the future pasture production. Rutledge et al. (2017) and Keller et al. (2021) suggest that annual pasture growth may remain robust or increase under climate change due to carbon dioxide fertilisation and improved plant efficiency. Conversely, Babylon et al. (2023) projected reduced summer growth for the Upper North Island, without corresponding increases in winter or spring, resulting in lower annual yields. There is consensus across studies that seasonal feed supply is increasingly misaligned

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with the feed demand of spring-calving dairy farms, particularly due to reduced summer and autumn pasture growth in Northern New Zealand. Empirical evidence also indicates increasing climate pressure on farm systems, including larger summer moisture deficits, heat stress and weaker pasture persistence (Glassey 2011; Glassey et al. 2021; Woodward et al. 2025). While climate is likely to have an impact on PCH, a consequence of the mismatch in pasture supply and feed demand is an increased reliance on supplementary feeding, shifting its role from filling short-term deficits to compensating for structural imbalances in the feed system. Poor control over supplementation on farms reduces grazing pressure, which can reduce pasture utilisation through pasture wastage created by reduced grazing times and higher post-grazing residuals (Stockdale 2000; Penno et al. 2006; Sheahan et al. 2013)

Marmont et al. (2024) examined the economic implications of declining pasture harvest in Northland, Waikato and Bay of Plenty, and showed that widespread uptake of more resilient forages and farm-system options could generate substantial economic benefits relative to a counterfactual response of increasing supplementary feed. However, the national and wider regional economic consequences of pasture decline across New Zealand remain unclear. The potential economic value of pursuing farm systems and forage technologies to mitigate or reverse declines in pasture harvest is well understood in the Upper North Island, but less so in other regions in New Zealand or nationally. Therefore, the objectives of this study were to estimate the national and regional economic costs associated with declining pasture harvest on New Zealand dairy farms, and to quantify the value of strategic investment in a suite of forage and farm-system technology options to either slow or reverse the decline in pasture harvest.

Materials and Methods

The Dairy Sector Pathways (DSP) describes the population of dairy farm businesses in New Zealand and dynamically simulates them by integrating a biophysical farm system with economic models (Doole 2019; Doole et al. 2021). The framework links farm management actions to changes in biophysical parameters and farm outputs, which in turn are linked to economic outcomes. This allows changes in inputs, such as PCH, supplement use, and stocking rate, to be traced through to production outcomes such as milksolids production, operating profit, and asset position. An annual time-step forecasting procedure utilises the biophysical and economic models to predict changes in the representative population over time. Several references provide further detail on how the DSP has been developed and applied in prior research (Doole 2019; Doole et al. 2021; Marmont et al. 2024; Farrell et al. 2025; Ministry for Primary Industries 2025; Wreford et al. 2026).

The DSP generated a baseline representation of the New Zealand dairy sector using DairyBase (DairyNZ 2025b) and Dairy Statistics (DairyNZ and Livestock Improvement Corporation Limited 2025). Data from the Baseline programme, which matches DairyBase data with Overseer environmental data (Overseer Limited 2025) were used to generate distributions of key biophysical parameters relating to each DairyBase farm's system. A representative population was created to align with regional and district-level distributions reported in Dairy Statistics, with financial and physical information drawn from DairyBase. Generated farms were cross-checked against AgriBase data (AsureQuality 2024) to ensure consistency within districts. This population served as the baseline for scenario analysis, enabling estimation of regional and national economic outcomes using a farm-level simulation framework rather than relying solely on historical DairyBase data. Summary statistics for the generated population are reported in Table 1.

Scenarios

Four scenarios were modelled. A baseline scenario (BL) that holds pasture and crop harvested and milksolids per cow constant over time, providing the reference case for deriving the cost of pasture decline. Milksolids per cow was held constant to avoid conflating the impact of supplement use to drive genetic gain. A business-as-usual (BAU) scenario applies region-specific declines to PCH over time. The BAU scenario assumes that in response to declining PCH, farms will increase their use of supplementary feed to maintain a constant milksolids per cow, with no adoption of new forage or farm system technologies.

The strategic investment mitigation (SI-M) scenario also accounts for a PCH decline but assumes that adopting more resilient forage and farm-system options mitigates part of that decline over the modelling horizon. The strategic investment improvement (SI-I) scenario instead assumes that farms can improve their PCH at a rate matching genetic gain, described as around 40% of the growth in milksolids per cow in the past decade (Livestock Improvement Corporation Limited n.d.), reflecting a higher uptake and effectiveness of these technologies.

Modelling Assumptions

In DairyBase, PCH is not measured directly on the milking platform but is estimated using back-calculations based on herd energetics. The calculation uses animal energy requirements (CSIRO 2007; Nicol and Brookes 2007), and subtracts the contribution from

Table 1 Summary statistics of the generated population

Variable	Mean	Median	SD	Min	Max
Milking platform (ha)	155	132	90	16	838
Peak cows milked (cows)	439	362	271	40	2,601
Stocking rate (cows/ha)	2.8	2.8	0.4	1.6	4.5
Pasture eaten (kg DM/ha)	11,358	11,114	2,270	3,677	23,614
Supplement eaten (kg DM/ha)	2,466	2,195	1,717	0	16,326
Milksolids production (kg MS/ha)	1,099	1,073	306	347	2,640
Dairy operating profit ($/ha)	2,586	2,478	964	429	7,998

imported feeds and off-farm grazing to estimate the energy supplied by pasture and crop on the milking platform. As a result, the PCH variable in this study represented estimated feed supplies by on-farm pasture and crops rather than direct measured yield.

DairyBase assumes that all pasture has a metabolizable energy (ME) of 11 MJ ME/kg DM. The DSP relaxes this assumption by deriving an average ME value for each farm over the season. It is plausible that climatic effects (e.g. nighttime temperature, moisture deficits and elevated CO_2) will impact forage quality (Lee et al. 2017; Moyo and Nsahlai 2021; Chapman et al. 2025) including reductions in plant nitrogen and crude protein concentrations, which impact feed quality and utilisation. It's not possible to disentangle changes in yield and nutritional value over time; we represent the reduction in pasture in yield terms and adjust supplement responses through the equivalent energy lost.

Regional pasture-harvest decline assumptions were informed by trends reported in Mills and Neal (2021) and Marmont et al. (2024) but were specified more conservatively than in earlier studies. The justification for a conservative approach was that Mills and Neal (2021) estimated historical trends over a relatively short period, and the estimated slope is sensitive to the specific years included in the analysis. In the North Island, pasture harvest loss was assumed to be the equivalent of 0.35 t DM/ha/decade initially, increasing linearly to 0.50 t DM/ha/decade by the 2064/65 season. In the South Island, losses were assumed to be dampened in the first 20 years, starting at 0.175 t DM/ha/decade, matching the North Island rate after 20 years, and then increasing to 0.50 t DM/ha/decade. This reflects the expectation that climate change impacts will emerge earlier and more strongly in the North Island, with greater impacts in the South Island occurring later in the century.

The trends were applied as a percentage annual decline, calculated relative to the average PCH in each region. This implicitly assumes that pressure on harvested pasture leads to greater absolute losses (kg DM) on farms with higher baseline PCH.

Under the SI-M scenario, it is assumed that the adoption of forage technologies and farm-system practices reduces PCH loss by 50% relative to BAU, resulting in a slower rate of decline. Under the SI-I scenario, a proportion of farms adopt a suite of technologies and practices, such as climate resilient pasture species, precision grazing technologies (i.e., virtual fencing and location collars) and farm system practices (e.g., earlier calving, round-length management, earlier culling) that increase PCH at a rate equivalent to the energy required to generate 40% of the increase in milksolids per cow specified in Dairy Statistics (DairyNZ and Livestock Improvement Corporation Limited 2025). This 40% share reflects the estimated contribution of genetic gain to historical increases in production (Livestock Improvement Corporation Limited n.d.). Table 2 reports the assumed reductions in PCH under the BAU scenario and the corresponding reductions under SI-M (50% of BAU), while Table 3 reports the assumed increases in PCH under the SI-I scenario.

Input and output prices were held constant in real terms, which is equivalent to assuming all prices change at the same rate of inflation. A milk price of $7.50 was used, representing an approximation of the long-term average over the past decade (DairyNZ 2026). When farms increased supplement use, they were assumed to utilise their existing supplement mix, or a regional average mix if supplements had not previously been imported. Importing supplementary feed was assumed to incur both the direct cost of the supplement and additional costs to other cost lines, consistent with estimates reported in Neal and Roche (2019) and Ramsbottom et al. (2015), who found the additional cost associated with an extra dollar of direct spend on supplement is between $0.53 – $0.66. A conservative estimate of $0.50 per dollar of supplementary feed expenditure was applied.

In response to declining pasture availability, regrassing and cropping activities were assumed to increase over time, reflecting that climate change affects

Table 2 Assumed reduction in PCH (kg DM/ha) per year in the BAU scenario

Region	2024/25	2034/35	2044/45	2054/55	2064/65
Northland	0.40%	0.45%	0.49%	0.53%	0.57%
Waikato	0.32%	0.35%	0.39%	0.42%	0.45%
Bay of Plenty	0.33%	0.37%	0.40%	0.44%	0.47%
Taranaki	0.31%	0.34%	0.38%	0.41%	0.44%
Lower North Island	0.34%	0.38%	0.41%	0.45%	0.49%
West Coast - Top of the South	0.19%	0.34%	0.46%	0.50%	0.54%
Canterbury	0.12%	0.21%	0.28%	0.31%	0.33%
Otago - Southland	0.15%	0.28%	0.38%	0.41%	0.44%

The reduction in the SI-M scenario is 50% of the reductions specified in this table

Table 3 Assumed increases in PCH (kg DM/ha) per year in the SI-I scenario

Region	2024/25	2034/35	2044/45	2054/55	2064/65
Northland	0.34%	0.34%	0.34%	0.34%	0.34%
Waikato	0.29%	0.29%	0.29%	0.29%	0.29%
Bay of Plenty	0.21%	0.21%	0.21%	0.21%	0.21%
Taranaki	0.18%	0.18%	0.18%	0.18%	0.18%
Lower North Island	0.33%	0.33%	0.33%	0.33%	0.33%
West Coast - Top of the South	0.23%	0.23%	0.23%	0.23%	0.23%
Canterbury	0.19%	0.19%	0.19%	0.19%	0.19%
Otago - Southland	0.18%	0.18%	0.18%	0.18%	0.18%

forage persistence, yield and quality. Regrassing costs were assumed to increase by 1% per year, reaching 40% over the modelling period. Costs associated with implementing new forage or farm-system technologies were not included; therefore, estimated net present values (NPVs) should be interpreted as returns before implementation costs are incurred. While the analysis includes changes in regrassing and cropping costs associated with changing pasture performance, it does not explicitly account for the capital, operating, training, or transition costs associated with specific technologies such as virtual fencing, climate-resilient forage systems, or other farm-system innovations. Consequently, the estimated benefits should be interpreted as the economic value available to support investment in these solutions, relative to BAU.

Scenario comparisons used a real discount rate of 4%, following the approach set out in Marmont et al. (2024). This corresponds to an 8% nominal discount rate and an assumed inflation rate of 4%. All values from 2024/25 to 2049/50 were discounted and reported as 2024/25 cash flows.

Land-use change, adjustments required by feed and contracting providers, and climate impacts on non-dairy feed producers were not modelled. All farms were assumed to remain in dairy production. While declining pasture and crop productivity is likely to also affect supplementary feed producers (e.g., maize growers and grazing providers) and increase land requirements as supplementary feed use rises, these effects were not modelled and considered outside the scope of this analysis.

Strategic investment adoption pathway

The strategic investment scenarios (SI-M and SI-I) explicitly incorporate the gradual adoption of a suite of forage and farm system technologies, intended to improve pasture persistence, resilience and performance under climate pressure. These technologies either reduce the rate of pasture decline (SI-M) or increase PCH over time (SI-I), relative to BAU. Adoption is represented as a stylised bundle of complementary solutions rather than an uptake of a single technology. For SIM, regional adoption rates match Marmont et al. (2024) for Northland, Waikato, and Bay of Plenty, scaled to 90% for Taranaki and the Lower North Island, and to 75% for the South Island. Adoption rates in the SI-I scenario are assumed to be 50% higher than SI-M, reflecting stronger economic incentives where technologies generate net productivity gains.

Table 4 Adoption pathway of forage and farm system technologies in the SI-M scenario

Region	2024-25	2034-35	2044-45	2054-55	2064-65
Bay of Plenty	0%	0%	6%	19%	31%
Canterbury	0%	0%	5%	14%	24%
Lower North Island	0%	0%	6%	17%	28%
Northland	0%	0%	6%	19%	31%
Otago - Southland	0%	0%	5%	14%	24%
Taranaki	0%	0%	6%	17%	28%
Waikato	0%	0%	6%	19%	31%
West Coast - Top of the South	0%	0%	5%	14%	24%

The adoption rates for the SI-I scenario are 50% higher than the rates specified in this table

Adoption pathways were informed by Marmont et al. (2024), who derived farmer adoption rates from the uptake of forage technologies, such as AR1 endophyte grasses. A logistic function modelled the adoption rate, with no uptake in the first ten years to reflect delayed commercialisation, followed by gradual adoption.

The annual adoption rate determines the proportion of farms experiencing a modified pasture and crop harvest yield trajectory. Under SI-M, adoption reduces the annual rate of pasture decline by 50% relative to BAU. Under SI-I, adoption progressively increases PCH at a rate equal to production growth attributed to genetic gain. Regional outcomes, therefore, reflect both the assumed pasture response and the proportion of farms adopting over time, allowing the economic value of strategic investment to be assessed while accounting for delayed commercialisation and incomplete uptake. Table 4 highlights the adoption rates within each region across time in the SI-M scenario. While the rates may be considered conservative at the individual technology scale, the adoption pathway represents the uptake of a bundle of forage and farm-system technologies rather than a single proven technology.

Results

Net present values (NPVs) of operating profit were used to summarise the long-term economic outcomes for the four scenarios. The strategic investment scenarios represent a stylised response by farmers to declining PCH and do not explicitly represent a specific forage or farm-system technology. The economic cost of pasture decline is measured as the difference between the BAU and BL scenarios. The value of mitigation and improvement is measured as the difference between the SI-M and BAU scenarios, and the SI-I and BAU scenarios, respectively. To provide an upper bound on the value of mitigation and improvement, the SI-M and SI-I scenarios were also compared with BAU, assuming full adoption in each. Table 5 presents the NPVs for each scenario relative to the baseline.

Our results indicate that at the national level, declining pasture harvest imposes a substantial long-term economic cost on the New Zealand dairy sector. The associated decline without strategic investment (BAU) is modelled at $10.5 billion over 2024/25 – 2064/65, relative to a $98.6 billion value generated in the Baseline scenario, constituting approximately an 11% reduction. This reflects a reduction in pasture supply and an increased reliance on supplementary feeds, both of which erode farm operating margins over time. Without any attempts to mitigate or improve PCH, the sector will require a 68% increase in the use of supplement to maintain production, requiring around 2.83 million tonnes of extra supplement. The proportion of feed sourced from imported supplement nationally increases from 17% to 29%.

Regionally, the economic impact scales with sector size. Waikato is the most affected region, with an estimated $3.0 billion decline in NPV driven by pasture decline over the modelling period. Canterbury's relative advantage of growing pasture under irrigation provides a partial buffer, resulting in lower losses at the sector scale than in Waikato and Otago–Southland. In contrast, regions such as Northland and West Coast – Top of the South experience smaller absolute losses due to their size but remain highly exposed because the magnitude of decline represents a larger proportion of their baseline annual pasture and crop harvest.

Strategic investment pathways generate positive economic value relative to the BAU scenario. The mitigation scenario partially offsets the cost of pasture decline, with the value of mitigation estimated at $0.5 billion in improved operating profits relative to BAU. The strategic improvement scenario generates a larger benefit, increasing operating profits by $2.6 billion relative to BAU. This reduces the economic cost of pasture decline from $10.5 billion under BAU to approximately $7.9 billion relative to the Baseline scenario. These benefits arise from the uptake of climate-resilient forages, precision grazing

Table 5 Cost of pasture decline and value of SI (NPV, $millions)

Region	Cost of decline (BAU)	Value of mitigation (SI-M)	Value of improvement (SI-I)	Value of full mitigation (SI-M)	Value of full improvement (SI-I)
Bay of Plenty	-890	48	220	389	1,176
Canterbury	-1,499	69	345	668	2,334
Lower North Island	-932	45	239	403	1,416
Northland	-978	48	245	406	1,336
Otago - Southland	-1,625	73	345	721	2,320
Taranaki	-1,035	51	229	458	1,349
Waikato	-3,041	163	858	1,325	4,583
West Coast - Top of the South	-505	22	103	220	699
National	-10,505	518	2,584	4,590	15,212

technologies (e.g. virtual fencing) and farm-system practices. In both cases, strategic investment reduces the economic cost of pasture decline but does not fully offset it. The largest benefits from both mitigation and improvement are observed in Waikato, Canterbury, and Otago–Southland. This indicates that partial adoption of measures to mitigate or reverse pasture decline is economically valuable, but insufficient on its own to fully reverse long-term impacts.

When full adoption was assumed after 2034/35, the value of mitigation increased to $4.6 billion, while the value of improvement was $15.2 billion. Waikato would capture the largest share of this benefit, with gains of $1.3 billion from mitigation and $4.6 billion from improvement. While these outcomes represent an upper bound that abstracts from implementation and adoption constraints, they highlight the economic cost of inaction and delay. Around a $1.5 billion cost to pasture decline occurs in the 10 years it takes to commercialise the technology, before any adoption occurs. This underscores the importance of both the timing and scale of responses. The magnitude of the difference between full and partial adoption further highlights the importance of achieving widespread uptake. Maximising adoption of mitigations to reduce pasture decline is likely to require innovations that are economically viable and can be integrated into existing farm systems, supported by effective extension and farmer engagement.

Conclusions

This study demonstrates that declining PCH imposes substantial long-term economic cost on the New Zealand dairy sector, with losses projected to exceed $10 billion in net present value over 2024/25 – 2064/65 if trends in pasture decline continue. The results indicate that declining pasture while maintaining production by increasing reliance on supplement erodes farm operating margins and the sector's traditional low-cost advantage against international competitors.

Strategic investment pathways that mitigate pasture decline generate an estimated $0.5 billion in additional operating profit relative to business-as-usual, while pathways that reverse the decline generate approximately $2.6 billion. The value of these benefits is heavily dependent on both the timing and the scale of adoption, and the results suggest that the longer the sector takes to resolve the downward declining pressure on pasture, the larger the economic cost associated with it. Delays in the development, commercialisation, and uptake of solutions to mitigate or reverse the decline in pasture substantially reduce the sector's ability to minimise its economic impacts.

These findings suggest that pasture decline represents a structural challenge for the dairy sector. Addressing this challenge requires not only sustained investment in forage science and farm-system innovations, but also timely action. These solutions will need to mitigate or improve not only today's pasture decline but the potential for even greater pressure on pasture and crop harvests in the future. Early action to identify, test, and adopt effective solutions at scale will be critical to minimising longterm economic impacts and preserving the competitiveness of New Zealand's pasturebased dairy systems.

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