**BEFORE THE COMMISSIONERS APPOINTED ON BEHALF OF THE OTAGO REGIONAL COUNCIL**

| | |
|---|---|
| **UNDER** | the Resource Management Act 1991 (the **Act** or **RMA**) |
| **IN THE MATTER** | of an original submission on the Proposed Regional Policy Statement for Otago 2021 (**PRPS**) |
| **BETWEEN** | **OTAGO WATER RESOURCE USER GROUP** |
| | **Submitter OS00235 and FS00235** |
| | **FEDERATED FARMERS NZ INC** |
| | **Submitter OS00239 and FS00239** |
| | **DAIRY NZ** |
| | **Submitter FS00601** |
| **AND** | **OTAGO REGIONAL COUNCIL** |
| | **Local Authority** |

---

**EVIDENCE IN CHIEF OF MARIO ANDRES FERNANDEZ CADENA**

---


**GALLAWAY COOK ALLAN LAWYERS**
Bridget Irving / Phil Page
bridget.irving@gallawaycookallan.co.nz
phil.page@gallawaycookallan.co.nz

P O Box 143
Dunedin 9054
Ph: (03) 477 7312
Fax: (03) 477 5564

## EVIDENCE IN CHIEF OF MARIO ANDRES FERNANDEZ CADENA

### Summary

1. Reductions of Nitrogen leaching from farms will impose mounting costs on top of the Essential Freshwater (EFW) package and the inclusion of agricultural emissions in the Emissions Trading Scheme (ETS) in 2025. At least a quarter of farms may shut down in the Otago region by 2040 due to the lack of cost-effective mitigation practices or technologies that generate cost-savings while meeting any reduction level. Losses on the regional economy will be significant given the importance of dairy production in Otago.

2. Appropriate timeframes to meet the reductions are required to allow farmers to accommodate their production plans, adopt new technologies and research-backed practices. Furthermore, it allows further investigations into what the most cost-effective designs and features are to achieve reduction targets.

3. My evidence about the mitigation practices is mixed. That is, the uniform application of mitigation practices may not be cost-effective as it is not clear whether the mitigation practices can balance their implementation costs with greater efficiencies on N leaching reduction.

4. Therefore, the staged and careful transition to achieving N leaching reductions in the long run is critical to preserving the viability of farms as well as the economic structure of the Otago region.

### Qualifications, experience, and background

5. My full name is Mario Andres Fernandez Cadena. I am currently employed as Principal Economist at DairyNZ Limited (DairyNZ). I joined the organization in May 2022, following working as a Senior Researcher at the Auckland Council and as an Economist at Landcare Research New Zealand.

6. I am an expert in land use models at global, national and regional scales. I built one agricultural land use model for the Missouri River Basin in the United States in the fulfilment of my PhD degree. I have used and expanded other land use and general equilibrium models for New Zealand case studies. I have built mathematical programming models for the analysis of urban matters and vulnerability to climate change. My work has been peer-reviewed and published in national and international journals.

7. I have the following qualifications:

   (a) Bachelor of Economics from the Polytechnic School of Sciences, Ecuador;

   (b) Master of Science: Environmental Economics from the University College London; and

   (c) Doctor of Philosophy: Agricultural Economics from Texas A&M University.

**Code of Conduct**

8. I acknowledge that I have read and agree to comply with the Environment Court's Code of Conduct for Expert Witnesses, contained within the Environment Court Practice Note 2014. My qualifications as an expert are set out above. I confirm that, unless I state otherwise, the issues addressed in this statement of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I might express during this process.

**Scope and Structure of Evidence**

9. My evidence focuses on several areas with regards to the Proposed Otago Regional Policy Statement (pRPS) June 2021:

   (a) The key aspects of the dairy sector for Otago.

(b) The method I use to analyse the implications of reducing N leaching on the dairy sector and timeframes for achieving this.

(c) The effects of multiple timeframes and reductions on farms profitability.

(d) The effects of multiple timeframes and reductions on debt levels and farm viability.

**The dairy sector is a key component of the economy**

10. The dairy sector is an important component of the New Zealand economy. It is often the nation's largest exporter by value, though this varies depending on product prices. The sector provides around a third of the value of all national merchandise exports, generating annual export revenue of around $19.1 billion. The national significance of the sector was reinforced by its economic resilience in the face of the Global Financial Crisis in 2008. This resilience has been on display recently as the sector continued to be a steadfast producer during the Covid-19 pandemic. The dairy sector is expected to generate 41.2% of the primary industries' export revenue in 2022, corresponding to a growth of 3% from 2021 (Ministry for Primary Industries, 2021).

11. Dairying employed around 50,000 people in 2019, with around 70% of these jobs being on farms and the remainder in the processing sector (Sense Partners, 2020). The dairy sector provided around $3.4 billion in wages in 2019, with around 80% of these being provided in rural areas (Sense Partners, 2020).

12. The economic benefits of dairy production flow onto other sectors of the economy. Dairy farmers are the largest purchasers of agricultural support services, basic wholesale materials, and veterinary services in New Zealand. Further, dairy-processing companies are the largest consumers of polymer and rubber products and rail transport. In total, the expenditure of dairy farmers is around $14.7 billion (Sense Partners, 2020). Therefore, benefits of dairy production for the

economy are highly favourable for regional development, particularly in areas where other sources of revenue and jobs can be limited (NZIER, 2018).

13. Prime Minister Jacinda Ardern highlighted the importance of the primary sector to the economy through the initial Covid-19 response and its significance in moving toward economic recovery as a nation. A plan was announced to grow primary sector exports by $44 billion (NZD) in the next decade, further emphasising the importance of maintaining the dairy sector's economic health and business viability at a national, regional and district scale (NZ Herald, 2020).

14. The Otago region is a valued contributor to the wider dairy sector, with 5.5% of New Zealand's dairy cows (Dairy Statistics, 2020). Dairying in the rural Otago region provides 5.6% of the employment opportunities, which is about 4 times higher than the national average (Infometrics, 2020). Otago dairy also bolsters the regional economy by generating $525 million in revenue (Sense Partners, 2020).

15. Dairy related roles represent 13.5% and 8.1% of the total roles in the Clutha and Waitaki districts, respectively (Infometrics, 2021). Dairying has provided 5% and 4% job growth from 2000 to 2019 for the rural districts of Waitaki and Central Otago, respectively (Sense Partners, 2020). Job growth between 2000 and 2019 in the districts of Clutha and Waitaki has been more than double the total growth in the region (Sense Partners, 2020).

16. Dairy related roles (farming and products) are a vital component of the Otago district economies. Economic growth in the rural Otago regions has slowed in recent times; the recovery of these rural economies will be aided by existing (and new) roles within the dairy sector (Infometrics, 2021; NZIER, 2020). Such assistance is evident in the Clutha district, where dairy farming has held the top position for job creation from 2020 to 2021, being responsible for 10.2% of new roles (Infometrics, 2021).

## Method

17. This analysis focuses on the economic impact of different levels of N leaching reductions on dairy farms in the Otago region. N leaching reductions are an example of the type of contaminant reduction signalled in the pRPS. This indicator is used to illustrate potential economic effects as the Otago Regional Council has not communicated the actual size of the targets, the environmental contaminants of interest, and the areas where reduction targets are required for the timeframes (i.e. the specific year for farmers to comply with the targets). Without that detail it is not possible to assess the actual cost of a specific proposal. Therefore, the analysis explores the value of setting long and flexible timeframes that allow farmers to adapt their operations and minimize the costs of achieving a selected reduction target like the representative N leaching used in this analysis.

18. I use a mathematical programming model to analyse profitability of farmers conditional on the diversity of farms in terms of production, assets structure, debt, greenhouse gas emissions and nitrogen leaching (Doole, 2021).

19. The model uses a sample of 67 farms selected from the National Baseline Project to model nitrogen mitigations (Dairy NZ, 2019). The sample depicts a variety of economic and environmental variables of farms in the region, which is an important factor to measure the economic impacts of reductions in N leaching (Doole, 2020a, 2021). Table 1 shows some descriptive measures.

Table 1: Descriptive Variables

| | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|
| Total Ha | 223.8 | 72.9 | 91.5 | 443.1 |
| Stocking rate (cows/ha) | 3.0 | 0.3 | 2.2 | 3.6 |

| | | | | |
|---|---|---|---|---|
| Production (kg MS/cow) | 418.2 | 37.9 | 329.9 | 516.3 |
| Production (kg MS/ha) | 1,244 | 150.0 | 946.0 | 1,600 |
| Assets ($/ha) | 47,229 | 11,416 | 11,869 | 79,971 |
| Liabilities ($/ha) | 27,439 | 8,237 | 6,187 | 43,086 |
| Fertiliser (kg N/ha) | 191.1 | 42.8 | 84.7 | 277.5 |
| N leaching (kg N/ha) | 51.2 | 21.3 | 17.7 | 126.9 |
| Operating profit ($/ha) | 2,156 | 1,081 | 605 | 6,241 |

20. The model studies the period 2017-2080. The endpoint is chosen to incorporate longer timeframes and to allow the useful representation of the staged implementation of any reductions. The baseline scenario embeds no change in management to reduce N leaching but includes the operation starting in 2025 of the Essential Freshwater (EFW) package and the inclusion of agricultural emissions in the Emissions Trading Scheme (ETS).

21. The economic impact is measured by estimating profit losses to the farms, the dairy sector and then the Otago region. It is also measured by the potential non-viability of farms. The model simulates permanent reduction levels of up to 50% below baseline levels.

22. The economic value of longer and flexible timeframes to achieve the reductions is exemplified in Figure 1, which shows the alternative scenarios and transition paths. A stringent timeframe scenario entails famers having to implement reductions as early as in 2030 or 2040 (Stringent 1 and Stringent 2 transition paths respectively). This implies large N leaching reductions in the intermediate years until the end of the timeframe, with consequent large profit losses and thus

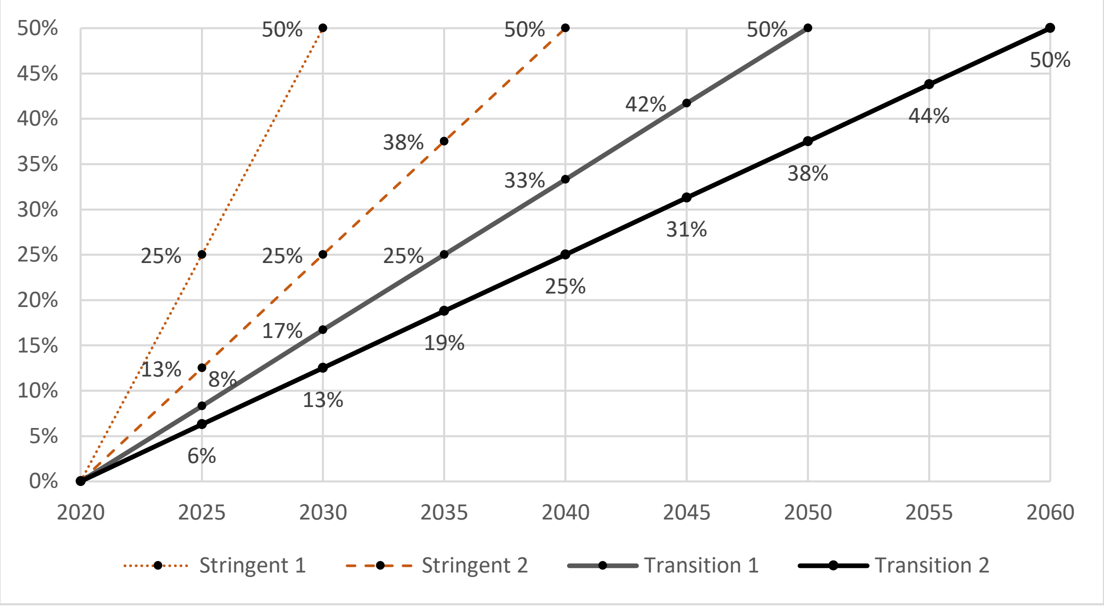
negative impacts on farm debt, resilience and ultimately viability. In turn, a flexible timeframe scenario entails relatively smaller reduction targets in the intermediate years until the end of the timeframe in 2050 or 2060 (Transition 1 and Transition 2 transition paths respectively). This implies a staged transition on achieving N leaching reductions in the long run while preserving the viability of farms as well as the economic structure of the Otago region.

23. Therefore, the economic value is represented by the profit losses and cost decreases due to a staged transition toward meeting the reduction targets. This staged transition entails that farmers need more flexibility to accommodate production plans, be in a better position to adopt mitigation practices or technological innovations, develop skills, build trust and engagement between regulators and farmers, and increase the feasibility of implementing research outcomes associated with mitigation strategies at scale (Leslie, 2020).

24. The model includes the requirement that farms are to pay principal on outstanding loans in 2030 (Doole, 2020a). The model also estimates the debt to assets ratio (DAR), where DAR figures of 25 or below are considered healthy for farms operations, while a DAR of around 50 is more reflective of the average dairy farm in New Zealand, but a DAR above 90 likely indicates a non-performing loan (Doole, 2020a; Dunstan et al., 2015).

25. I emphasize that my evidence does not suggest that any specific reduction level should be implemented. My evidence constructs a broad landscape of the likely impacts of reductions, which improves the understanding of the value of setting long and flexible timeframes for compliance (Adenuga et al., 2020). As the pRPS has not defined a set of targets, this approach is fit for purpose.

Figure 1: Transition paths to meet up to 50% reductions under multiple timeframes




26. The model starts with a scenario using currently available and adopted management options to reduce N leaching (the base practices scenario). The model then incorporates other more interventionist and experimental mitigation practices to explore their potential role and economic value in further reducing N leaching over time, namely:

(a) Pivot irrigation: it is assumed that changing from border dyke to centre pivot irrigation costs $6,000/ha to buy and install a centre pivot, increased repairs and maintenance amount $20/ha/year and increased electricity at $20/ha/year. Associated costs for levelling borders, re-fencing, tree lines, shifting water troughs, re-grassing levelled areas is assumed at $3,600/ha with 7% annual interest. Reduction in N leaching is 75% relative to the baseline (Dairy NZ, 2019).

(b) Plantain pasture: It is assumed that a third of the farm is resown annually at $150 per ha. Reduction in N leaching is 17.5% relative to the baseline (Beukes et al., 2021).

(c) Wintering all cows in a roofed off-paddock facility: It is assumed to cost $3,500 per cow to construct free stall barn plus $1,000 per cow as associated costs including increasing effluent storage. Maintenance costs amount $20 per cow added as maintenance, which includes manure handling and spreading, plus general maintenance. Reduction in N leaching is 30% relative to the baseline (Beukes et al., 2021).

(d) Fodder beet cropped on 4% of milking platform: This is for wintering part of the herd and/or transition feeding, followed by an oats catch crop. Extra dry matter from fodder beet allows for reduced autumn N fertiliser, where the oats catch crop is sown staggered over time after grazing. It is assumed to cost $600 per ha to grow oats and $560 per ha harvesting and ensiling. Reduction in N leaching is 3% relative to the baseline (Beukes et al., 2021), but there is risk implementing the catch-crop strategy on wet heavy soils.

**The effects of multiple timeframes and reductions on farms profit losses**

27. The reductions will impact each farm differently across time because of the fluctuations of milk price across years and volatility, baseline N leaching levels, existing mitigation practices that have been adopted, time and perception about the adoption of new mitigation practices and technologies, and changes in the value of assets and debt (Doole, 2020b, 2020a)

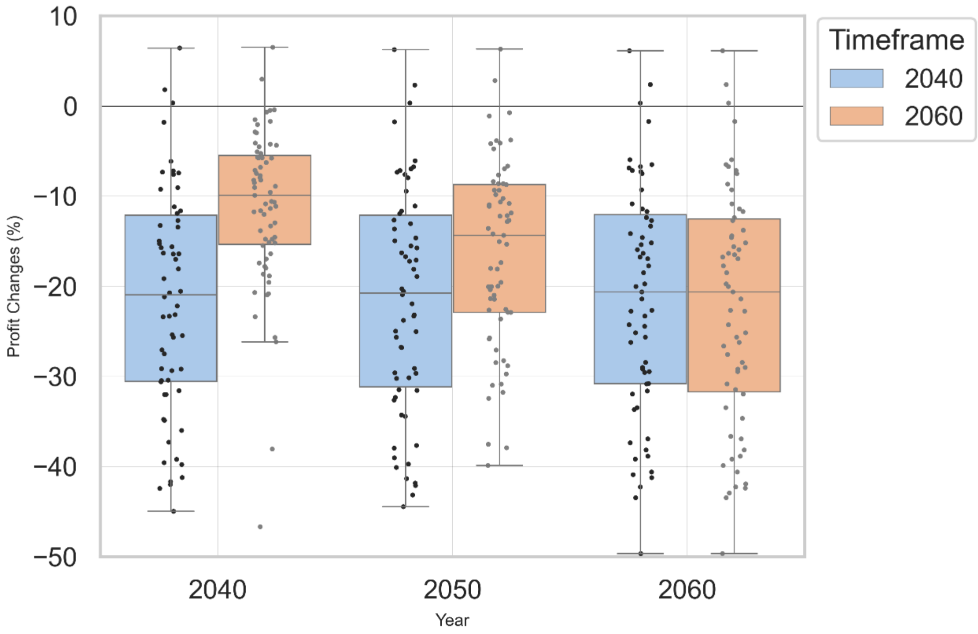
28. Figure 2 shows the changes in profit (relative to the baseline) for the base practices scenario and two different years set as timeframes to achieve the reduction level: 2040 and 2060. Figure 2 shows the diverse effects that the N leaching reductions will have on individual farms due to their diversity. Each dot represents the profit change for an individual farm with respect to the baseline, any dot below the zero line indicates the farm is incurring in profit losses. Each boxplot represents the distribution of farm profit changes by year.

29. Figure 2 shows that some farms may accommodate the N leaching reductions into their production plans to generate cost savings so that positive profit changes occur, but the vast majority of farms will report losses.

30. Figure 2 also shows the economic value of setting longer and more flexible timeframes to achieve the 50% reduction level. For example, under a stringent timeframe set at 2040 (blue boxes), the mean profit losses for farms are about 21% below the baseline both in 2040 and in 2050. In turn, if the timeframe is set at 2060 (orange boxes) the mean profit losses decrease in 2040 to 10.7% and to 15.7% in 2050.

31. That is, the intermediate lower reduction levels allow farmers to prorate decision plans over a longer time horizon and minimize costs. Farms have to meet lower intermediate reductions until 2060, as shown in Figure 1 above, compared to the relatively shorter period until 2040 where the cost of reductions is magnified (Doole, 2020b, 2020a).

Figure 2: Profit changes (%) for a 50% Reduction in N leaching, base practices, and multiple years of compliance: a) 2040, b) 2060




32. The Annexure shows the changes in profit when mitigation practices are introduced in the model. The purpose is to explore their role with respect to the reduction levels and the multiple timeframes. Those practices may be expected to allow for improvements in the efficiency with which N leaching is managed. This would allow net positive outcomes within which profit increases (or at least profit losses decrease) while reducing N leaching (Doole, 2020b, 2020a)..

33. In Figure A1, I introduce plantain pasture as a mitigation practice. For every timeframe, the mean economic losses are slightly higher compared to the base practice scenario in Figure 2. That is, while greater N leaching reductions can increase with mitigation, there are operating expenses associated (e.g. annual re-sowing of paddocks), which may vary considerably between farms. That is, though mitigation practices may result in efficiency improvements in the use of nitrogen inputs and therefore reduce profit losses, such net positive outcome occurs in only seven of the 67 farms.

34. Figure A1 also shows that longer and flexible timeframes contribute to decreasing N leaching reduction costs. A similar pattern of effects

occurs for the fodder beet mitigation practice (Figure A3 in the Annexure).

35. Figure A2 exemplifies the case where an investment-heavy mitigation practice of pivot irrigation is used. Profit losses are large regardless of the timeframes. Furthermore, only 30 of the initial 67 farms suffer losses less than 80% below the baseline, which implies that more than half of the farms may not be viable in this scenario. A similar pattern occurs for wintering adoption as a mitigation practice. This is in Figure A4 in the Annexure.

36. Consequently, the implications that stand out are as follows:

(a) The economic costs of the potential reduction levels are high. Arguably, for many of the farms the residual amount of nitrogen in the baseline, after the introduction of the EFW and ETS mandates is limited, which exacerbates the mitigation costs regardless the timeframe or the practices adopted (Doole, 2012; Doole, Marsh, et al., 2013).

(b) The responses of farms to the targets and timeframes are not uniform (Daigneault et al., 2018; Holland & Doole, 2014; Kaye-Blake et al., 2019; Vibart et al., 2015). Those responses are tied to the availability of (or the lack of) cost-effective mitigation practices to attenuate the production and profit decreases in the face of stringent targets and timeframes (Doole & Romera, 2015). My evidence shows that practices may be cost-effective only in a small group of farms whereas for the rest further research and longer timeframes are needed to identify which are fit for purpose.

(c) As the uniform application of mitigation practices may not be cost-effective considering the diversity of farms in terms of investment, production and environmental constraints, their subsequent adoption is complex. Thus, it is not possible to conclude whether their outcomes are positive to the dairy sector overall (Doole, 2021; Pannell et al., 2006, 2014). Therefore, further research is needed on a case-by-case basis to identify the appropriate mitigation measures at farm-level, perception of farmers and mechanisms to improve penetration and adoption. This is warranted only under longer and more flexible timeframes for compliance. Consequently, reduction levels would work better if they accounted for the heterogeneity of farms and practices as well as baseline environmental conditions and geographically targeted regulation (Kaye-Blake et al., 2019)

**The effects of multiple timeframes and reductions on debt levels and farm viability**

37. The allocation of N leaching reduction levels has strong implications for the viability of New Zealand dairy farms (Doole, 2020a; Holland & Doole, 2014) because profit losses affect cash surplus and the capacity to repay debt. For the interpretation of the results, farms with DAR estimates of 25 or below are considered to be in good economic position, while a DAR of around 50 is reflective of the average dairy farm in New Zealand, but a DAR above 90 likely indicates a non-performing loan (Doole, 2020a; Dunstan et al., 2015). That is, farms are not generating enough revenue to cover debt and are likely to shut down.

38. Figure 3 shows the resulting DAR for reduction levels of 50% for the base practices scenario. For a timeframe set at 2040 (blue boxes), the mean DAR is 73 for 2040, which increases to 101 in 2050 and 121 in 2060. For a timeframe set at 2060 (orange boxes) the DAR estimates are slightly lower with the longer timeframes, the mean DAR is 63 for 2040, which increases to 92 in 2050 and 115 in 2060. That is, Figure 3 indicates that the permanent nature of the reduction levels, coupled with the lack of cost-effective mitigation practices and mechanisms to attenuate the policy shock, will only imply worsening economic impacts as time passes by. Longer timeframes may not suffice to prevent a share of dairy farms becoming non-viable.

39. Results above should be interpreted along with those in Table 2. Table 2 shows results for multiple levels of N leaching reduction: 10%, 30% and 50% below the baseline, and for two timeframes: 2040 and 2060.

40. Table 2 exemplifies the heavy burden of N leaching reductions after the introduction of the EFW package and the ETS. That is, out of the 67 farms used for analysis as representation of the farm population, about 17 (25.4% of the population) may shut down in 2040 even for a reduction level of 10%. The longer timeframe set at 2060 does not improve the landscape significantly as 16 farms (23.9% of the population) will still leave the industry by 2040. Furthermore, for a higher reduction level of 50% and a timeframe set at 2040, 24 farms (35.8% of the population) will shut down by 2040. The longer timeframe reduces that number to 19 (28.4% of the population). That is, though the flexible timeframes show economic value by reducing profit losses, farms are still at great risk of non-viability.

41. Consequently, the results imply that the only way to achieve high levels of reduction is for certain farms to ultimately go out of business. Therefore, the Otago dairy industry may shrink by at least 24% by 2040.

42. Non-viable farms correspond to those with high baseline DAR before the introduction of the reduction levels, negative relation between profits and N leaching reductions, and farms that already suffered significant losses due to the EFW and ETS coming into force. Therefore, additional N leaching reduction requirements become increasingly costly and directly compromise farm viability.

43. To complete my discussion and the role of mitigation practices, Figure A5 shows the DAR as plantain pasture is introduced as mitigation practice. The mean DAR figures for the three timeframes are fairly similar to those in Figure 3. That is, though plantain pasture may imply (in theory) larger reductions on N leaching compared to the base practices scenario, its effectiveness cannot be extrapolated to

all dairy farms. That is, pasture plantain is not a great determinant for farms to remain viable.

44. Similarly, Figure A6 shows the DAR when pivot irrigation is introduced as mitigation practice. We cap profit losses to 50% below the baseline and assume those farms are no longer viable. That is, pivot irrigation implies that 37 of the 67 farms may shut down operations. From the remaining 30 farms, at least 10 have DAR figures greater than 90.

45. That is, adoption of mitigation practices is costly, which implies further decreases in profit and become another channel that affect the ability to meet debt. As farmers are already under stress in the base practices scenario, the mounting costs of mitigations will leave lower residual income and their equity is negatively affected (Doole, 2020a, 2020b).

46. Therefore, more research is needed to fully understand the potential of mitigation practices on achieving reduction targets while minimizing costs conditional to the spatial and economic characteristics of farms. This is relevant as timeframes to achieve long-term visions over any transition period should allow dairy farmers enough flexibility to adjust at a rate that accounts for the high economic impacts.

Figure 3: Debt to assets ratio for a 50% Reduction target, base practices and multiple years of compliance: a) 2040, b) 2050, c) 2060

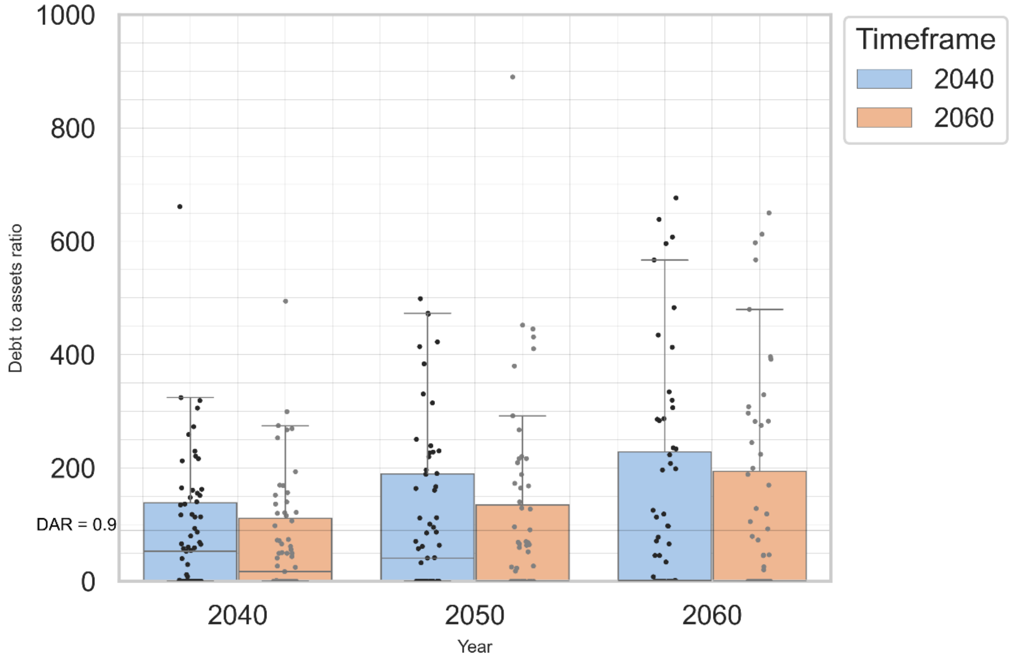



Table 2: Shrinkage of the industry in 2040 due to the reduction levels

| | | Percentage of N leaching reductions | | |
|---|---|---|---|---|
| | Timeframe | 10% | 30% | 50% |
| Number of farms shutting down | 2040 | 17 | 19 | 24 |
| | 2060 | 16 | 18 | 19 |
| Share of farms shutting down (%) | 2040 | 25.4 | 28.4 | 35.8 |
| | 2060 | 23.9 | 26.9 | 28.4 |

**The effects of multiple timeframes and reductions on the aggregate dairy sector and the Otago region**

47. The cost for the dairy sector is calculated by summing the profit changes across all farms.

48. Nonetheless, the costs for the dairy sector flow on to the rest of sectors of the economy. Both for suppliers of services and goods to farms as well as to dairy-processing companies and meat processors, and ultimately to households that are either employed or purchase from these sectors (Doole, 2020b). These regional costs are calculated based on Doole (2020b) where a multiplier of 2 is applied to the dairy sector costs. Though this approach is a coarse approximation to the regional costs, relative to a more comprehensive general equilibrium model, it provides a proper approximation of the flow-on impacts.

49. Table 3 shows the estimated cost to the dairy sector and the Otago region. For the base practices scenario, a longer timeframe from 2040 to 2060 implies that costs for the sector in 2040 will reduce from $7.3 million to $3.2, a 55% reduction.

50. The regional costs also decrease if a long timeframe is allowed. For example, if the timeframe is set at 2040, regional costs in 2040 amount $14.6 million, which decreases to $6.5 million if the timeframe is set at 2060.

51. Therefore, total costs under the base practices scenario may reach $21.9 million if the timeframe is set at 2040, but a substantial decrease to $9.7 million if it is set at 2060.

52. As mentioned above, the results should be interpreted on top of the impacts sourcing from the ETS and the EFW mandates coming into force in 2025. That is, there is a significant pipeline of policy changes to which farmers will have to adapt. N leaching reductions add layers of complexity that further complicate the current economic and financial environment of dairy farms. Most importantly, results in Table 3 should be interpreted with caution. My evidence uses a sample of 67 farms, but there are 455 operating in the region. Therefore, the cost figures represent a lower bound. That is, the aggregate costs for the region may be even higher by a factor of 6 or 7.

53. Results in Table 3 shows that the introduction of plantain pasture scenario decreases sector losses by 6% (from $7.3 million to $6.8 million), but longer timeframes in turn represent that decrease of losses are by 50% (from $6.8 million to $3.4 million). That is, greater economic value is achieved by allowing longer timeframes for reductions.

54. The above emphasizes the nuanced landscape of the profit losses at farm-level where, for example, only 7 farms report cost savings due to plantain pasture. Out of those farms, 4 have sizes above the sample mean, which introduces further research questions that should be resolved (under long timeframes) to better understand how farm size and other economic and environmental variables affect the creation of positive outcomes from mitigation practices.

55. The main implications that stand out relating to profit and sector losses, and viability are as follows:

(a) Potential reduction levels coming from the pRPS are likely to result in higher DAR figures, which will make it more difficult for farmers to access credit to fund operating and mitigation expenses. This implies that a significant share of farms will become non-viable. Therefore, land prices may decrease as the business is no longer attractive because of the stringency of the N leaching reductions. This will result on an excess supply of land that adds downward pressure on both land and asset prices, which circles back to further worsening DAR figures (Doole, 2020a, 2020b). As time goes by, the industry will shrink in size and not be able to employ resources, affecting the whole region in terms of employment levels and flow-on effects to other economic sectors.

(b) Furthermore, in reality, farmers may anticipate that profit losses are likely to occur and decide to shut down operations or change land use even before the introduction of the N leaching reductions. Consequently, sector and regional losses may be even higher. Long and flexible timeframes may attenuate the economic impact, but on top of the operation of the EFW package and the ETS, a wider discussion is needed around the features of the pRPS and its high economic impact.

Table 3: Sectoral, regional, and total losses for 2040 – base practices scenario

| | Year for compliance or timeframe | |
|---|---|---|
| | 2040 | 2060 |
| | Sector costs | |
| Base practices | 7,309,180 | 3,258,026 |
| Plantain pasture | 6,820,270 | 3,395,419 |
| Pivot irrigation | 14,298,989 | 13,511,650 |
| | Regional costs | |
| Base practices | 14,618,360 | 6,516,053 |
| Plantain pasture | 13,640,540 | 6,790,838 |
| Pivot irrigation | 28,597,978 | 27,023,299 |
| | Total change | |
| Base practices | 21,927,540 | 9,774,079 |
| Plantain pasture | 20,460,811 | 10,186,258 |
| Pivot irrigation | 42,896,968 | 40,534,949 |

**Concluding Remarks**

56. The pRPS prescribes that waterways in the Otago region should be safe for human contact. This implies reductions on contaminants to be achieved for multiple timeframes between 2030 and 2050. Nonetheless, specific reduction levels and the mapping between those levels and timeframes (i.e. the specific year for farmers to

comply) have not been defined. Therefore, there is uncertainty about their potential stringency.

57. This analysis explores the value of setting long and flexible timeframes that allow farmers to adapt their operations and minimize the costs of achieving the reduction targets.

58. I use a mathematical programming model to analyse profitability of farmers conditional to the diversity of farms in terms of production, assets structure, debt, greenhouse gas emissions and nitrogen leaching (Doole, 2021). I define as a stringent timeframe scenario where farmers have to implement reductions as early as in 2030 or 2040. This implies large reductions in the intermediate years until the end of the timeframe. In turn, a flexible timeframe scenario entails relatively smaller reduction targets in the intermediate years until the end of the timeframe in 2050 or 2060. This implies a staged transition on achieving N leaching reductions in the long run while preserving the viability of farms as well as the economic structure of the Otago region. My evidence then sheds light on what farmers can do to accommodate the reductions into their production plans and what that might mean for profitability and viability of farms.

59. I find that a hypothetical N leaching reductions of 50% will result in large farm profit, sector and regional losses. The sector may lose $7.3 million dollars in 2040 and the region $14.6 million. There is economic value if a timeframe is set at 2060 where those losses decrease by 55%. However, even for reduction levels of 10% and 30%, N leaching reductions are a heavy burden for farms, which leads to at least 17 farms (25% of the population) to shut down. This implies significant shrinkage of the dairy industry in Otago.

60. Though the sector and regional losses decrease if the timeframes for compliance are set at 2050 or 2060, these may not suffice to prevent industry shrinkage due to the lack of cost-effective mitigation practices and the heavy losses from the EFW package and the likely introduction of the ETS. Losses on the regional economy will be significant given the importance of dairy production in Otago (Holland

& Doole, 2014). Most importantly, those losses can be even higher by a factor of 6 or 7 considering I use a sample of 67 farms of 455 existing in the region.

61. Considering the current geopolitical environment, it is worth mentioning that across time the impacts of N leaching will interact with changes in milk price, diversity of operational efficiency across farms, farmer behaviour and responses to changing economic and financial conditions (e.g. interest rates and labour shortage), the mounting effects of other policies (e.g. pricing of GHG emissions), availability of mitigation practices, debt management and the penetration and acceptability of new technologies (Doole, 2021; Doole, Vigiak, et al., 2013). That is, the uncertainty introduced by the pRPS adds layers of complexity that further complicate the production decisions of farmers.

62. A potential source of the large economic losses is the uniform application of the reduction levels across all farms. That is, considering the diversity of farms, not all are in the same position to achieve N leaching reductions cost-effectively.

63. Therefore, alternative policy settings should be investigated. For example, the reduction mandate could be set only to those farms that are the top 25% emitters (17 farms in my sample). They may be requested to reduce N leaching to the corresponding percentile 70 levels (about 62 Kg per ha). The policy may entail that farmers can negotiate between them on how to share the burden of the reduction and the cost-effective mechanisms or practices to reach compliance. This design would result on an aggregate decrease of N leaching of about 12% below the baseline. This is a proper starting point for a comprehensive better-designed policy package. Arguably, the economic impacts will be lower as these farms have more room to accommodate the reductions across the transition paths shown in Figure 1. That is, the transition across time through low reduction levels set at intermediate stages will make it easier to move toward policy compliance at a minimum cost.

64. My evidence about the mitigation practices is mixed. That is, the uniform application of mitigation practices may not be cost-effective as it is not clear whether the mitigation practices can balance their implementation costs with greater efficiencies on N leaching reduction. A positive balance is achieved in only a small sample of the population (7 of the 67 farms when comparing the base-practices scenario with adoption of plantain pasture). This is a matter that requires further research that considers the spatial characteristics of catchments and rohes, the associated trade-offs between economic, environmental and social outcomes, differences in farm types, and budget limitations. Therefore, the application of the pRPS needs to be better informed, well targeted, flexible, and simple to implement, which requires a collective effort, good data and further research so that cash flow problems do not jeopardize it (Piñeiro et al., 2020). This pipeline of work can be achieved only under long and flexible timeframes, otherwise the economic impacts will be large.

65. There are many factors that influence the capacity of farmers to invest in land, water and forest conservation, and to pursue sustainable practices. Those factors involve agricultural institutions, policies and regulations, social protection, infrastructure and markets, prices, off-farm employment opportunities and structural poverty (Piñeiro et al., 2020). Hence, the required reduction targets and the timeframes shape the flexibility that farmers will have to accommodate production plans and adoption of mitigation practices. Severe or sudden reduction targets applied uniformly across farms will disrupt the trade-off between environmental outcomes and the adoption of the least expensive mitigation (Doole & Romera, 2015; Holland & Doole, 2014; Kaye-Blake et al., 2019).

66. The dairy sector is a complex and dynamic system where N leaching reductions may have positive and negative impacts (Kaye-Blake et al., 2019; Vibart et al., 2015). The pRPS should have a degree of flexibility on the timeframes set for compliance, though that may not suffice when mitigation practices involving heavy investment are to be implemented. Therefore, a balanced approach between meeting environmental goals at a minimum cost requires further research

about the absorptive capacity of the environment, the ability to spread the burden of the economic impacts across farms and regions, and the level of uncertainty when the targets are discussed and finally come into force.

67. Based on my analysis a staged approach to implementing reduction targets will decrease their impact on dairy farming profitability and viability. Since the pRPS does not define targets, it is critical that it provide a method for a carefully planned transition to meet environmental goals while preserving farms viability. Transitional timeframes to meet long-term visions informed by the assessment of water quality and quantity *and* the capacity of farms to adapt to the proposed regulatory changes are likely to reduce the number of farms which are lost because they are no longer viable.

## References


Adenuga, A. H., Davis, J., Hutchinson, G., Patton, M., & Donnellan, T. (2020). Analysis of the effect of alternative agri-environmental policy instruments on production performance and nitrogen surplus of representative dairy farms. *Agricultural Systems*, *184*. https://doi.org/10.1016/j.agsy.2020.102889

Beukes, P., Chikazhe, T., Dalley, D., & Woods, R. (2021). *Step Change – Science and Policy work stream*.

Dairy NZ. (2019). *Mitigation Modelling for Dairy farms in North and South Otago*.

Dairy Statistics. (2020). *New Zealand Dairy Statistics 2019-2020*. https://www.dairynz.co.nz/publications/dairy-industry/new-zealand-dairy-statistics-2019-20/

Doole, G. J. (2012). Cost-effective policies for improving water quality by reducing nitrate emissions from diverse dairy farms: An abatement-cost perspective. *Agricultural Water Management*, *104*, 10–20. https://doi.org/10.1016/j.agwat.2011.11.007

Doole, G. J. (2020a). *Statement of Evidence - Proposed Plan Change 2 to the Horizons One Plan*.

Doole, G. J. (2020b). *Statement of Evidence - Proposed Plan Change 7: Waimakariri*.

Doole, G. J. (2021). *Economic impacts of proposed greenhouse-gas emission pathways on New Zealand dairy farms*.

Doole, G. J., Marsh, D., & Ramilan, T. (2013). Evaluation of agri-environmental policies for reducing nitrate pollution from New Zealand dairy farms accounting for firm heterogeneity. *Land Use Policy*, *30*(1), 57–66. https://doi.org/10.1016/j.landusepol.2012.02.007

Doole, G. J., Vigiak, O., Pannell, D. J., & Roberts, A. M. (2013). Cost-effective strategies to mitigate multiple pollutants in an agricultural catchment in North Central Victoria, Australia. *Australian Journal of Agricultural and Resource Economics*, *57*(3), 441–460.

Dunstan, A., Skilling, A., Newman, M., & Mounsey, Z. (2015). An updated assessment of dairy sector vulnerabilities. *Reserve Bank of New Zealand Bulletin*, *78*(8).

Holland, L. M., & Doole, G. J. (2014). Implications of fairness for the design of nitrate leaching policy for heterogeneous New Zealand dairy farms. *Agricultural Water Management*, *132*. https://doi.org/10.1016/j.agwat.2013.10.008

Infometrics. (2021). *Infometrics: regional economic profiles*. https://ecoprofile.infometrics.co.nz/clutha%0ADistrict/Gdp/Structure, https://ecoprofile.infometrics.co.nz/Waitaki District/Gdp/Structure%0A

Leslie, J. (2020). *Statement of Evidence - Part B of proposed Plan Change 7 of the Canterbury Land and Water Regional Plan*.

Ministry for Primary Industries. (2021). *Situation and Outlook for Primary Industries*.

NZ Herald. (2020). *Jacinda Ardern outlines plan to live NZ primary export earnings*. https://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=1234 6105%0A

NZIER. (2018). *An analysis of the flow-on benefits of dairy's revenue generation*.

NZIER. (2020). *COVID-19: The recovery ahead Assessing the sectoral impact and policy implications for Government spending*.

Pannell, D. J., Llewellyn, R. S., & Corbeels, M. (2014). The farm-level economics of conservation agriculture for resource-poor farmers.

*Agriculture, Ecosystems & Environment*, *187*, 52–64. https://doi.org/10.1016/J.AGEE.2013.10.014

Pannell, D. J., Marshall, G. R., Barr, N., Curtis, A., Vanclay, F., Wilkinson, R., Pannell, D. J., Marshall, G. R., Barr, N., Curtis, A., Vanclay, F., & Wilkinson, R. (2006). Understanding and promoting adoption of conservation practices by rural landholders. *Australian Journal of Experimental Agriculture*, *46*(11), 1407–1424. https://doi.org/10.1071/EA05037

Piñeiro, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Opazo, C. M., Owoo, N., Page, J. R., Prager, S. D., & Torero, M. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability 2020 3:10*, *3*(10), 809–820. https://doi.org/10.1038/s41893-020-00617-y

Sense Partners. (2020). *Dairy's economic contribution 2020 update*. https://www.dcanz.com/UserFiles/DCANZ/File/Dairy economic contribution slides _Sense Partners August 2020.pdf

## Annexure

**Figure A1**: Profit Changes (%) for a 50% Reduction target, plantain pasture available as mitigation and multiple years of compliance: 2040, 2060

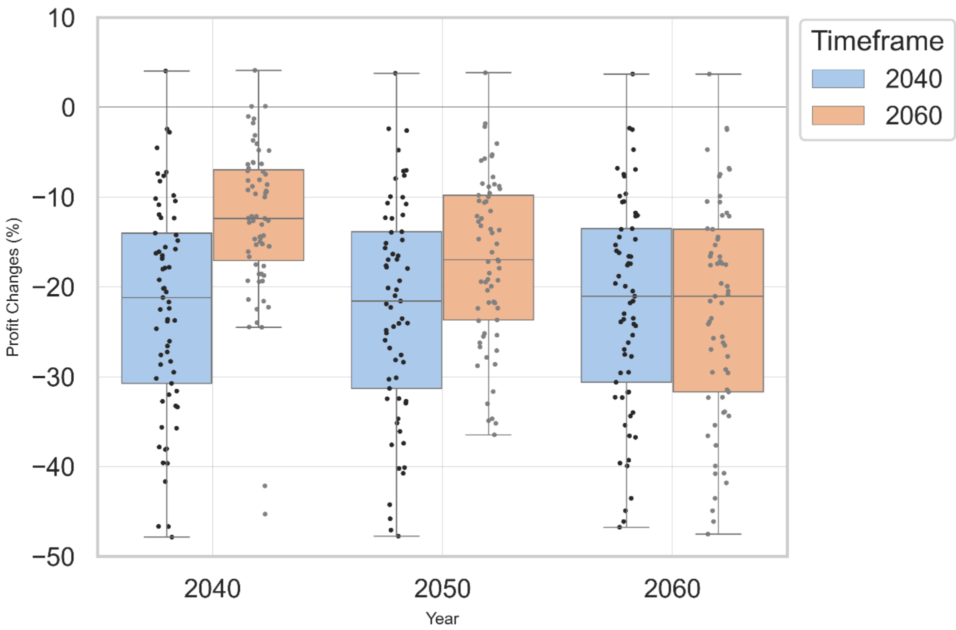



**Figure A2**: Profit Changes (%) for a 50% Reduction target, pivot irrigation available as mitigation, and multiple years of compliance: 2040, 2060

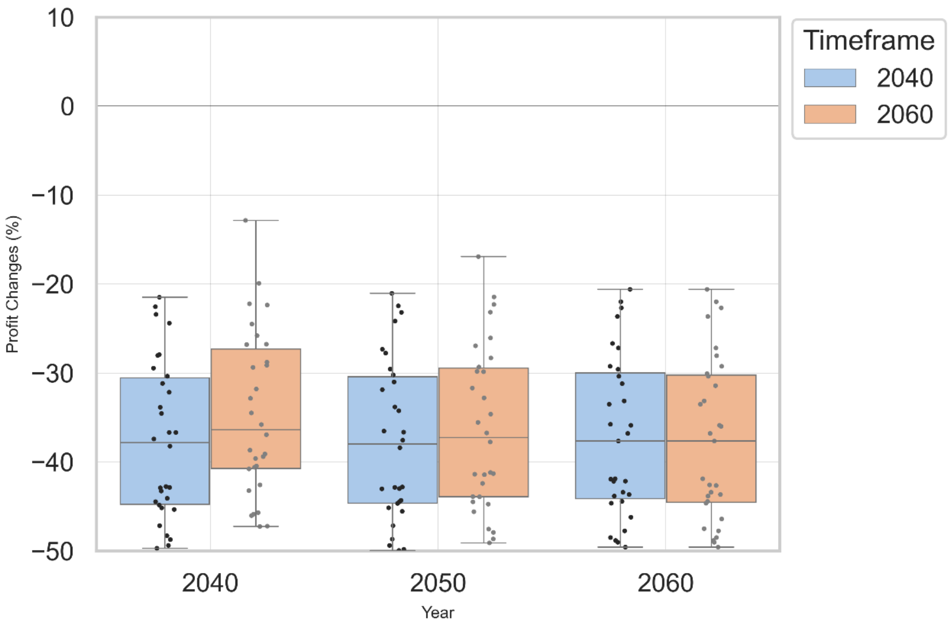


**Figure A3**: Profit Changes (%) for a 50% Reduction target, fodder beets available as mitigation, and multiple years of compliance:  2040, 2060

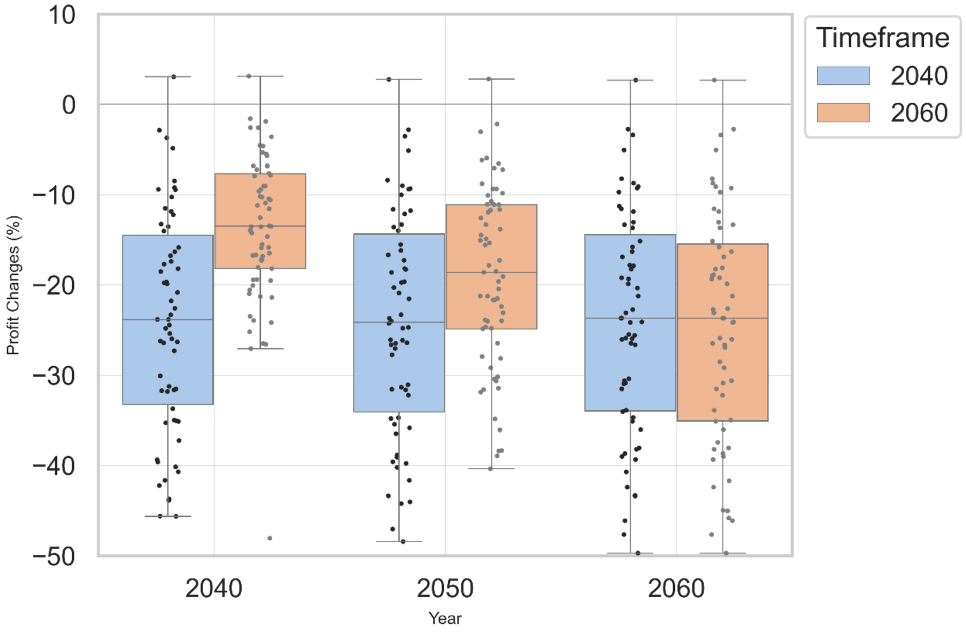



**Figure A4**: Profit Changes (%) for a 50% Reduction target, wintering available as mitigation, and multiple years of compliance: 2040, 2060

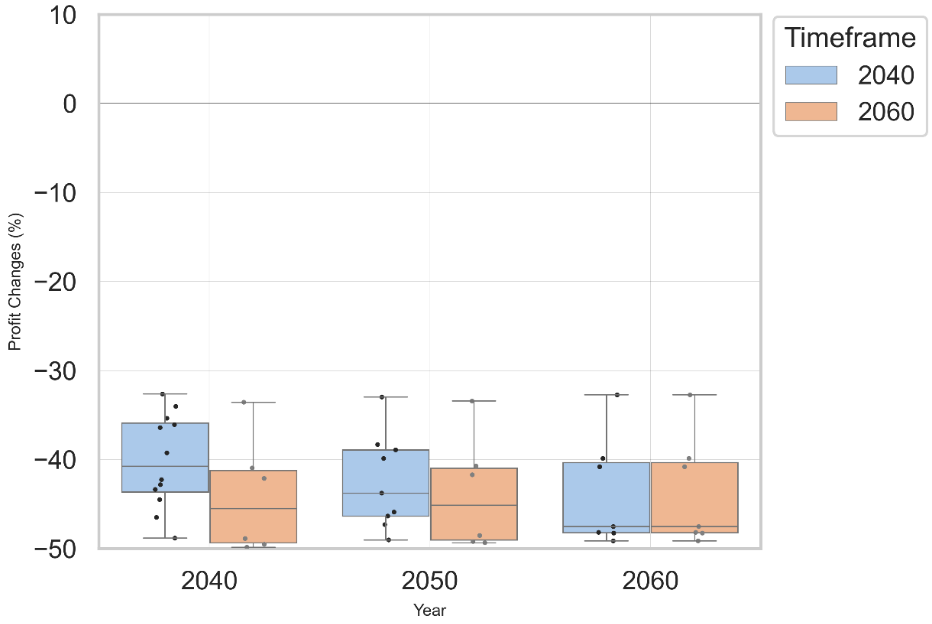


**Table A1**: Sectoral, regional and total changes

| | Year | Year for compliance, or timeframe 2040 | 2050 | 2060 |
|---|---|---|---|---|
| | | Sector Costs | | |
| Base practices | 2040 | 7,309,180 | 4,512,726 | 3,258,026 |
| | 2050 | 7,197,706 | 7,263,270 | 5,181,033 |
| | 2060 | 7,183,227 | 7,248,825 | 7,364,948 |
| Plantain pasture | 2040 | 6,820,270 | 4,477,749 | 3,395,419 |
| | 2050 | 6,732,257 | 6,806,489 | 5,042,023 |
| | 2060 | 6,712,879 | 6,787,143 | 6,903,965 |
| Pivot irrigation | 2040 | 14,298,989 | 13,764,935 | 13,511,650 |
| | 2050 | 14,122,607 | 14,167,957 | 13,753,413 |
| | 2060 | 14,148,533 | 14,193,906 | 14,222,381 |
| | | Regional costs | | |
| Base practices | 2040 | 14,618,360 | 9,025,452 | 6,516,053 |
| | 2050 | 14,395,412 | 14,526,540 | 10,362,066 |
| | 2060 | 14,366,454 | 14,497,650 | 14,729,895 |
| Plantain pasture | 2040 | 13,640,540 | 8,955,497 | 6,790,838 |
| | 2050 | 13,464,513 | 13,612,977 | 10,084,046 |
| | 2060 | 13,425,758 | 13,574,285 | 13,807,929 |
| Pivot irrigation | 2040 | 28,597,978 | 27,529,870 | 27,023,299 |
| | 2050 | 28,245,214 | 28,335,915 | 27,506,826 |
| | 2060 | 28,297,065 | 28,387,813 | 28,444,762 |
| | | Total change | | |
| Base practices | 2040 | 21,927,540 | 13,538,178 | 9,774,079 |
| | 2050 | 21,593,117 | 21,789,809 | 15,543,099 |
| | 2060 | 21,549,682 | 21,746,475 | 22,094,843 |
| Plantain pasture | 2040 | 20,460,811 | 13,433,246 | 10,186,258 |
| | 2050 | 20,196,770 | 20,419,466 | 15,126,069 |
| | 2060 | 20,138,637 | 20,361,428 | 20,711,894 |
| Pivot irrigation | 2040 | 42,896,968 | 41,294,805 | 40,534,949 |
| | 2050 | 42,367,821 | 42,503,872 | 41,260,238 |
| | 2060 | 42,445,598 | 42,581,719 | 42,667,143 |

**Figure A5**: Debt to assets ratio for a 50% Reduction target, plantain pasture available as mitigation, and multiple years of compliance: 2040, 2060

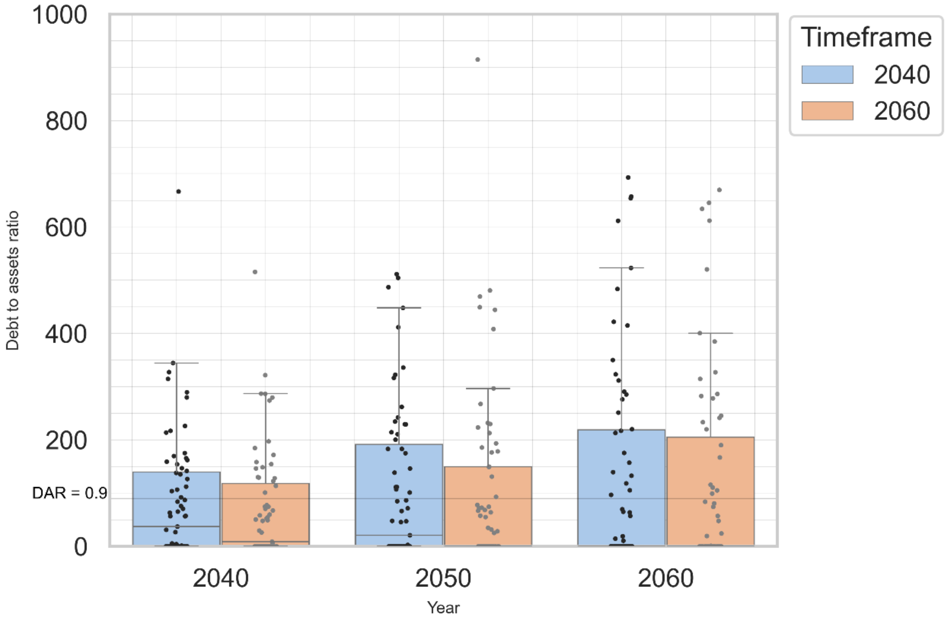



**Figure A6**: Debt to assets ratio for a 50% Reduction target, pivot irrigation available as mitigation, and multiple years of compliance: 2040, 2060

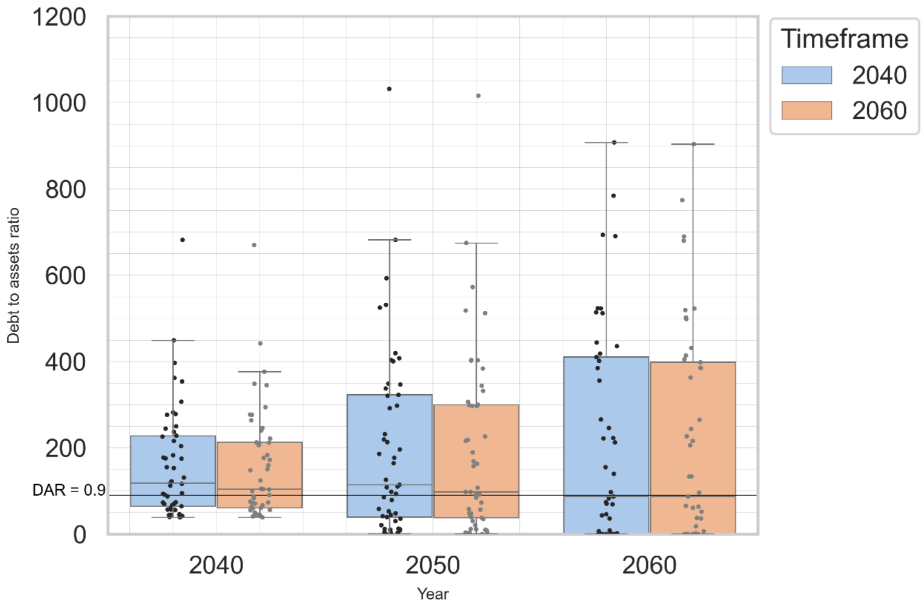


**Figure A7**: Debt to assets ratio for a 50% Reduction target, fodder beets available as mitigation, and multiple years of compliance: 2040, 2060

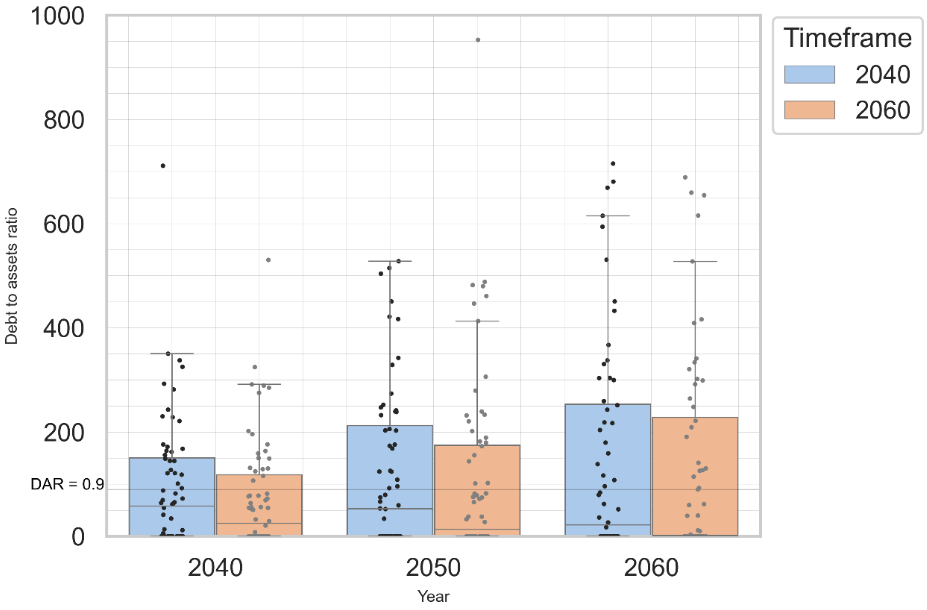



**Figure A8**: Debt to assets ratio for a 50% Reduction target, wintering available as mitigation, and multiple years of compliance: 2040, 2060