

Exploring farm level response to multiple drivers of change, a West Coast case study

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Abstract

Developing resilient, profitable, and robust dairy farm businesses in response to multiple drivers of change (e.g., water quality regulations, a low carbon economy) is challenging. This study explored methods for working with dairy farmers and stakeholders from the West Coast of New Zealand to evaluate options for system change. Physical, financial, and environmental data from the study farms were analysed and benchmarked to provide farmers with information on how their financial and environmental performance compared with others. The most profitable farm had the lowest purchased nitrogen (N) surplus. However, high pasture production and utilisation resulted in higher methane emissions for this farm. FARMAX and OVERSEER models were used to apply principles of the top performing farm to two selected study farms. These study farms largely succeeded in reducing N surplus and methane emissions, but operating profit was reduced, suggesting a complete system rethink is needed including focusing on growing and harvesting more home-grown feed with less N input, and scrutiny of farm working expenses. This study showed that benchmarking, farmer participation and modelling has the potential to create a positive environment that motivates farmers to review their current performance, extract solutions from their local peers and partner with researchers.

Keywords: Co-development, dairy farm performance, profitability, nitrogen surplus, methane emissions

Introduction

Farmers are currently facing pressure to meet local, national, and international regulatory requirements relating to emissions to air and water, uncertainty associated with biosecurity risks, rising input costs, and accelerating impacts of climate change and the need to adapt. A challenge for researchers is to co-develop, with farmers and other stakeholders, farm systems that are suitable across a range of possible future climates, with low environmental footprint, and that are practical, profitable, and easily adoptable.

Farms are usually categorised based on similarity of their farming system, region, climate, and soils.

Comparisons within a category, or ‘benchmarking’, is an approach used to identify, learn, and adapt better practices from peer farmers to help improve farm performance (Khan, 2010). This process usually involves gathering data that allows comparisons between farms, especially against the best performing farms within the benchmark group. The process of benchmarking encourages farmer participation by highlighting issues of efficiency, environmental sustainability, cost of production and profitability. Using local farmer data in identifying performance gaps to improve farm performance, can be a way of engaging farmers to change (Anderson and McAdam, 2004).

The West Coast dairy sector in the South Island of New Zealand operates in a distinctive environment with its own set of unique challenges (Dalley and Gardner, 2012). The region has relatively high rainfall (>2050mm per annum), but with seasonal dry periods that are variable across the region (Macara, 2016). The soils are poorly drained and may have an impermeable iron pan. As a result of high rainfall and poorly drained soils, pasture utilisation can be a challenge and supplements are imported to cope with low pasture utilisation; however, this can negatively impact profitability. In addition, the local milk processing company previously paid lower milk prices compared with the rest of New Zealand, which put further pressure on profitability.

Current environmental regulations require farmers to use less than 190 kg N/ha of synthetic nitrogen fertiliser and minimise the impact of grazing on soil conditions. There is also a government target to reduce methane emissions by 10% by 2030 (DairyNZ, 2021). Furthermore, with forecast climate changes, the West Coast region is expected to become wetter, particularly in winter and spring. Increased average rainfall in the Southern Alps will increase river flows, potentially leading to increased flooding events (Carey-Smith et al., 2018).

The aim of this study was to engage with West Coast dairy farmers and stakeholders to co-develop a resilient, profitable, and robust farm businesses to respond to these drivers of change, including water quality regulations and a move towards a low-carbon economy.

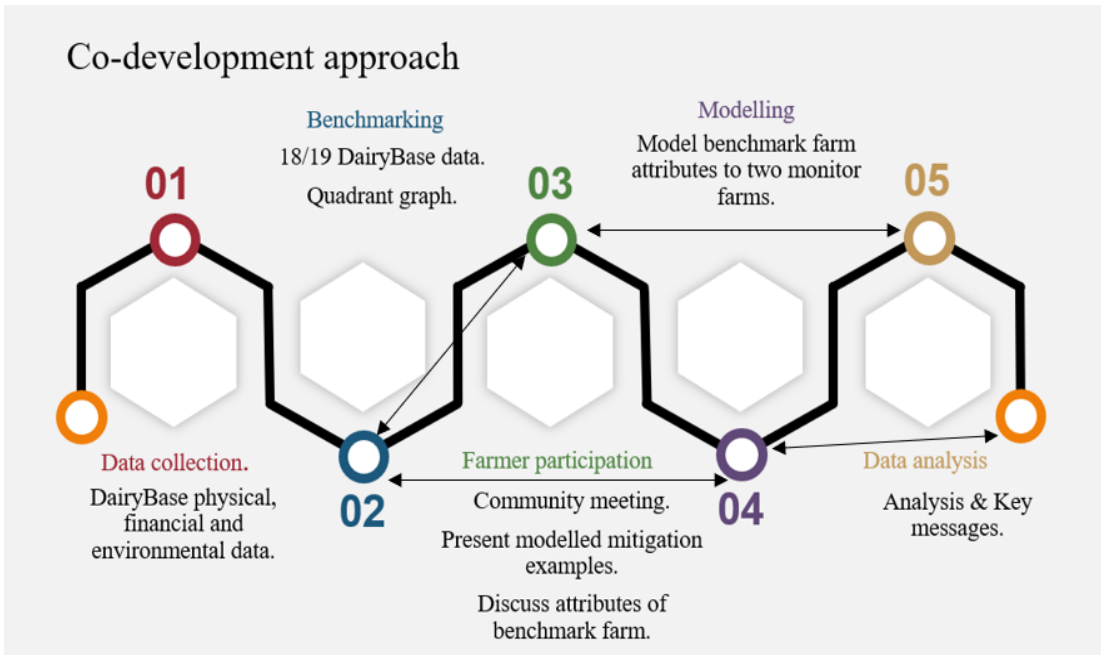


Figure 1 Co-development approach taken in the presented study

Materials and Methods

This study was part of a larger programme that worked with farmer groups to explore current and future challenges to their farming businesses arising from regulations and changing climate. The approach was designed to engage farmers and stakeholders to participate in the co-development of dairy systems that could remain profitable whilst responding to multiple drivers of change, *e.g.*, water quality regulations and a low carbon economy (Figure 1).

Data collection

Physical, financial, and environmental data were extracted from DairyBase (DairyBase - DairyNZ) for all recorded West Coast dairy farms for the 2018/19 season ($n = 15$). This season was chosen because at the time of analysis, it represented the most recent production year with the most complete data set.

Benchmarking

The benchmarking process provided farmers with information on how farms in the region varied in financial and environmental outcomes and how they themselves compared to other farms in their own region, challenging them to rethink their farm system.

Key performance indicators for the 15 case study farms were visualised on quadrant graphs (Figures 2 and 3) which showed the relationship between operating profit, methane emissions and purchased N surplus. Methane emissions were calculated using the OVERSEER

(Watkins and Selbie, 2015) model, presented as tonnes CO₂ equivalent per hectare per year. Purchased N surplus was defined as the balance between N inputs and N outputs, *i.e.*, how much N was imported minus N removed in product (Pinxterhuis, 2019). Any N surplus indicated the potential environmental risk of leaching and ammonia and nitrous oxide emissions (Chapman *et al.*, 2018). Reducing N surplus not only benefits the environment but can also contribute to farm profitability.

On the quadrant graphs, the axes represented the medians of the X and Y variables, creating four quadrants. Four quadrants were determined, A to D, starting from top-left to bottom-right, with quadrant A being the most and D the least desirable position. The quadrant graphs were used to show how the 15 farms were positioned relative to each other in terms of environmental footprint and profit, *i.e.*, benchmarking. These graphs were shared at local workshops so farmers could see the performance of their own farms compared with that of their peers, or farms from their district, which 'resonated' with their farm system. This created conversations and questions about top performers and what they were doing differently. Workshop attendees noticed one outstanding farm in quadrant A of the N surplus graph with lower purchased N surplus and higher operating profit (Figure 2). The farm was coded BF (benchmark farm). Two West Coast farms (Farm 1 and 2) were selected as farms on which modelling could be done to explore the options suggested by the group. The farms were selected based on their involvement in

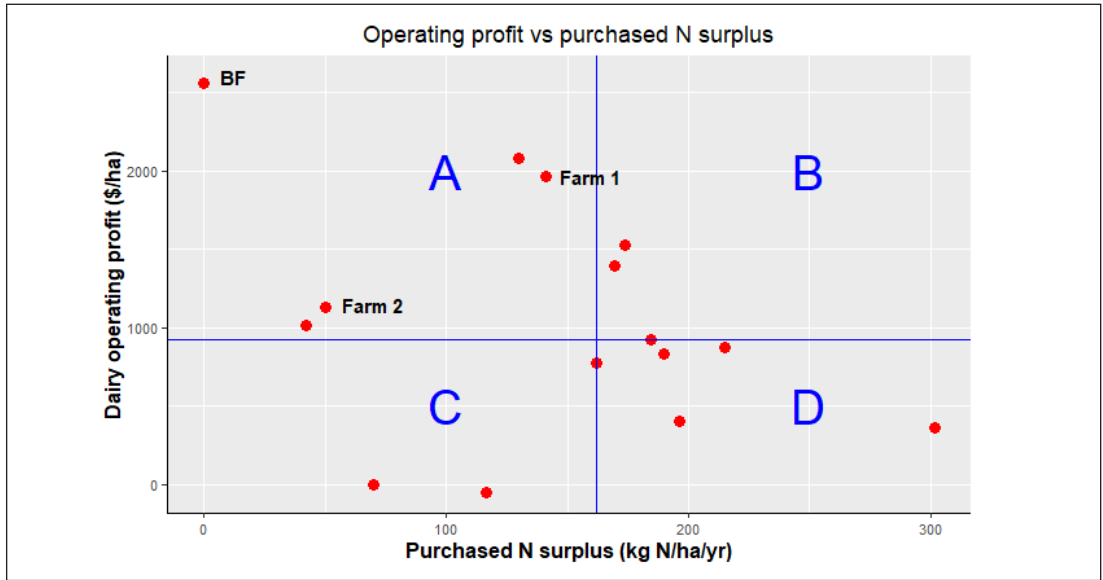


Figure 2 Quadrant graph of operating profit versus purchased N surplus for West Coast dairy farms ($n = 15$) for 2018/19 season, showing the position of the benchmark farm (BF), and two case studies, Farm 1 and 2. Median values are shown as blue lines.

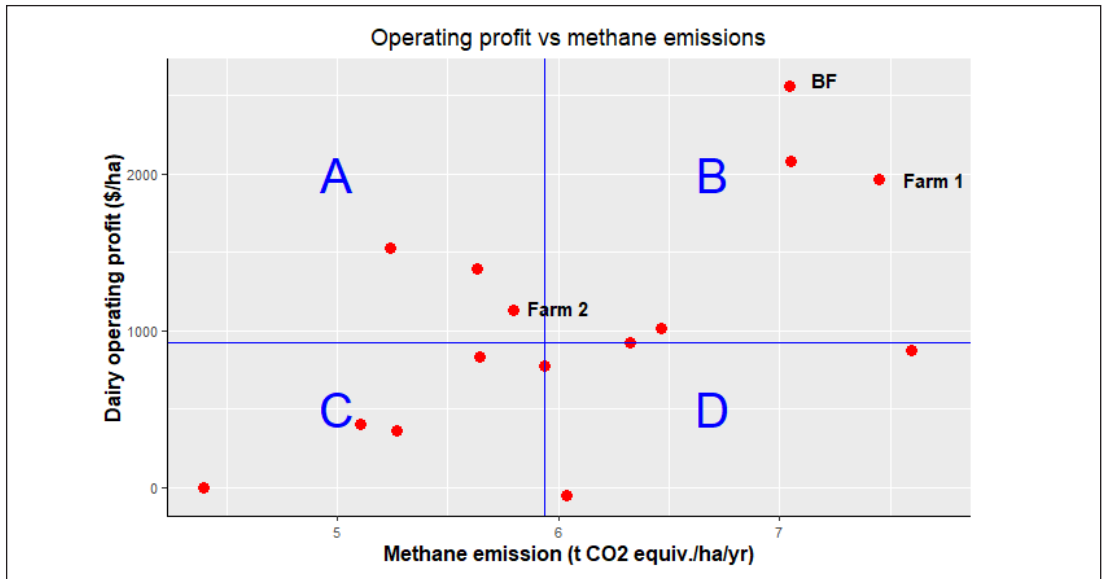


Figure 3 Quadrant graph of operating profit versus methane for West Coast dairy farms ($n = 15$) for 2018/19 season, showing the position of the benchmark farm (BF), and two case studies, Farm 1 and 2. Median values are shown as blue lines.

a regional monitoring project, willingness to support the project, availability of data and representation of two distinct subregions of the West Coast.

Farmer Participation

The benchmarking results were presented at a community workshop involving case study farmers, other local farmers, consultants, researchers and other

rural professionals. The aim was to explore opportunities for change to better balance profit and environmental outcomes. Farmers were interested in knowing why some farms performed better: were there commonalities in farm setup or management that dictated why certain farms fell into A for N surplus versus profit (Figure 2), or for methane versus profit (Figure 3)? What were the key ‘levers’ that can move a farm towards the A quadrant?

This approach to data presentation was developed to focus thinking on increasing profitability and reducing environmental footprint. The quadrant graphs were found to be good conversation starters. The quadrant graphs encouraged farmer participation by identifying farm system or management components that needed improvement relative to their peers.

Case study modelling

FARMAX (Bryant et al., 2010) and OVERSEER models were used to predict the outcomes of applying attributes of the benchmark farm (BF) to the case study Farms 1 and 2. FARMAX is a whole-farm decision support model that predicts the production and economic outcomes of managerial decisions. OVERSEER is a whole farm decision support model that predicts nutrient loss to land and air. A combination of the two models was used to predict the economic and environmental impact of applying attributes of BF. This approach encouraged farmers to participate in evaluating changes they suggested for the case study farms to try and match the operating profit and environmental footprint of BF. Key attributes of BF included (compared to other farms in the region) lower imported supplement, lower N fertiliser use (30 kg/ha/annum), higher pasture utilisation with little surplus for conservation, and a low cost-structure. Three scenarios were modelled on each case study farm: 1) matching BF levels of imported supplements, 2) matching both supplements and stocking rate and, 3) matching N fertiliser application rate. The low cost-structure of BF was not matched explicitly, except as a consequence of the three scenarios, as farm cost-structure can sometimes be driven by personal circumstances (e.g., wages, insurance and repair and maintenance decisions).

Data analysis and key messages

The DairyBase team provided the full data set (with full anonymity) for the 15 West Coast dairy farms, which included approximately 260 farm descriptive variables. This data set was cleaned by selecting 83 variables most relevant to the outcomes investigated, including methane, purchased N surplus and operating profit. The farms were divided into two groups (X and Y) based on the median operating profit. Group X farms were above the group median operating profit and Group Y were below. Box plots were generated for the recorded farm variables that were most likely “drivers” of why farms clustered below or above the median lines (Figure 4), as decided by group consensus. FARMAX and OVERSEER predictions of key variables (profit, methane emissions, pasture and crop eaten/ha and N surplus) were generated for Farms 1 and 2 after applying BF attributes.

Results and Discussion

Farmer participation

Farmers were interested to better understand the types of local farming systems which were represented in the most profitable with lowest environmental indicators on the quadrant graph. Farmers had an opportunity to select from the benchmark farm, options they considered most useful for their own situation; with the modelling results and assumptions underpinning them as guidelines. The options for improvement were driven by local farmers in the group whose results showed higher profit and lower environmental impact compared to the rest of the group.

The participatory approach process was effective in collecting farmer views of their farming practices, actions available to them both now and into the future. One of the key advantages of participatory approach was using local data in providing farmers ownership to the solutions of their own challenges and extract solutions from their peers.

Data analysis

The analysis found that more profitable farms (Group X) generally have lower farm working expenses, have higher total feed eaten and consequently, higher methane emissions, utilise more home-grown pasture and crop, lower N fertiliser use, and lower N surplus compared with less profitable farms (Group Y; Figure 4). Farm 1 and 2 positions in Figure 4 were before applying BF principles.

A comparison of BF and case study farms 1 and 2 shows that the BF system is characterised by low imported supplement, low N fertiliser use, growing and utilising a high amount of pasture and crop per hectare, and having low farm working expenses. Furthermore, a higher stocking rate is associated with an increase in the amount of home-grown feed eaten in comparison to farms 1 and 2 (Table 1). It is widely accepted that higher stocking rates can enhance pasture utilisation (McEvoy et al., 2009).

Exploring Modifications to Case Study Farms

Three modification options were explored for Farm 1 and 2: i) matching BF levels of imported supplements, ii) matching both supplements and stocking rate, and iii) matching N fertiliser application rate. Before applying modifications on Farm 1, the farm was 23% less profitable, 6% higher on methane emissions and had higher purchased N surplus (140 kg N/ha) compared to BF. Matching BF imported supplements and N fertiliser use resulted in lower methane emissions than BF, but the operating profit was 28% and 41% lower (Table 2). All modifications resulted in reduced purchased N surplus, methane emissions and operating profit (Table 2). The BF had other low-cost features which

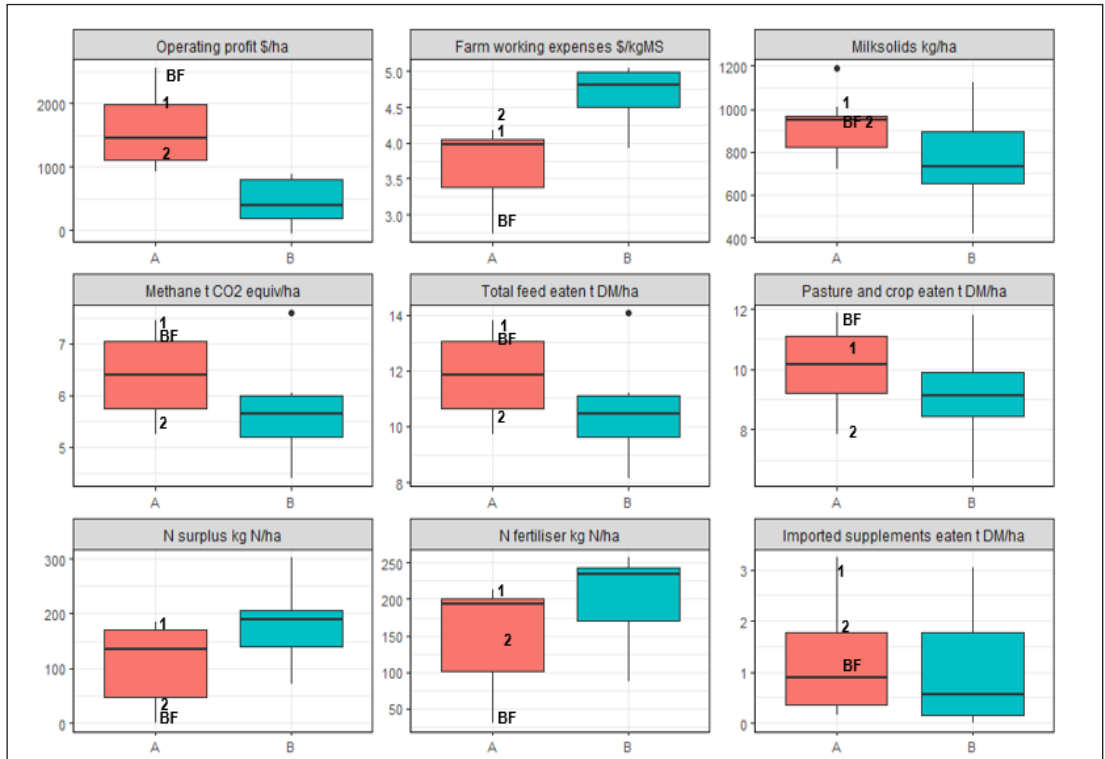


Figure 4 Characteristics of farms above median operating profit (\$/ha) (Group X, red) and below median operating profit (Group Y, blue), showing the position of the benchmark farm (BF), and case study farms 1 and 2.

we assumed could not be applied directly to Farm 1, including low labour, animal health, irrigation, farm dairy, vehicles, electricity, and pasture renewal costs.

Before applying modifications on Farm 2, the farm was 56% less profitable, 18% lower on methane emissions and had higher purchased N surplus (50 kgN/ha) compared to BF. The three modifications on Farm

2, resulted in reduced purchased N surplus, methane emissions and operating profit (Table 3). Matching BF imported supplements by removing expensive imported supplements improved Farm 2 operating profit. Imported supplements and fertiliser are more expensive for West Coast farmers than other regions primarily due to the extra cost of \$50/tonne for transport from

Table 1 Farm physical data for the 2018/19 season for the case study farms 1, 2, benchmark farm (BF) and West Coast group average. MS = Milksolids.

Farm	1	2	BF	Average (n=15 farms)
Effective farm area ha	95	155	102	160
Stocking rate cows/ha	2.5	2.3	2.6	2.4
Purchase N surplus kgN/ha	140	50	0	142
Methane kg CO ₂ equiv/ha	7450	5800	7045	6066
Milk production kg MS/ha	1148	954	1008	912
Milk production kg MS/cow	458	435	392	387
Pasture and crop eaten t/ha	10.4	7.8	11.9	10
Imported supplements %	25	27	9	24
Total feed eaten t/ha	13.8	10.7	13.0	13.2
N fertiliser kg/ha	200	151	30	166
Farm working expenses \$/kg MS	4	4.04	2.74	4.24
Operating profit \$/ha	1968	1130	2562	1022

Canterbury over the Southern Alps to the West Coast region. Farm 2 has much lower home-grown feed eaten and stocking rate than BF and imports higher amounts of supplements to sustain similar production per hectare to BF, resulting in higher farm working expenses (Table 3).

One of the key advantages of using the co-development approach was the use of local data to motivate farmers to recognise their challenges and develop their own solutions. Farmers felt it was critically important to have regionally specific data and knowledge to adapt to the changing regulations. This approach was effective in

Table 2 Implications of case study farm 1 implementing benchmark farm (BF) principles. All percentage changes are relative to BF (Farm data for BF according to DairyBase for the 2018/19 season).

Farm	BF	Farm 1. Before modifications	Farm 1. Match BF imported supplements	Farm 1. Match BF imported supplement and stocking rate	Farm 1. Match BF N fertiliser use
Effective farm area ha	102	95	95	95	95
Stocking rate cows/ha	2.6	2.5	2.5	2.6	2.5
Purchase N surplus kgN/ha	0	140	108	108	22
Methane kg CO ₂ equiv/ha	7045	7450	7022	7208	6874
Methane % change relative to BF	0	6%	-0.3%	2%	-2%
Milk production kg MS/ha	1008	1148	1038	1055	1005
Milk production kg MS/cow	392	458	414	404	401
Pasture and crop eaten t/ha	11.9	10.4	10.6	10.9	10
Imported supplements %	9	25	9	9	32.6
Total feed eaten t/ha	13.0	13.8	12.9	13.3	12.7
N fertiliser kg/ha	30	200	200	200	30
Farm working expenses \$/kg MS	2.74	4.0	4.0	4.03	4.29
Operating profit \$/ha	2562	1968	1843	1857	1514
Operating profit % change relative to BF	0	-23%	-28%	-28%	-41%

Table 3 Implications of case study Farm 2 implementing benchmark farm (BF) principles. All changes are relative to BF.

Farm	BF	Farm 2. Before modifications	Farm 2. Match BF imported supplements	Farm 2. Match BF imported supplement and stocking rate	Farm 2. Match BF N fertiliser use
Effective farm area ha	102	130	130	130	130
Stocking rate cows/ha	2.6	2.3	2.3	2.5	2.3
Purchase N surplus kgN/ha	0	50	42	48	5
Methane kg CO ₂ equiv/ha	7045	5800	5532	5764	5508
Methane % change relative to BF	0	-18%	-21%	-18%	-22%
Milk production kg MS/ha	1008	954	917	948	912
Milk production kg MS/cow	392	430	391	384	389
Pasture and crop eaten t/ha	11.9	7.8	8.0	8.2	7.3
Imported supplements %	9	27	9	9	34
Total feed eaten t/ha	13	10.7	9.9	10.4	9.9
N fertiliser kg/ha	30	151	151	151	27
Farm working expenses \$/kg MS	2.74	4.04	3.82	4.01	4.16
Operating profit \$/ha	2562	1130	1187	1101	924
Operating profit % change relative to BF	0	-56%	-54%	-57%	-64%

eliciting farmers' views of local farming practices and actions available to them both now and into the future. The farmers were interested in better understanding the setup and management that made some local farms more profitable with a lower environmental footprint. They asked about the key levers to use to achieve similar financial and environmental performance. Implementing the co-development approach and benchmarking created a positive environment that motivated farmers to extract solutions from their local peers.

In the sample of 15 West Coast dairy farms it was unusual for the same farm to have both lower purchased N surplus and lower methane emissions, while still being above the group median for operating profit (*i.e.*, in group X). The farm attributes for lower purchased N surplus are more compatible with high operating profit. This aligns with the ideal of using less resources to attain a higher output *i.e.*, higher efficiency of N use. The farms with less purchased N surplus had lower cost of production as shown by their lower farm working expenses (Figure 4). The more profitable farms (group X) generally produced more milk solids per hectare, have more feed eaten per hectare mainly comprising of home-grown feed. The OVERSEER model current way of calculating methane is directly associated with dry matter intake. Consequently, lower methane and higher operating profit were difficult to achieve at the same time. In a related study, Neal and Roche (2020) looked at profitability and resilience of pasture-based dairy farms and found that greater profit was associated with more home-grown pasture and crop eaten, higher stocking rates, higher production per cow and lower farm working expenses. The efficiency of pasture-based dairy systems is largely driven by annual pasture production, pasture utilisation and feed conversion (Vibart et al., 2012). The correlation between methane emissions and profit poses a challenge to the industry's effort to reduce methane whilst increasing or maintaining profit.

When modelling the effects of applying BF principles to the case study farms, matching the proportion of imported feed reduced purchased N surplus on the case study farms but could not match BF operating profit. However, case study Farm 2's operating profit improved, mainly from the removal of expensive imported supplement. This outcome demonstrates that removing unprofitable feed from the system can present a win-win situation.

Matching imported supplements and stocking rate of BF required an increase in stocking rate and a decrease in imported supplements for both case study farms. Because pasture and crop eaten are less than BF for both case study farms, this scenario resulted in reduced milk production. With less feed available,

the feed intakes were lower resulting in lower methane emissions. Purchased N surpluses were lower because of less imported supplement N. However, both farms lost profitability because more cows per hectare required more feed for maintenance and less feed was converted to milk.

When case study farms matched BF in terms of N fertiliser, there were large reductions in N surplus. Reducing N fertiliser use from 150-200 kg/ha/annum (case study farms) to 30 kg/ha (BF) assuming 1kg of applied N fertiliser per hectare grow 10 kg pasture per hectare, created pasture deficit. The deficit had to be filled with imported supplements. Although imported supplements constituted an inflow of N, surplus N was still lower because of the lower crude protein content of these supplements (PKE and grains) relative to pasture. However, these changes resulted in large reductions in operating profit for both farms, because cheaper N-boosted pasture was replaced by more expensive imported feed.

The key message from this modelling exercise was that for the case study farms to match BF in terms of N surplus and profitability they needed to grow and utilise more pasture while using less N fertiliser, and by running a farm budget with a lower cost structure for major items like labour and animal health. Such systems are likely to have relatively high methane emissions, like BF. The strengths of the BF compared with the two selected farms was to achieve greater pasture and crop eaten per hectare with less N fertiliser and supplements. This strength has flow-on effects that intuitively reduce farm working expenses and purchased N surplus. Neither of the case study farms could match the most profitable farm by implementing only one or two principles. Instead, a complete system rethink was required, with no guarantee of success, because other factors outside the manager's control (*e.g.*, soil type and climate) may be limiting. Nevertheless, growing and harvesting as much pasture as the environment allows is a key lever for the West Coast farmers, which might not be relevant in reducing methane emissions.

Conclusion

This study showed that benchmarking and co-development with farmers has the potential to create a positive environment that motivates farmers to review their current performance and extract solutions from their peers. The most profitable West Coast dairy farms in this study grew and utilised more home-grown feed while using less N fertiliser and had lower farm working expenses. Although purchased N surpluses for these farms are generally lower than the median, methane emissions are higher. This leaves a conundrum when striving for the trifecta of high profit, low N surplus and low methane emissions. Farms need to strike a balance

between these metrics, requiring scrutiny of all aspects of the farm business.

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