The economic impacts of declining pasture harvest on Northland and Waikato dairy farms

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Abstract

Estimated pasture and crop harvest in Northland and Waikato is decreasing at approximately 0.5 and 1.0 t DM/ha/decade, respectively. However, milk production has been stable over time due to increased supplement use and farm system changes. Declining pasture harvest trends driven by climate change are predicted to continue. Understanding the impact of this decline on the economic performance of the pastoral sector in the future and to what extent farmer adaptation may mitigate the impact is essential. Farm-level data of estimated pasture harvest losses is combined with the Dairy Sector Pathways (DSP) model to estimate the impact of either: a) continued decline in pasture harvest offset by increased supplement use (BAU) or: b) integrating more climate-resilient pasture species and practices into the farm (FA), on dairy farm profit in Northland and Waikato/Bay of Plenty. Net present value (NPV) of dairy operating profit associated with FA increased by $1.3b over BAU across Northland, Waikato and Bay of Plenty regions by 2050. Developing forages resilient to climate change will apply to Northland immediately, and to regions further south as temperatures increase. Therefore, developing and incorporating resilient forages into adapted farm systems is critical to the future of pastoral farming in New Zealand.

Keywords: Climate change, dairy farms, economics, pastures, persistence, resilience

Introduction

Over the last two decades, while pasture harvest on dairy farms has trended down, supplement use has filled the feed gap to sustain milk production especially so in Northland (Mills and Neal 2021; DairyNZ 2023). This may explain why the seriousness of the pasture decline has not been realised more widely.

Previous modelling results have been relatively optimistic around the impact of climate change on forage-based farming systems (e.g. Keller et al. 2021). These may have overemphasised the benefit of positive effects, such as CO_2 fertilisation and warmer temperatures promoting growth, while understating the negative effects, such as extreme weather events, reduced quality of feed, lack of soil moisture availability, and greater weed and pest incursions (e.g. Dodd et al. 2011; Mansfield et al 2021). Dodd et al. (2011) modelled both the effect of higher temperatures and higher CO_2 levels on subtropical species (i.e. kikuyu, commonly found in Northland) and found that, in the future, quality would not be fit for milking cows for at least two months of the year (< 10 MJME/kg DM), and that southward spread of sub-tropical species could cost a hypothetical Manawatu farm $25,000 a year, or a high-quality feed deficit of 500 kg/cow/annum.

Other factors, such as earlier calving and reduced stocking rates, may exacerbate the challenges posed by increased climate variability. This could lead to heightened risks, such as difficulties in matching variable feed supply to demand. By way of evidence, the region-level trends in pasture and crop harvest are informative. Since 2005, mean harvest of pasture and crop has remained static in Canterbury and Southland (Mills and Neal 2021). However, both Waikato and Northland, have significant negative trends for mean pasture harvest (Mills and Neal 2021). Additionally, pasture harvest in Northland (a warmer climate) is ~9 t DM/ha, 25% lower than Waikato (~12 t DM/ha) (Mills and Neal 2021). Climate projections indicate that both Northland and Waikato are expected to warm by between 0.7°C and 1.1°C by 2040, depending on the representative concentration pathway used. These projections show a small temperature gradient from North to South (Ministry for the Environment 2018). In coastal New South Wales (NSW), Australia, where the climate is near-analogous to Northland, pasture harvest is around 7.5 t DM/ha (which is lower than in Northland), with a flat or declining trend, again, as seen in Northland and Waikato (Beca 2020; NSW DPI 2022). Further to the north, Queensland has an even lower average pasture harvest and a declining trend (Beca 2020). In summary, there is strong evidence for three key propositions:

a) There is a net negative time trend effect for pasture harvest equivalent in regions north of Waikato.
b) At any given point in time, regions to the north (closer to the equator with warmer climates) experience lesser pasture harvest equivalent than more southerly regions.
c) Climate change has a broadly similar effect to moving north for farmers in New Zealand.

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Taken together, the implications are that without improved adaptation, in two to four decades, Northland could be in the pasture harvest situation of NSW. In six decades, 25% of Waikato's milk production from cost-effective home-grown pasture could be lost when the central Waikato climate approaches the Northland of today (given pasture decline at 50kg DM/ha/year relative to 12t DM/ha/year pasture harvest).

Pasture modelling work by Beukes et al. (2021) sheds light on the population dynamics of ryegrass pastures when driven by future climate projections, which integrate temperature and moisture stress. This work suggests that the length of time taken for ryegrass pastures to fall to 50% basal coverage is likely to decrease substantially, most dramatically in the Waikato. Some niche areas may improve, potentially due to increased rainfall offsetting temperature effects, but in the main, the effect is negative. Lower basal cover is likely to allow the ingress of weeds and other pasture species that are likely to be less palatable. A likely response by farmers with current knowledge would be increased re-grassing, which may have adverse environmental and future pasture persistence effects (e.g. sediment, soil carbon losses or black beetle populations).

Babylon et al. (2023) reiterate that future pasture growth rates for Waikato are declining, but also that they are declining faster in summer relative to improvements in winter and early spring. Over the next two decades, the net effect would be to substantially increase the feed deficit in summer if adaptation is not made, from about 1.5 t DM/ha to almost 2.5 t DM/ha.

Evidence for modelling impacts of climate change

A trend of declining pasture harvest; Mills and Neal (2021) analysed DairyBase data for temporal trends in pasture and crop harvest on dairy farms. They found significant negative trends for median levels of pasture and crop harvest in Northland and Waikato, roughly equivalent to a reduction of 0.5 and 1.0 t DM/ha respectively per decade. This is relevant because it is a reduction in average pasture harvest of 11% and 4%, respectively, and pasture harvest is one of the critical drivers of on-farm profit and international competitiveness (Neal and Roche 2019). It is important to note that pasture harvest in DairyBase is estimated by a back-calculation methodology, the pasture harvest combines the effect of pasture quality and quantity, where both are likely to be reduced.

Mackay et al. (2023) compared climate-driven modelled pasture yields with actual yield measurements and find substantial consistency between modelled negative trends in pasture harvest and actual reductions. The consistency between modelled and observed pasture harvest (Mackay et al. 2023) highlights the need for innovation to allow farmers to respond to the effects of climate change.

Predicted decline in productivity of perennial ryegrass-based pasture under future climates

Using NIWA climate projections with pasture models, Babylon et al. (2023) predicted a deterioration in perennial ryegrass growth rates because of climate change under even conservative warming scenarios.

Greater performance of alternative pasture species in Northland

McCahon et al. (2021) demonstrate that perennial ryegrass-based pastures fail to persist beyond three years in plot and paddock-scale trials, declining to a contribution of less than 20% of the pasture biomass. In comparison, tall fescue and cocksfoot pastures maintained a minimum 80% contribution to the pasture by the end of the three-year study.

In addition, a series of farmer interviews carried out by AgFirst and Primary Purpose found that farmers consider current species are not performing, or there is a lack of guidance on how to establish and manage these for enhanced resilience to climate, and that early adopters are one of the most trusted sources of advice on pasture species alternatives in Northland (AgFirst and Primary Purpose, personal communications, 2023).

Farmer perspectives are further imbedded in the adoption rates which are derived in the context of previous pastoral innovations which serve as a realistic upper bound on adoption via the adoption framework discussed in the following section.

This research aims to understand how declining pasture harvest will likely affect those farms most immediately exposed to the implications of climate change. The effects calculated are the financial performance of farms given an adoption decision around adaptation, which is scaled to their collective economic contribution.

Materials and Methods

Model Description

The Dairy Sector Pathway (DSP) model (Doole 2019) is a dynamic-simulation framework that describes the behaviour of individual farm businesses across time through the implementation of concise, integrated biophysical and economic models using DairyBase data. DairyBase is a voluntary industry good data set used to quantify trends in the industry in financial, physical, and environmental data. DairyBase uses an energetics back-calculation (energy demand for animal maintenance and milk production, less energy supplied by supplement) to determine pasture and crop harvest (Nicol and Brookes 2007). Therefore, the decline in pasture and crop harvest is likely due to a combination of reduced feed grown (t DM) and declining feed quality due to with increased kikuyu ingress given increased temperatures (Campbell et al. 1996). Regardless, the result is the same, less energy is provided to the animals from pasture. The DSP has been used to evaluate the impact of science and policy interventions, including different levels of plantain adoption at the farm- and sector-level (Doole et al. 2021). The DSP is unique in that it simulates the entire population of farms that existed in the baseline period and can then report on the variability between farms.

For this paper, the DSP model was configured to Northland and Waikato/Bay of Plenty, the regions requiring the most change and adaptation in the next two decades. The farms in DSP which originate from DairyBase are then stepped forward in annual time steps subject to the assumptions under each scenario detailed in the following sections.

Once farms were modelled using the DSP, the present value of total dairy operating profit for each year is calculated using the discount rate detailed in the assumptions section. The present values can then be used to compare the effects of a changing climate through time on the regional dairy sector via the scenarios outlined in the following sections, ceteris paribus.

Modelling Assumptions

Milk production and pasture harvest per hectare were assumed to remain constant over time, similar to what occurred over the last 15 years in Northland, with shortfalls in pasture harvest made up with additional supplement (Mills and Neal 2021; DairyNZ, 2023). Pasture growth was reduced by the amounts specified in Table 1. For Northland and Waikato/Bay of Plenty, the lesser of the regional trends identified in Mills and Neal (2021) is used (-0.5 t DM/ha).

Input and output prices are unchanged (equivalent to all prices changing at the same rate of inflation). Additional supplement has the same product mix as the existing supplement where the supplement mix is 16% Maize Silage, 11% Pasture Silage and 73% Palm Kernel Expeller. The associated costs of supplementary feeding – additional labour, machinery, fuel and depreciation – required is 1.5-times the cost of the supplement, which is conservative, being less than the lower end of the range identified by Ramsbottom et al. (2015) of 1.53 and Neal and Roche (2019) of 1.53-1.66.

The quantity of re-grassing and cropping, and therefore total cost (given constant prices), will increase over time as pasture persists for a shorter period as described in Table 1. More resilient forages and farm systems would mean less re-grassing and cropping, which would likely lead to benefits in retaining soil carbon, less soil erosion and sedimentation, and plausibly lower N loss to water. No estimation of these additional environmental benefits was included.

A real discount rate of 4% was utilised to determine the net present value (NPV), composed of a nominal discount rate of 8% and an inflation rate of 4%. All values from 2024 to 2050 were discounted to a 2024 NPV.

Lastly, the effect of land use change (e.g. dairy land to sheep and beef), input providers (e.g. feed), service providers (e.g. consultants) and providers of contract services (e.g. re-grassing) were not modelled. However, due to the assumed requirement for more supplement and re-grassing in a changing climate under all scenarios, a negative impact on these groups is unlikely.

Scenarios

A scenario approach is utilised to compare how adaptation may mitigate the effects of climate change on pasture harvest and farm performance where scenario design is informed by the research presented in the 'evidence for modelling impacts of climate change section,' namely Mills and Neal (2021). The Business As Usual (BAU) scenario subjects farmers to the same trends observed in recent seasons i.e. declining pasture harvest on dairy farms in northern regions, while milk production is maintained constant through the higher use of supplements.

We expect farms to begin to implement more adaptation options organically, thus the second scenario is modelled; the Farmer Adaptation (FA) scenario. The FA scenario consists of farmers adjusting their choice of forages and carrying out actions to mitigate the pasture harvest declines experienced in BAU. This could include informal farmer testing, adoption of forages and different management practices that enhance resilience, such as deferred grazing. The assumptions associated with each scenario are detailed in Table 1.

The study was intentionally structured such that it was indifferent to the specific innovation so that the results could be considered through a long-term lens, highlighting the need for investment and progress in pastoral resilience given a changing climate.

Adoption Framework

There are a range of factors that determine the rate of adoption of new technologies (Kuehne et al. 2017), such as improved forages, farm systems and other forms of on-farm change. The factors that relate to the level of adoption of technology can be grouped into four quadrants (population-specific influences on the ability to learn about the innovation, relative advantage for the population, learnability characteristics of the innovation, relative advantage of innovation (Kuehne et al. 2017). In the case of the farmer adaptation scenario, we could not easily evaluate the performance given we

Table 1 Assumptions for DSP Modelling. The numbers in Table 1 are in relation to the baseline period (2010-2020).

Business-As-Usual (BAU) Scenario				
Region		**2024-2030**	**2030-2040**	**2040-2050**
Northland	Pasture harvest equivalent	-0.5t	-1.0t	-1.5t
	Cropping cost	+10%	+20%	+30%
	Regrassing cost	+20%	+40%	+60%
Waikato/Bay of Plenty	Pasture harvest equivalent	-0.5t	-1.0t	-1.5t
	Cropping cost	+10%	+20%	+30%
	Regrassing cost	+20%	+40%	+60%
Farmer Adaptation (FA) Scenario				
Region		**2024-2030**	**2030-2040**	**2040-2050**
Northland	Pasture harvest equivalent	-0.4t	-0.7t	-1.05t
	Cropping cost	+5%	+10%	+15%
	Regrassing cost	+10%	+20%	+30%
Waikato/Bay of Plenty	Pasture harvest equivalent	-0.4t	-0.7t	-1.05t
	Cropping cost	+5%	+10%	+15%
	Regrassing cost	+10%	+20%	+30%

Table 2 Headline Rates of Adoption for Farmer Adaptation Scenario.

Time Horizon	Adoption Rate of Farmer Adaptation (%)
2031	6
2041	18
2051	27

would be hypothesising how a technology that does not yet exist might perform. However, the farmer adaptation scenario has two positive factors of adoption; firstly, that dairy farmers regularly undertake pasture renewal (Yang and Rijswijk 2017) which can be adapted with relative ease to adopt emergent technologies and secondly that farmers value discussion groups and input from experts which means that information dissemination is unlikely to be an inhibitor of adoption (Yang and Rijswik 2017).

As an indicator for what adoption of the farmer adaptation scenario we look the adoption of a pastoral innovation, the AR1 Endophyte - as detailed in Caradus et al. (2013) - which four years after preliminary release represented approximately fifteen percent of commercially sold ryegrass, rapidly going on to represent 70% before being superseded by new Endophytes (e.g. AR37 and NEA2). While the adoption potential of AR1 was likely greater than that of the farmer adaptation scenario it is a useful reference point and was used to inform the assumed adoption rates presented in Table 2.

Results and Discussion

The modelling and its underlying assumptions previously outlined were a way of describing how some farmers might adapt to the changing conditions laid out in the introduction without prescribing what the specific innovation might be. That is to say that any innovation, be it a pasture species selection or a management practice change that fulfils the assumptions presented in Table 1 is equivalent in this context.

Our results indicate that under the BAU scenario, the net present value of the dairy operating profit for Northland and Waikato/Bay of Plenty (2024-2050) amounts to \$19B (Table 3), despite the trend for lower pasture performance, higher costs and lower profits.

Under the FA scenario, where farmers made some adaptation, they improved performance over the BAU scenario by \$1.4b (Table 3), given that the NPV of dairy operating profit (2024-2050) was \$21B (Table 3). Economic benefits accrued primarily due to a smaller reduction in pasture harvest under the FA scenario as climate change progressed. This means less supplement and associated costs incurred. More resilient forages would also mean less cropping and re-grassing costs would be incurred, though in the short term, an increase may occur to replace less resilient options.

These economic benefits are based on the adoption rates described in Table 2, therefore if the adoption rates of innovations associated with FA were to exceed those outlined in Table 2 the economic benefits would

Table 3 NPV results (2024-2050, Rounded to millions).

Scenario	Northland	Waikato/Bay of Plenty	Total
Business-As-Usual (BAU)	$2,897	$16,756	$19,653
Farmer Adaptation (FA)	$3,071	$17,996	$21,067
FA - BAU	$174	$1,240	$1,414

be larger.

The potential impact of climate change in terms of decreasing pasture harvest was modelled to consider the benefits that farmer adaptation of climate-adapted forages and farm systems could deliver. We compare the BAU scenario to the FA scenario, however, this is a simplistic view given that many farmers would likely be unable to continue farming in the same way under BAU. Further, FA is approximated from expert opinion for what might be done relative to BAU most specifically around changes to pasture species selection or management practices. Arguably, if a concerted effort combining research and extension in a co-development approach was available it could lead to substantially better outcomes than the farmer adaptation scenario.

Further, the sort of changes adopted under the Farmer Adaptation scenario would likely not be exclusive to the dairy sector. That is to say that as and when technological advancements relating to pasture harvest are developed in the dairy sector, they would spill over into other pastoral sectors, i.e. dry stock farming. While the innovations may be relatively less effective in alternative sectors than those they were developed for, they would likely spill over into dry stock farming. When the innovation diffuses into other sectors it would likely still lead to material economic benefits given the sizable number of hectares in dry stock farming.

Conclusions

We estimate that if all farms in Northland adopted farm system changes in line with the FA scenario, such as more resilient pastures, the benefits in the form of reduced supplement, re-grassing and cropping costs, would lead to a total dairy operating profit $1.4b greater than that under BAU.

Future research into climate adaptation could develop tools such as management practices and new species to increase potential pasture improvements. Given the contrast between the two scenarios in this research, we would expect that any future investment would also experience favourable economic impacts.

Any investment into such research would lead to improvements in the wider pastoral farming sector. In addition to a positive economic impact, it would also equip farmers with the innovations required to improve pasture harvest and therefore production given the evident trend of declining pasture harvest. However, any of the gains derived from future research would require extensive extension efforts to be diffused throughout the farming population.

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