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Key Determinants of Profit for Pasture-based Dairy Farms[1]

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Abstract

The key determinants of profit for pasture-based dairy farms and the impact on business performance of changes in pasture harvest, milk production per cow and production system, as determined by pasture as a per cent of cow's diet, are explored. One of the intended outcomes from this paper is to define a core group of ratios that can be used to reliably analyse farm business performance and identify which areas of a dairy farming business are performing well or poorly. An effective ranking of this core group of ratios is identified. A further intended outcome is to answer a common question as to whether the selection of a production system is relevant in determining the level of profit of a dairy farm or if the dominant determining factor in the level of profit is the operator's proficiency and accuracy in executing daily management decisions. A database of Australian dairy farm performance was analysed to determine which financial and physical ratios correlate with profit. How the more significant ratios change in relation to changes in pasture harvest, milk production per cow and production system is reviewed.

Pasture harvest was identified as the most important single factor impacting on profit as expressed by return on capital (R^2 = 0.41), with the second most important factor, stocking rate, having an R^2 = 0.25. The selection of a production system also significantly impacts on the resulting level of business performance due to its substantial impact on a wide range of key profit-related ratios. As a result, this paper proposes that both the level of pasture harvest and the choice of production system can be combined with operator proficiency to form the three primary factors that influence the level of profit on pasture-based dairy farms.

Key words: dairy farming, profit, pasture harvest, milk production per cow, production system.

Introduction

Dairy farming is one of the most complex businesses to manage given the mix of ruminant livestock (cattle) and pasture/crop production along with the impact of weather and a range of other environmental challenges. In addition, there is a high proportion of variable costs in dairy farming, which means managers must continuously consider multiple production factors relating to milk, livestock and pasture/crops as well as a wide range of cost factors to ensure they can trade

[1] Mark Neal of DairyNZ completed the statistical analysis presented in this paper and provided insights into methodologies and interpretation. Gonzalo Tuñon completed the original statistical analysis utilised in the initial development of this paper and provided insights into interpretation.

profitably. One of the outcomes of this situation is that there is no single dominating factor that dairy managers can focus on to maximise profit. Another outcome is that there are multiple 'levers' that must be 'pushed' in regard to production and 'pulled' in regard to cost. A further outcome is that farmers and their advisors often do not agree on which levers and which farm performance ratios are the important ones to monitor and manage, which does at times result in farmers and their advisors deciding that the only essential task on the farm is to manage the business well by executing proficiently whichever set of farm policies the farm operator has chosen.

In this paper, the results from interrogating a large and diverse set of Australian dairy farm data are described. By utilising statistical analysis of this dataset, the intent was to determine whether there was support for defining a core group of ratios which, if monitored and managed, may result in future improvements in profit with some degree of reliability. Presuming that this core group of ratios could be defined, then the intent was to address three of the most common questions farmers and their advisors ask: 'how important is 1) pasture harvest, 2) milk production per cow, and 3) choice of production system, to improving profit, and what impact do changes in these three factors have on dairy business performance?'

This paper is relevant to pasture-based, but not confinement, farms where 'pasture' includes all pasture and other crops consumed by the cows in-situ as well as any pasture mechanically harvested on the dairy farm, and where 'pasture-based' refers to farms where cows consistently walk to paddocks and harvest the pasture themselves. There is no minimum percentage level of pasture in the diet required for the definition of being pasture-based. However, in practice it is rare to see pasture-based farms with less than 25-30 per cent pasture in the diet annually, excluding periods of severe drought as, below these levels, farmers will usually decide to stop having their cows expend energy to walk to paddocks and graze small amounts of pasture, but rather confine them to a feedlot to maximise feed conversion to milk.

The analysis is based on 207 sets of Australian dairy farm data from 2005/06. All the sets of farm data were processed through Red Sky software, so they have all been analysed using a uniform methodology. The data is primarily from four States: Victoria, Tasmania, South Australia and Western Australia, although there are a small number of datasets from southern New South Wales. The Victorian and southern New South Wales datasets were primarily collected by Red Sky Agricultural (Red Sky) or Intelact, an independent consultancy company, with a substantial percentage of these datasets coming from farms attending discussion groups. There were some datasets collected by Red Sky or Intelact in Tasmania, South Australia and Western Australia, although the majority of these data were collected as part of industry-funded projects.

The industry-funded Tasmanian data were collected by the Department of Primary Industry, Water and Environment (DPIWE) as part of their annual state-wide benchmarking and Dairy Business of the Year (DBOY) competition. The industry-funded South Australian data were collected by several South Australian consultants and Red Sky, and was funded by Primary Industries and Resources South Australia (PIRSA) as part of a project that extended over three years (2005-2007). The industry-funded Western Australian data were collected by several Western Australian farm consultants and was funded by the Department of Agriculture and Food Western Australia (DAFWA) and Challenge Dairies as part of a project that extended over four years (2006-2009). There were several other funders in addition to DAFWA and Challenge Dairies in 2008-2009.

As the great majority of the datasets were collected via industry and/or government supported projects or in association with farmer study/discussion groups, the data is drawn from a full spectrum of production systems without commonality of focus. This results in the overall dataset being uncommonly unbiased compared to datasets collected by commercial organisations. All the data are from a year (2005/06) where milk price, supplement price and weather were within reasonable norms, so pasture harvest was within reasonable norms. Milk prices and all other milk ratios are reported in 'energy corrected milk' (ECM) with this corrected to 4.0% fat and 3.3% protein using the formula: ECM = milk production x ((0.383 x fat% + 0.242 x protein% + 0.7832) / 3.1138). Australia reports protein as true protein, so no adjustment is required for non-protein nitrogen. All dollar-denominated ratios are reported in USD and for this dataset the average AUD:USD foreign exchange rate was 1.339 (USD:AUD rate = 0.747).

Basis of Statistical Analysis

The software program, R (R Core Team, 2013), was used to undertake the statistical analysis in this paper. All except two of the graphs presented in this paper show associations, some of which are stronger than others. The graphs show a value for R^2, which measures what percentage of the variation in the ratio on the y-axis is explained by the single factor on the x-axis. The R^2 for farm data is unlikely to be very high because, even within a region, there are farms with different land capability, management capability, rainfall, stocking rate, and production system. This results in so many factors contributing to profit that it is difficult to single out just one factor as 'the cause'. However, a low R^2 value does not mean that a relationship is not statistically significant, or that it is not important to the level of profit on a farm or for the competitiveness of a dairy industry. The more important point is whether the underlying trend is strong, and whether the association represents a causal relationship.

Is the Underlying Trend Strong?

In most instances in this paper, the trends are strong. Visually this is seen in the graphs with a narrower shaded area around the trend lines, which relate to a lower P value. This shaded area represents a 95 per cent confidence interval; that is, if multiple random samples were analysed, 95 per cent of the confidence intervals constructed in a similar way would contain the true population mean.

For an association between variables, typically a P value of less than 0.05 is used as a threshold to determine its statistical significance; that is, there is less than a 5 per cent chance that the association has occurred due to random variation. The great majority of the figures in this paper have a P value of less than 0.001, which means there is less than one chance in a thousand that this association has occurred by chance. This is despite an R^2 value of less than 0.5 which means the trend explains less than 50 per cent of the variation. For this paper, where we are considering the relevance of trends for the dairy industry as a whole, the strength of the trend is more important than the R^2 value, and the strength of the trend is shown in the P value for the coefficient.

Does the Association Represent a Causal Relationship?

An association between two factors does not prove causation, but in some cases will be suggestive of a causal link. For example, if there was a strong association between higher pasture growth and higher rainfall then, because we know rainfall is independent of the farmer's actions and there are straightforward scientific mechanisms to suggest a causal link from moisture to growth, it is reasonable to infer that, within certain ranges, there is a positive causal link; i.e. more rainfall does lead to higher pasture growth. It should also be noted that the effect or impact may not be linear, though it might appear to be so. For instance, a flood is an excess of rainfall which is likely to suppress pasture growth or at least pasture harvest via grazing, though floods may occur infrequently in a given dataset, so the relationship can appear linear when there is reason to expect it is not.

Associations are often multifactorial. This occurs frequently in farm production systems so an association between two variables needs to be considered carefully for other explanations, or there is a risk of drawing the wrong inference. An example can be drawn from a recent paper titled "Profitable and resilient pasture-based dairy farm businesses in New Zealand" (Neal and Roche, 2020). This paper outlined that, within a specific region, farmers in the top quartile for operating return on assets have greater milk solids production per cow than the other three quarters of farmers. The difference for the more profitable farmers was 25 kilograms of milk solids per cow (approx. 342 litres ECM), and this was statistically significant. If the data from Neal and Roche (2020) were graphed with only milk solids per cow and operating return on assets, there would be a positive trend, and some would infer that higher production per cow was more profitable, and possibly go on to assume that more supplement can be justified to generate the higher level of profit. However, Neal and Roche (2020) also reported from the data that the more profitable farmers did not use greater levels of supplement (no statistical difference), but instead had greater pasture harvest (statistically significant), lower expenses per hectare and per kg milk solids (also statistically significant), and had less capital in the business per hectare (also statistically significant). In summary, an association between two variables may be statistically significant, but may not represent a simple causal relationship, which is why science and experience across a range of businesses and industries is valuable for interpretation when applied without bias.

Ratio Definitions and Calculations

Table 6 in the Appendix outlines the methodology utilised for calculating operating profit, which is the same as described by Beca (2020) and similar to that described by Hemme et al. (2014). Financing and lease/rent costs were excluded from this calculation of operating profit, other than where a lease/rent cost pertains to a support area utilised for livestock production (e.g. heifer growth) or feed production and, as a result, was included as a direct cost. Capital growth of assets was excluded from the calculation of operating profit.

Table 7 in the Appendix outlines the methodology utilised for calculating or defining each of the ratios referenced in the figures that follow.

What Correlates with Profit in Pasture-based Dairy Farming?

Return on total capital invested (ROC) is the ratio that defines profit as the return on the value of all assets employed in the business. In this analysis, changes in asset values, including appreciation of land values, are not included in this calculation of ROC and would be additional to the returns reported.

As Figures 1 and 2 confirm, profit per hectare and profit per cow strongly correlate with profit expressed as return on capital. The R^2 values are 79 per cent and 73 per cent respectively.

This would suggest that both profit per hectare and profit per cow are relevant proxies for ROC (excluding capital growth). Land is most often the asset that comprises the highest proportion of value out of total assets, while the cows, along with their replacements, are most often the asset that comprises the second highest proportion of value out of total assets. All ratios referencing cow numbers relate to the total number of cows in the herd, including both milking and dry cows.

Figure 3 confirms that operating profit margin could explain 75 per cent of the variation in ROC. This ratio outlines the percentage of total revenue retained as profit (before financing costs are deducted), and if converted into a decimal will describe the proportion of each 'dollar' of revenue that is retained as profit i.e. 20 per cent operating profit margin equates to 20 cents in each dollar of revenue retained as profit.

Figure 1. Profit per hectare impact on ROC

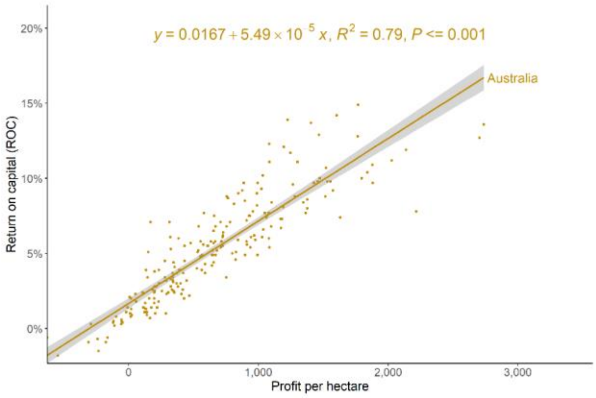
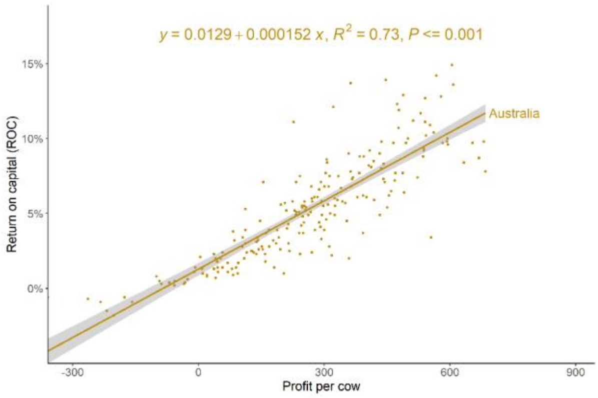


Figure 2. Profit per cow impact on ROC



As operating profit margin represents a 'marginal' return and does not reference an asset, its primary use would be to quantify financial risk. This can be highlighted by confirming that it would not normally be possible to confidently predict which of two farms, one with a 20 per cent profit margin and the other with a 30 per cent profit margin, has the higher level of profit as it is dependent on the amount of total revenue each farm produces per unit of capital invested. However, the farm with the higher profit margin (the 30 per cent profit margin that is keeping 30 cents per $1 earnt) will be able to cope with a larger movement in milk price or feed price or weather variability than the other farm, hence carrying a lower level of financial risk.

Figure 4 confirms that total operating expenses per litre (or per 'solids' = fat + protein) could explain 51 per cent of the variation in ROC. This ratio can be utilised to assess the level of cost control across all areas of the business. It provides a similar, though not an identical, assessment of business performance to cost of production (see Figure 5).

Figure 3. Operating profit margin impact on ROC

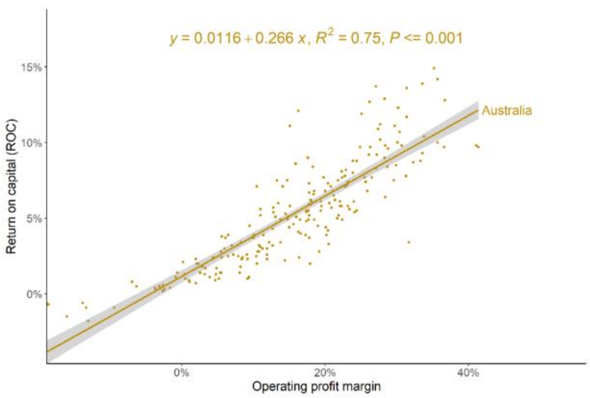


Figure 4. Total expenses per litre impact on ROC

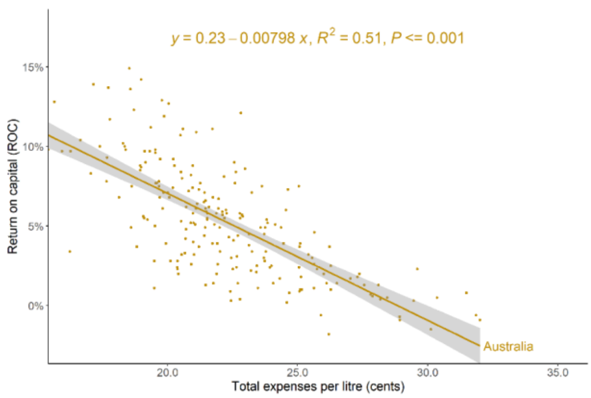


Figure 5 confirms that 'accounting' cost of production per litre (or per solids) could explain 44 per cent of the variation in ROC. No opportunity cost of capital is included. This methodology allows cost of production per litre to be directly compared to milk price, with the difference being the profit margin prior to debt servicing. This ratio would be considered a more complete measure than total operating expenses per litre as it includes revenue from livestock and other non-milk dairy sales which offset the expenses for this non-milk sales revenue, resulting in a more correct cost of production for milk sales. For farmers operating in export-focused dairy industries, maintaining a low cost of production that is competitive with other export-focused countries, is important for medium-term profitability. This has also become significantly more relevant for farmers operating in domestic-focused dairy industries if they are exposed to imports of dairy products. So dairy farmers in South Africa, for instance, have found that their milk price may lag trends in international prices, and not have the extreme highs and lows, but their milk price does now have a comparatively low premium to internationally-traded prices (Beca, 2020). This narrowing of the differences between international milk prices, regardless of hemisphere or region, appears to have been accelerated over the period from 2007-2013 by the large increase in imports of milk products by China (Gooch et al. 2017), and the large increase in exports of milk products by United States (Cessna et al. 2016).

Figure 6 confirms that pasture harvest in tonnes of dry matter of pasture per hectare could explain 41 per cent of the variation in ROC. This result is similar to what has been reported previously by Dillon et al. (2005). This ratio has the highest correlation to ROC, and by a wide margin, of any ratio outside of partial profit and total cost ratios.

Figure 5. Cost of production per litre impact on ROC

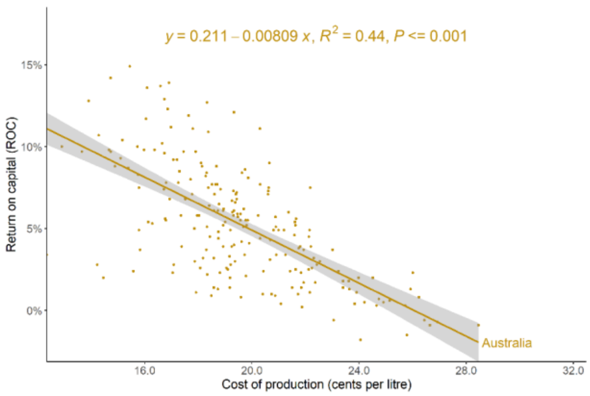


Figure 6. Pasture harvest (tonnes of dry matter per hectare per year) impact on ROC

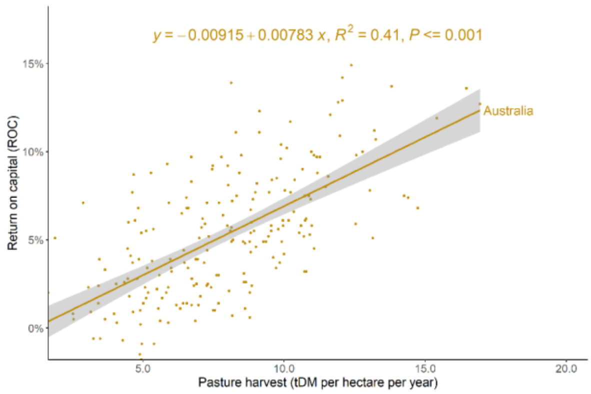


Figure 7 confirms that milk production per hectare could explain 20 per cent of the variation in ROC. As Figure 8 (milk production per cow) and Figure 9 (stocking rate) confirm, the correlation of milk production per hectare with ROC is primarily, if not entirely, due to stocking rate correlating with ROC. Milk production per cow does not positively correlate with ROC in this dataset, whereas stocking rate could explain 25 per cent of the variation in ROC (R^2 = 0.25).

Figure 7. Milk production per hectare impact on ROC

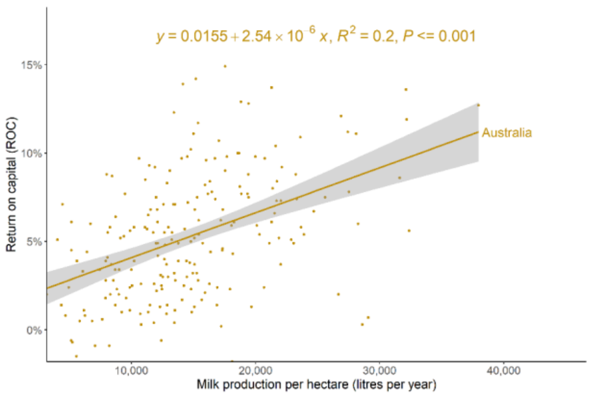
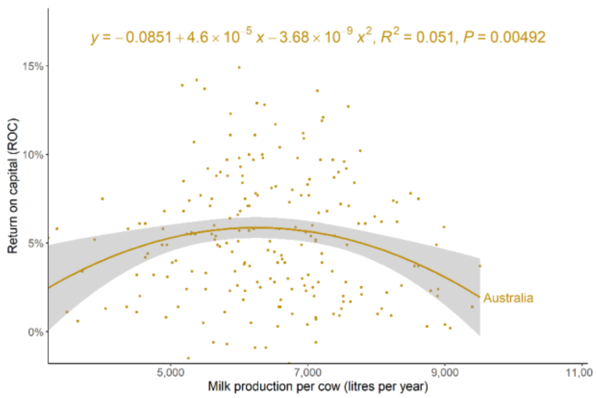


Figure 8. Milk production per cow impact on ROC



Furthermore, as Figure 10 (milk production per cow vs milk production per hectare) and Figure 11 (stocking rate vs milk production per hectare) confirm, milk production per cow explains just 13 per cent of the variation in milk production per hectare (R^2 = 0.13), whereas stocking rate could explain 78 per cent of the variation in milk production per hectare (R^2 = 0.78).

Figure 8 confirms that milk production per cow could explain 5 per cent of the variation in ROC, although there is neither a positive nor negative correlation with ROC. The relationship does imply that at very low or very high levels of milk production per cow there is a negative impact on profit. However, for a wide range of levels of milk production per cow there is no impact on profit.

Figure 9 confirms that stocking rate could explain 25 per cent of the variation in ROC. This positive correlation is primarily due to the relationship between increasing stocking rate and increasing pasture harvest, and between increasing pasture harvest and increasing ROC. Figure 10 confirms that milk production per cow could explain just 13 per cent of the variation in milk production per hectare. This does mean that milk production per cow has a comparatively low impact on milk production per hectare, whereas stocking rate has a high impact on milk production per hectare (see Figure 11).

Figure 9. Stocking rate impact on ROC

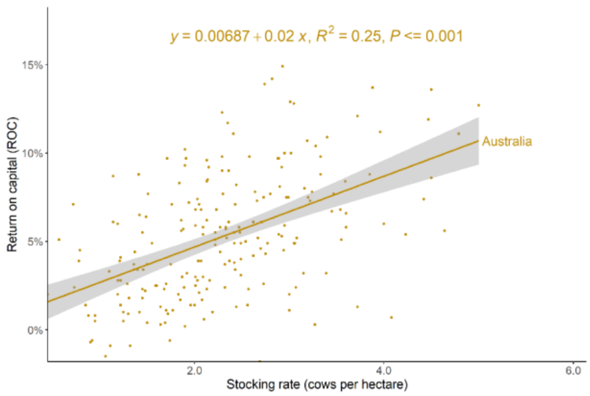


Figure 10. Milk production per cow impact on milk production per hectare

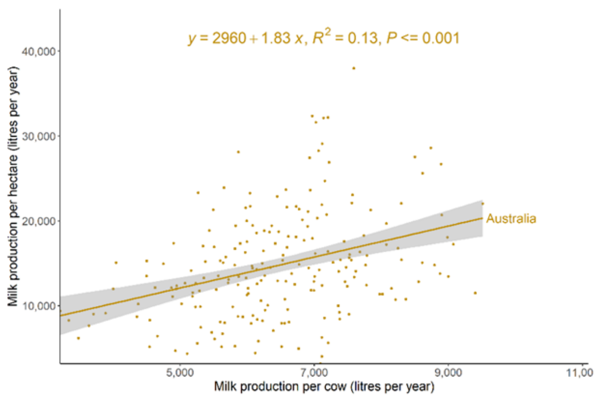


Figure 11 confirms that stocking rate (cows per hectare) could explain 78 per cent of the variation in milk production per hectare. This does mean that stocking rate has a high or comparatively dominant impact on milk production per hectare.

Figure 11. Stocking rate impact on milk production per hectare

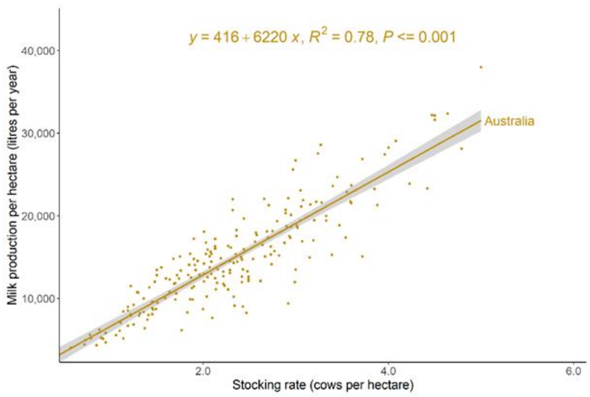


Figure 12. Total pasture cost per tonne dry matter impact on ROC

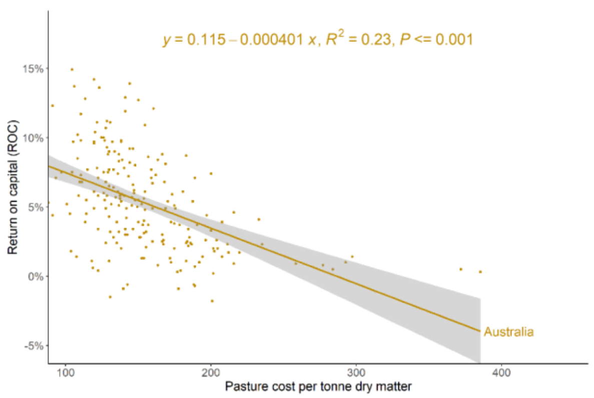


Figure 12 confirms that pasture cost per tonne dry matter could explain 23 per cent of the variation in ROC. This negative correlation is primarily due to the relationship between increasing pasture harvest and decreasing pasture cost per tonne dry matter, and between increasing pasture harvest and increasing profit.

Figure 13 confirms that total feed cost per litre (or per solids) could explain 21 per cent of the variation in ROC. Given this ratio includes all supplement and pasture cost, it represents the largest percentage of total expenses. As has been reported previously by Beca (2020), total feed costs usually comprise around 40-60 per cent of total costs for pasture-based farms and 60-70 per cent of costs for confinement (feedlot) farms. As a result, it has the largest impact on cost of production.

Figure 14 confirms that supplement cost per litre (or per solids) could explain 20 per cent of the variation in ROC. Supplement expenses include all concentrate costs and forage costs (excluding pasture costs related to the dairy area), as well as off-dairy farm grazing and support area costs.

Figure 13. Total feed cost per litre impact on ROC

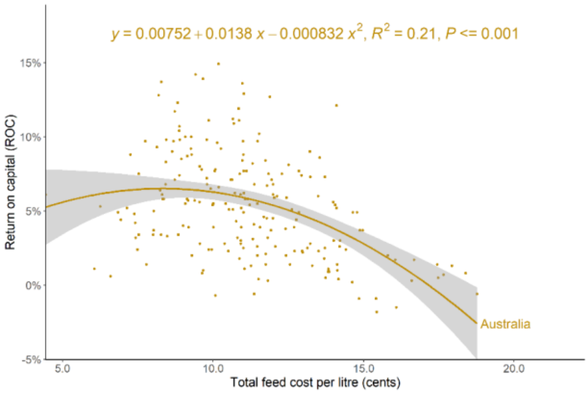


Figure 14. Supplement cost per litre impact on ROC

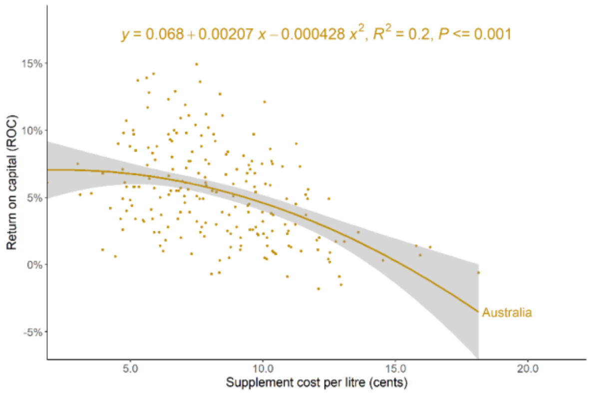


Figure 15 confirms that 'core per cow cost' (see Table 7) could explain 20 per cent of the variation in ROC. This ratio was developed by Red Sky so that a group of costs related to the cows that do not include supplements or people, both of which require their own targeted ratios, could be monitored. This ratio includes a mix of variable and fixed costs, although the fixed cost categories have a similar level of variability to the variable cost categories when divided by cow numbers, with all cost categories varying at least 50 per cent around the mean within this dataset. One of the most challenging aspects of analysing a dairy business and identifying strengths and weaknesses, including opportunities to improve business performance, is that there are so many intertwined production and management relationships that many ratios can be confounded by other ratios that are considered to be equally, or more, important. This ratio is the most relevant for determining the performance of a dairy business in controlling cow costs.

Figure 16 confirms that milk price could explain 20 per cent of the variation in ROC.

Figure 17 confirms that labour cost per cow could explain 18 per cent of the variation in ROC. Labour expenses, including management and any imputed labour costs, are usually the next largest area of cost in a dairy business after supplement/feed costs. This labour ratio is the labour ratio with the strongest correlation with profit. Figure 18 confirms that 'core per hectare cost per tonne dry matter of pasture harvest' could explain 17 per cent of the variation in ROC. This ratio was developed by Red Sky so that a group of costs related to the land area (effective hectares) that do not include supplements or people, both of which require their own targeted ratios, could be monitored.

Figure 15. 'Core per cow cost' impact on ROC

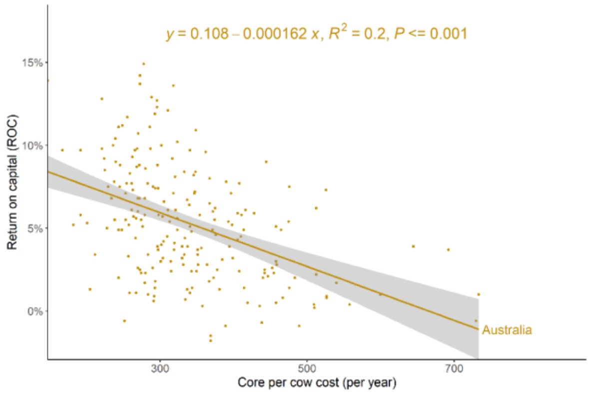
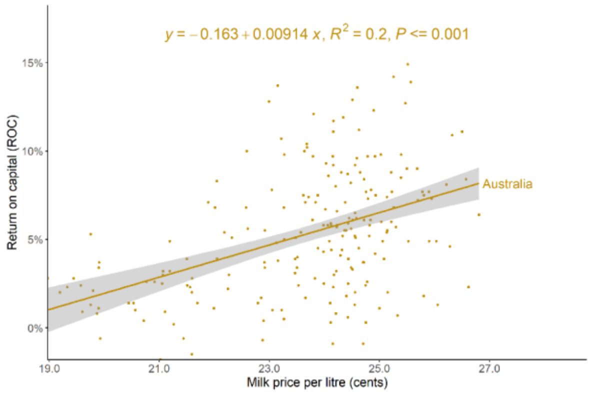


Figure 16. Milk price impact on ROC



This ratio includes a mix of variable and fixed costs, although the fixed cost categories have a similar level of variability to the variable cost categories when divided by effective hectares, with all cost categories varying at least 50 per cent around the mean within this dataset. This ratio is the most relevant for determining the performance of a dairy business in controlling farm area or 'hectare' costs, which to be relevant and have significance, needs to reference the amount of pasture harvested per hectare.

Figure 17. Labour cost per cow impact on ROC

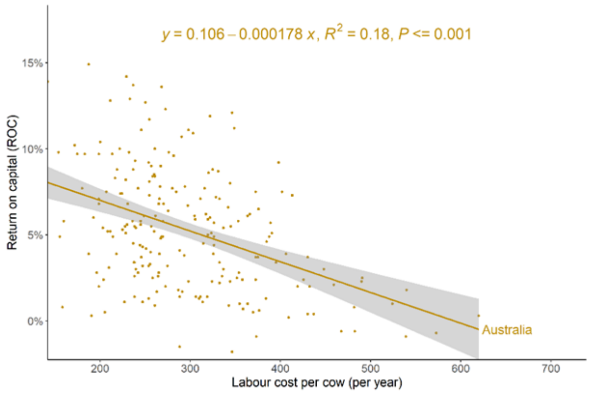


Figure 18. 'Core per hectare cost per tonne dry matter of pasture harvest' impact on ROC

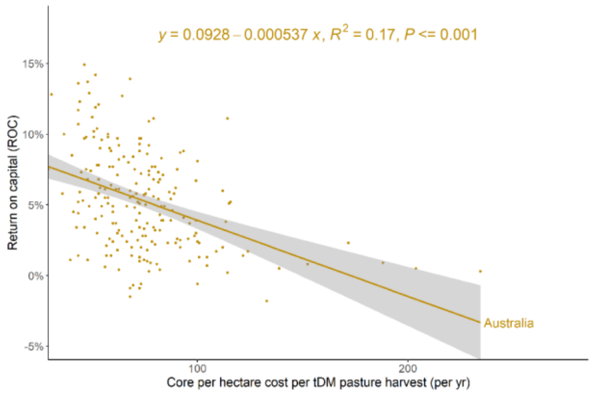


Figure 19 confirms that labour cost per litre (or per solids) could explain 17 per cent of the variation in ROC. Labour cost per litre must be based on energy corrected milk (or solids) as when non-energy corrected litres were utilised, the R^2 dropped to 0.12. Labour expenses, including management and any imputed labour costs, are usually the next largest area of cost in a dairy business after supplement/feed costs. This labour ratio is the labour ratio with the second strongest correlation with profit. The R^2 is only slightly lower than for labour cost per cow, though labour cost per cow is the more robust ratio due to it having a higher likelihood of causation. The majority of labour costs on a dairy farm are related to cow activities i.e. milking, feeding and caring for the cows. In addition, labour ratios utilising litres (or solids) can be confounded by significant variations in litres produced per cow via the feeding of concentrates, which may have a low impact on the use of labour.

Figure 19. Labour cost per litre impact on ROC

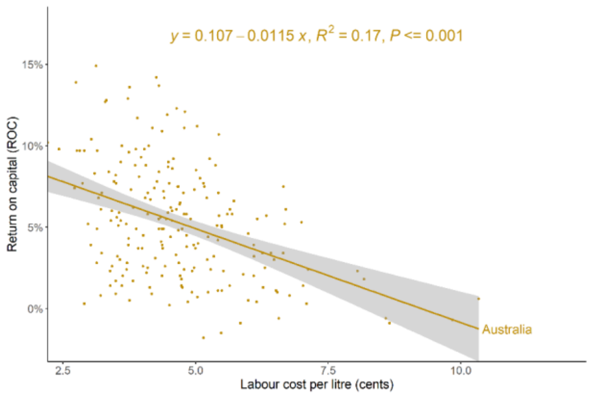


Figure 20. Labour efficiency (cows per full-time staff equivalent) impact on ROC

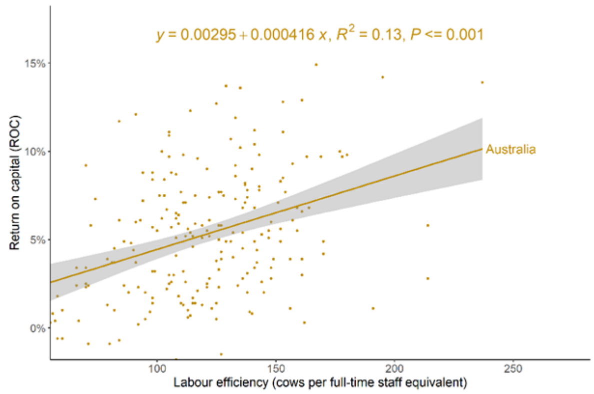


Figure 20 confirms that labour efficiency when represented by cows per full-time staff equivalent could explain 13 per cent of the variation in ROC. This ratio is based on a standardised number of full-time hours worked per week and is the labour ratio with the third strongest correlation with ROC. As labour costs are usually the next largest area of cost in a dairy business after supplement/feed costs, it can be beneficial to monitor a second labour ratio in addition to labour cost per cow. A second ratio will have more utility if it has a substantially different construct so that it might convey additional knowledge about business performance in the labour area. Labour efficiency based on cows per full-time staff equivalent provides this opportunity.

Figure 21 confirms that labour efficiency when represented by litres (or solids) per full-time staff equivalent could explain 11 per cent of the variation in ROC. Litres per full-time staff equivalent must be based on energy corrected milk (or solids) as when non-energy corrected litres were utilised, the R^2 dropped to 0.07. This ratio is the labour ratio with the fourth strongest correlation with profit. However, the R^2 is lower than for cows per full-time staff equivalent, which is the more robust ratio due to its higher likelihood of causation.

Figure 22 confirms that pasture as a per cent of the cow's diet could explain 8 per cent of the variation in ROC.

Figure 21. Labour efficiency (litres per full-time staff equivalent) impact on ROC

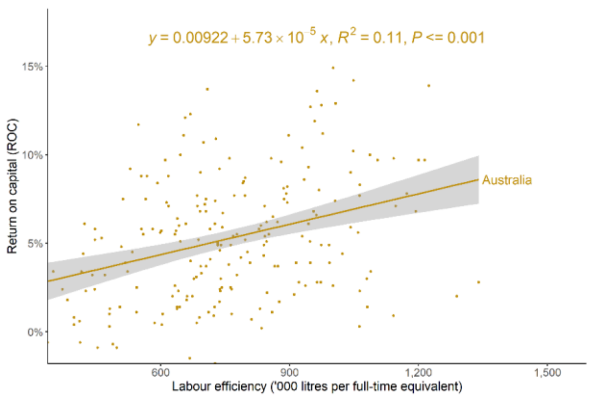
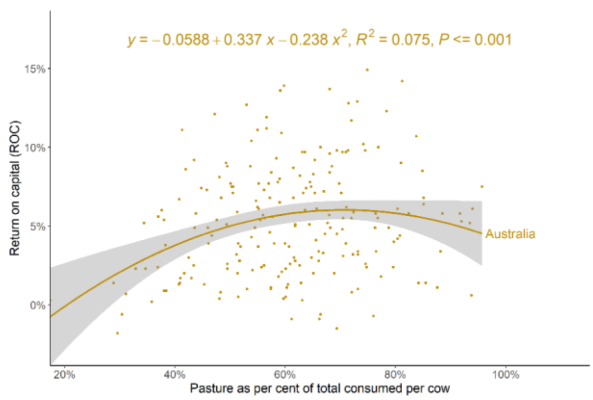


Figure 22. Pasture as per cent of cow's diet impact on ROC



The relationship can be described as one where as pasture as a per cent of the cow's diet decreases, there is initially little variation or impact on profit, although a negative impact becomes increasingly evident as the per cent of pasture decreases. This ratio defines the production system being implemented on a dairy farm, and the impact of changing production systems has been the subject of much discussion over the years. This relationship and the impact of decreasing the per cent of pasture in the diet is analysed in detail in the section devoted to this, in the latter part of this paper.

Figure 23. Pasture consumed per cow impact on ROC

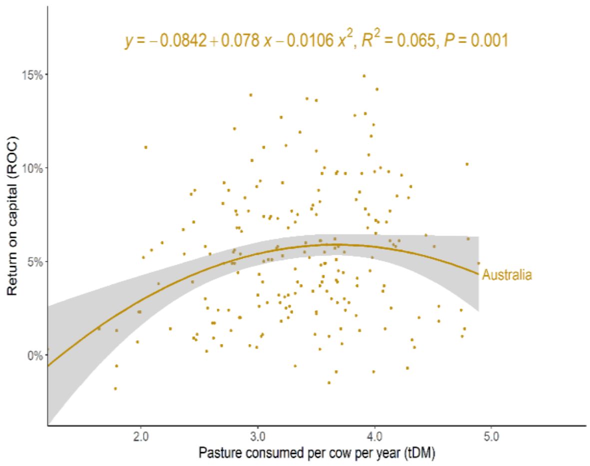


Figure 23 confirms that pasture consumed per cow could explain 7 per cent of the variation in ROC. This ratio is closely related to pasture as a per cent of the cow's diet, which defines the production system being implemented on a dairy farm. Similarly, the relationship can be described as one where as pasture consumed per cow decreases, there is initially little variation or impact on profit, although a negative impact becomes increasingly evident as the amount of pasture decreases.

Does Size of Dairy Farm have a Significant Impact on Potential Profit?

In most circumstances farm size is not a relevant factor in determining profit for dairy farmers, especially for pasture-based farmers. This is due to the great majority of expenses (greater than 90 per cent) being directly related to the number of cows or the number of hectares being farmed (or both). As a result, there are relatively minor economies of scale to be secured as dairy farms increase in size. This is borne out by Figures 24 and 25.

Figure 24. Farm size (hectare) impact on ROC

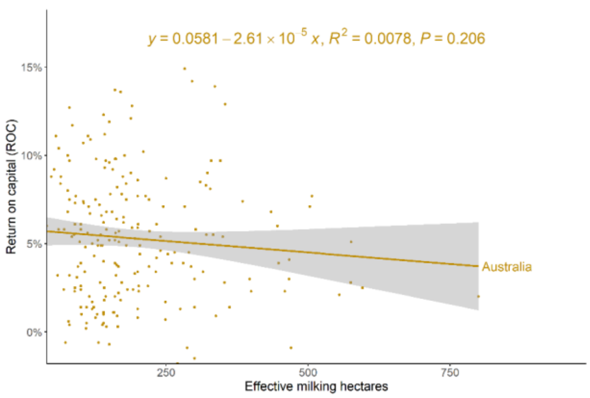
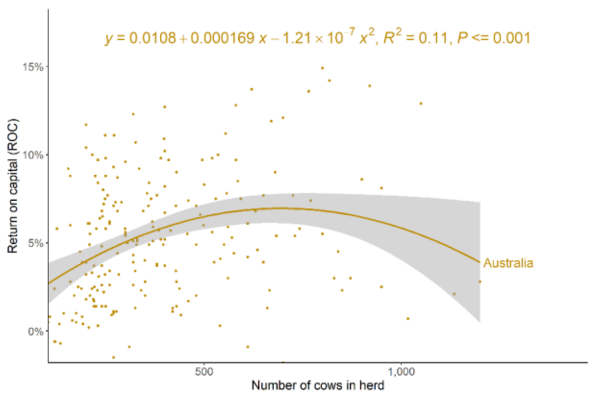


Figure 25. Farm size (cow numbers) impact on ROC



Farm size based on hectares could not explain any of the variation in ROC i.e. the relationship is not significant with $P > 0.05$. Farm size based on number of cows in herd could explain 11 per cent of the variation in ROC, with both very small and very large farms having lower profit than farms within a wide moderate farm-sized band. Very small farms (possibly less than 80-120 cows) are likely to have decreasing levels of profit as the capital (asset) cost per litre is likely to increase significantly, and the management cost per litre is also likely to increase significantly. Very large farms (possibly over 1,000 cows) are likely to have challenges from both management (people) efficiency due to the scale of the business and cow efficiency due to the impact on cows of larger herds and longer walking distances.

Figure 26 confirms that grams concentrate consumed per litre (or per solids) could explain 10 per cent of the variation in ROC. This ratio is closely related to pasture as a per cent of the cow's diet, which defines the production system being implemented on a dairy farm. Similarly, the relationship can be described as one where as grams concentrate per litre increases, there is initially little variation or impact on profit, although a negative impact becomes increasingly evident as the amount of concentrate increases. Grams concentrate consumed per litre has been calculated as the annual average. Due to the seasonal nature of pasture production and the much lower cost of pasture versus supplements, this ratio would need to be broken down into monthly, or more likely weekly, periods for it to be utilised with any reliability, which would suggest that this ratio has little utility in a dairy business.

Figure 27 confirms that grams supplement consumed per litre (or per solids) could explain 8 per cent of the variation in ROC. Supplement includes concentrates and forages but excludes pasture. As with concentrate consumed per litre, this ratio is closely related to pasture as a per cent of the cow's diet, which defines the production system being implemented on a dairy farm. The relationship can be described as having the same characteristics as grams concentrate consumed per litre, and similarly this ratio has little utility in a dairy business.

Figure 26. Grams concentrate per litre impact on ROC

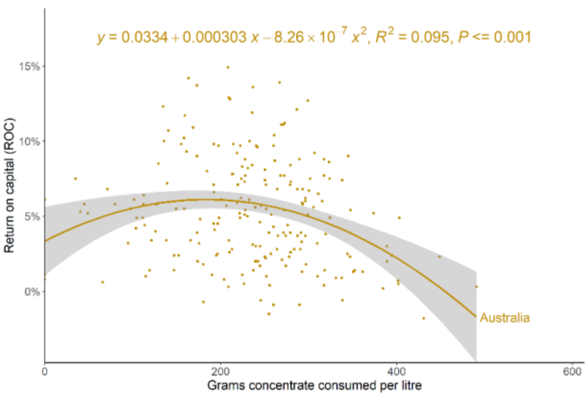


Figure 27. Grams supplement per litre impact on ROC

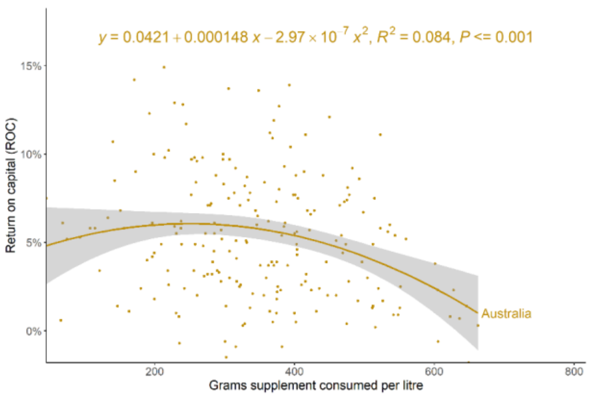


Figure 28 confirms that income over feed costs per cow could explain 25 per cent of the variation in ROC. Feed costs include concentrates and forages but exclude pasture, and this relationship has been analysed based on a full year of data. Although this ratio could potentially be utilised to assess performance in a dairy business, the seasonal nature of pasture production results in the amount of available pasture varying monthly and often weekly. Given pasture has a significantly lower cost per tonne dry matter than concentrates or forages, this changes the calculated result for annual income over feed costs on a monthly and/or weekly basis. As a result, the annual relationship would need to be developed into monthly and sometimes weekly targets, which would potentially be impractical.

Figure 29 confirms that income over feed costs per litre (or per solids) could explain 28 per cent of the variation in ROC. This ratio has the same characteristics and potential weaknesses of income over feed costs per cow.

Figure 28. Income over feed costs per cow impact on ROC

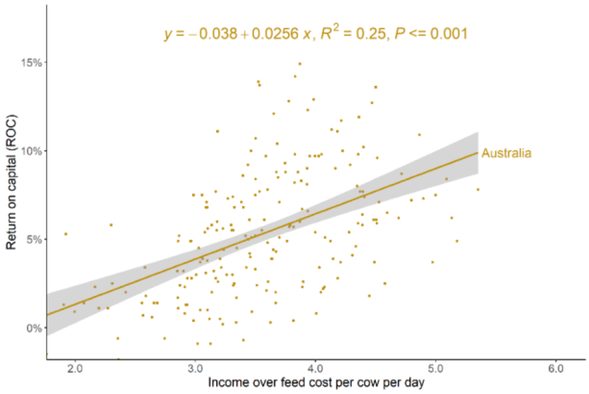


Figure 29. Income over feed costs per litre impact on ROC

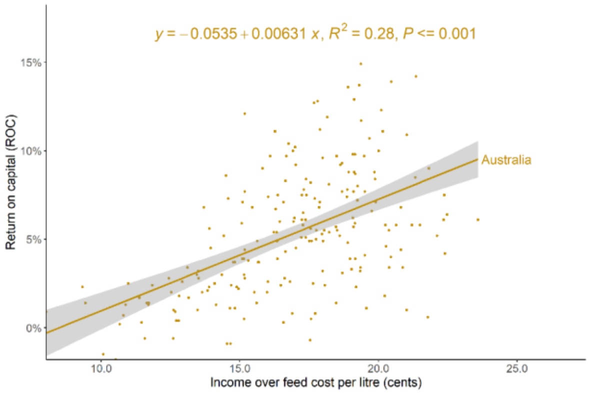


Table 1 is a summary of the primary ratios that have been outlined above which can provide a comprehensive and comparatively complete description of how a dairy farm business is performing. The design of these ratios is such that in most circumstances they describe different components of the business e.g. pasture vs supplements vs ratio between these vs labour vs cow costs (excluding pasture, supplement and hectares) vs hectare costs (excluding supplement and cows). This is important due to the high proportion of variable costs in pasture-based dairy farming businesses, including multiple production factors (milk, livestock and pasture/crops) impacting on a range of significant cost factors. This then means there is a risk one ratio can confound the calculation of a second ratio and/or that the two ratios can effectively be describing similar areas of business performance. For example, supplement cost per litre can dominate the calculation of total feed cost per litre, 'masking' or confounding the impact of pasture cost per litre, with total feed cost per litre then dominating the calculation of total expenses per litre. This then 'masks' or confounds the impact of labour cost per litre and all other non-feed costs per litre on total expenses per litre.

Over 150 different ratios have been calculated and analysed for their relationship to dairy farm profit, with this paper describing the ratios that were found to be statistically relevant to dairy farm performance.

Why Does Profit Improve with an Increase in Pasture Harvest?

As Table 1 outlines, the impact of increasing pasture harvest on increasing profit makes it the physical ratio with the highest coefficient of determination (R^2) in dairy farming. This has been reported previously by Dillon et al. (2005). Figure 6 confirmed that for this dataset, variations in pasture harvest could explain 41 per cent of the variation in ROC. Figures 32-39 outline the primary factors that are being impacted by, or are impacting on, pasture harvest and supporting the associated changes in profitability that can be explained from increasing pasture harvest.

Figure 30 confirms that pasture harvest could explain 59 per cent of the variation in profit per hectare. This confirms that pasture harvest has a larger impact on profit per hectare (R^2 = 0.59) than on profit determined by return on capital (R^2 = 0.41). This outcome is associated with the higher correlation of stocking rate to profit per hectare as compared to ROC, where profit per hectare does not account for the likely higher capital cost associated with land that has the capacity for higher levels of pasture harvest. Figure 31 confirms that pasture harvest could explain 27 per cent of the variation in profit per cow. This confirms that pasture harvest has a smaller impact on profit per cow than on profit determined by ROC.

Table 1. Hierarchy of dairy farm ratios based on their impact on profit

Primary ratio	R^2	P	Secondary ratio or proxy	R^2	P
Return on total capital (ROC) [defines profit]	**Comparator for other ratios**		Profit per hectare	0.79	<= 0.001
			Profit per cow	0.73	<= 0.001
Operating profit margin	0.75	<= 0.001	Profit per litre	0.76	<= 0.001
Cost of production per litre	0.44	<= 0.001	Total expenses per litre	0.51	<= 0.001
Pasture harvest	0.41	<= 0.001			
Pasture cost per tonne dry matter	0.23	<= 0.001			
Milk price	0.20	<= 0.001			
Milk production per hectare	0.20	<= 0.001	Stocking rate	0.25	<= 0.001
Supplement cost per litre	0.20	<= 0.001	Total feed cost per litre	0.21	<= 0.001
Core per cow cost	0.20	<= 0.001			
Labour cost per cow	0.18	<= 0.001	Cows per full-time staff equivalent	0.13	<= 0.001
			Labour cost per litre	0.17	<= 0.001
			Litres per full-time staff equivalent	0.11	<= 0.001
Core per hectare cost per tonne dry matter of pasture harvest	0.17	<= 0.001			
Pasture as per cent of diet	0.08	<= 0.001	Pasture consumed per cow	0.07	0.001
Ratios of low utility or relatively impractical to apply					
Milk production per cow	0.05	0.0049	Little to no positive or negative correlation with ROC		
Income over feed costs per litre	0.28	<= 0.001	Would need to be calculated on monthly or weekly basis		
Income over feed costs per cow	0.25	<= 0.001	Would need to be calculated on monthly or weekly basis		
Grams concentrate per litre	0.10	<= 0.001	Would need to be calculated on monthly or weekly basis		
Grams supplement per litre	0.08	<= 0.001	Would need to be calculated on monthly or weekly basis		

Figure 30. Pasture harvest impact on profit per hectare

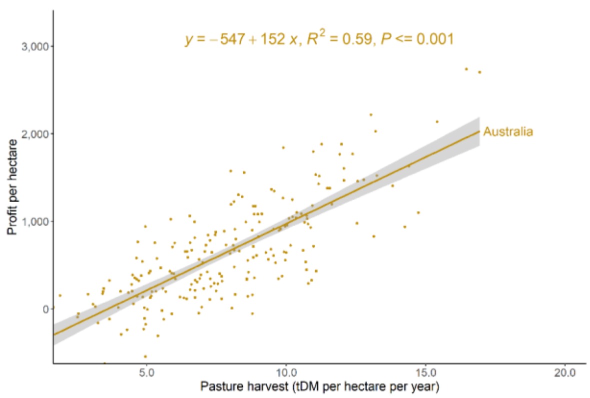


Figure 31. Pasture harvest impact on profit per cow

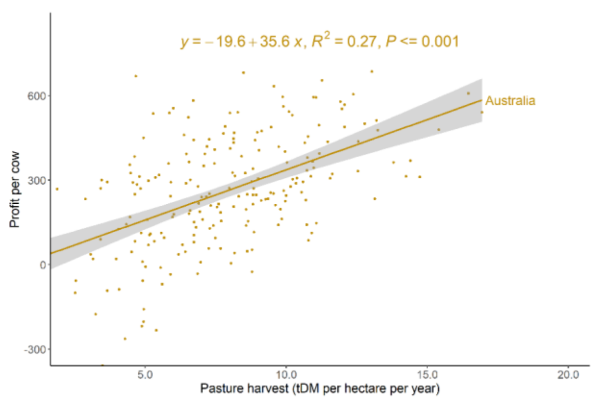


Figure 32 confirms that pasture harvest could explain 14 per cent of the variation in cost of production per litre (or per solids). This negative correlation confirms that increasing pasture harvest does contribute to a decrease in cost of production. Figure 33 confirms that stocking rate could explain 63 per cent of the variation in pasture harvest. This positive correlation confirms that increasing stocking rate has a primary association with increasing pasture harvest.

Figure 32. Pasture harvest impact on cost of production per litre

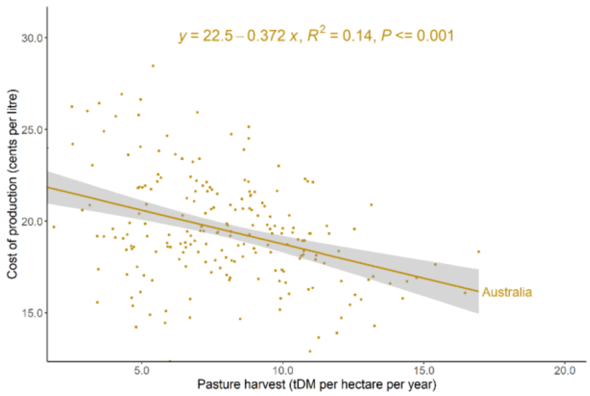


Figure 33. Stocking rate impact on pasture harvest

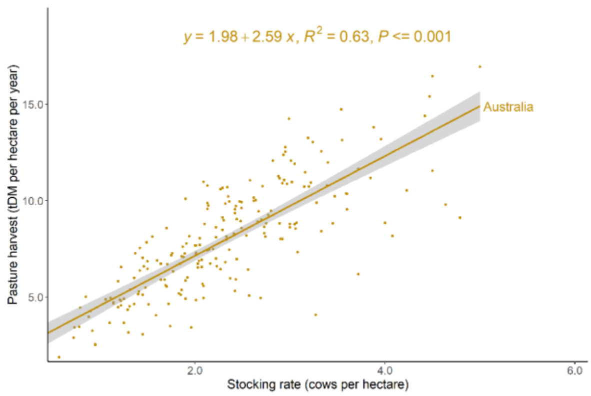


Figure 34 confirms that pasture harvest could explain 31 per cent of the variation in core per hectare cost per tonne dry matter of pasture harvest. This negative correlation suggests that increasing pasture harvest does contribute to a decrease in core per hectare cost per tonne dry matter of pasture harvest. This correlation is primarily due to the relationship between increasing stocking rate and both increasing pasture harvest and increasing milk production per hectare, which decreases the 'land' or area cost per hectare.

Figure 35 confirms that pasture harvest could explain 23 per cent of the variation in total pasture cost per tonne dry matter of pasture harvest. This negative correlation suggests that increasing pasture harvest does contribute to a decrease in pasture cost per tonne dry matter.

Figure 34. Pasture harvest impact on 'core per hectare cost per tonne dry matter of pasture harvest'

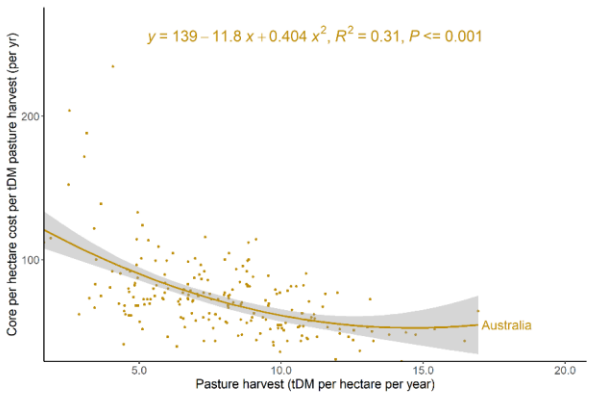


Figure 35. Pasture harvest impact on total pasture cost per tonne dry matter

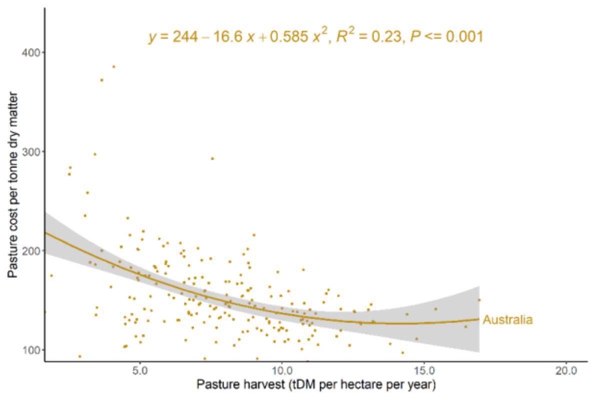


Figure 36 confirms that pasture harvest could explain 12 per cent of the variation in supplement cost per litre. This negative correlation suggests that increasing pasture harvest does contribute to a decrease in supplement cost per litre. Figure 37 confirms that pasture harvest could explain 9 per cent of the variation in labour cost per cow. This negative correlation suggests that increasing pasture harvest does contribute to a decrease in labour cost per cow.

Figure 36. Pasture harvest impact on supplement cost per litre

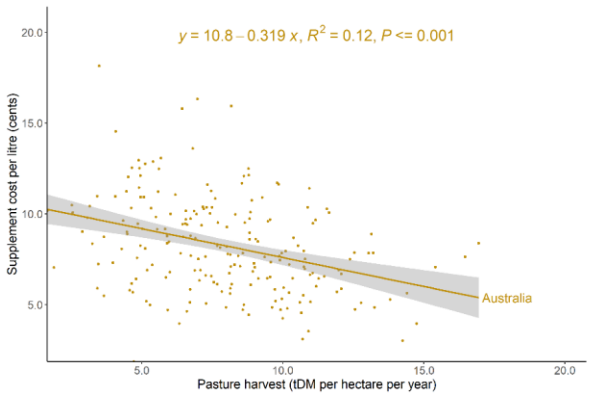


Figure 37. Pasture harvest impact labour cost per cow

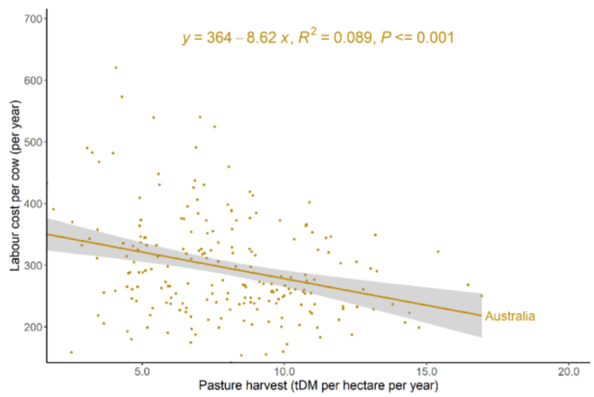


Figure 38. Pasture harvest impact on 'core per cow cost'

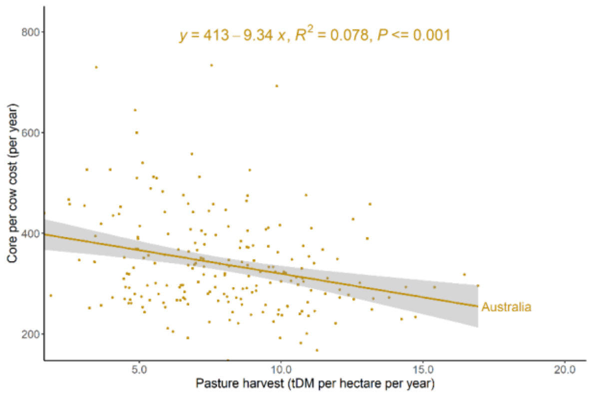


Figure 39. Pasture consumed per cow impact on pasture harvest

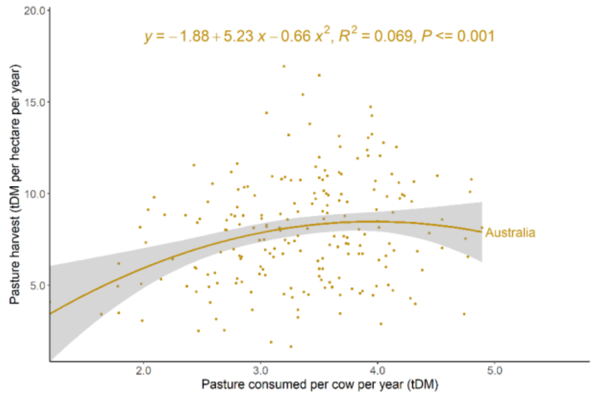


Figure 38 confirms that pasture harvest could explain 8 per cent of the variation in core per cow cost. This negative correlation suggests that increasing pasture harvest does contribute to a decrease in core per cow cost. Figure 39 confirms that pasture consumed per cow could explain 7 per cent of the variation in pasture harvest. This positive correlation suggests that increasing pasture consumed per cow does contribute to an increase in pasture harvest.

In summary, the primary impacts of increasing pasture harvest on the performance of a pasture-based dairy business are from lower pasture cost per tonne dry matter, lower core per hectare cost per tonne dry matter of pasture, lower supplement cost per litre, lower labour cost per cow, and lower core cost per cow. Changes in these ratios combine to lower the cost of production. Increasing stocking rate plays a significant role in increasing pasture harvest, which underpins the requirement to have sufficient cows grazing per hectare to optimise pasture harvest. These factors are outlined in Table 2.

Why does Profit not Improve, or not Substantially Improve, with Increases in Milk Production per Cow?

Figure 8 confirmed that variations in milk production per cow could explain 5 per cent of the variation in ROC, although there is neither a positive nor negative correlation with ROC. The relationship does imply that at very low or very high levels of milk production per cow that there is a negative impact on ROC. However, for a wide range of levels of milk production per cow there is no impact on ROC. Figures 42-48 outline the primary factors that are being impacted by, or are impacting on, milk production per cow and supporting the associated impact on profit that can be explained from increasing milk production per cow.

Table 2. Factors being impacted by pasture harvest

Primary factors being impacted by pasture harvest	As increases	R^2	P
Cost of production per litre	Decreases	0.14	<= 0.001
Core per hectare cost per tonne dry matter of pasture harvest	Decreases	0.31	<= 0.001
Pasture cost per tonne dry matter	Decreases	0.23	<= 0.001
Supplement cost per litre	Decreases	0.12	<= 0.001
Labour cost per cow	Decreases	0.09	<= 0.001
Core per cow cost	Decreases	0.08	<= 0.001
Other factors			
Stocking rate impact on pasture harvest	Increases	0.63	<= 0.001
Pasture consumed per cow impact on pasture harvest	Increases	0.07	<= 0.001

Figure 40. Milk production per cow impact on profit per hectare

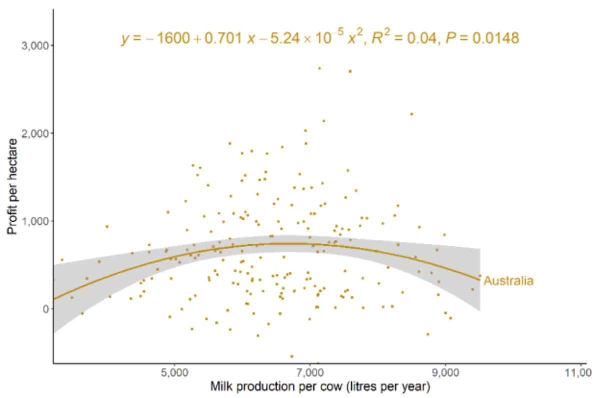


Figure 41. Milk production per cow impact on profit per cow

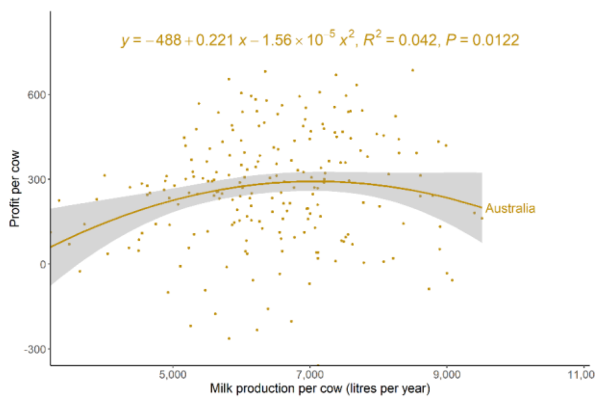


Figure 40 confirms that variations in milk production per cow could explain 4 per cent of the variation in profit per hectare, although there is neither a positive nor negative correlation with profit. The relationship is similar to the one with profit as determined by ROC. Figure 41 confirms that variations in milk production per cow could explain 4 per cent of the variation in profit per cow, although again there is neither a positive nor negative correlation with profit and the relationship is similar to the one with profit as determined by ROC.

Figure 42 confirms that variations in milk production per cow do *not* explain any of the variation in cost of production. The relationship presented in Figure 44 is *not* significant with P > 0.05. Figure 43 confirms that milk production per cow could explain 28 per cent of the variation in core per cow cost. This positive correlation suggests that increasing milk production per cow does contribute to an increase in core per cow cost.

Figure 44 confirms that milk production per cow could explain 26 per cent of the variation in supplement cost per litre. This positive correlation suggests that increasing milk production per cow does contribute to an increase in supplement cost per litre. Figure 45 confirms that milk production per cow could explain 22 per cent of the variation in total feed cost per litre. This positive correlation suggests that increasing milk production per cow does contribute to an increase in total feed cost per litre.

Figure 42. Milk production per cow impact on cost of production per litre

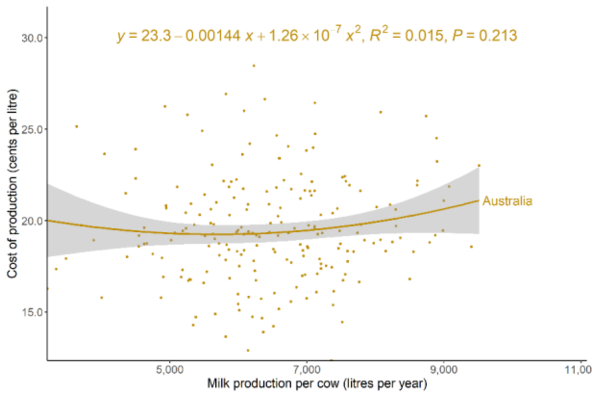


Figure 43. Milk production per cow impact on 'core per cow cost'

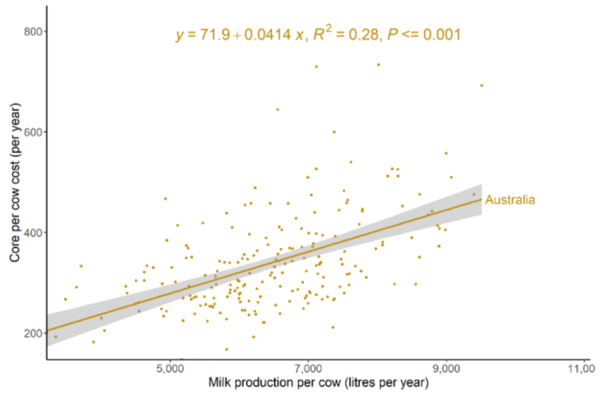


Figure 44. Milk production per cow impact on supplement cost per litre

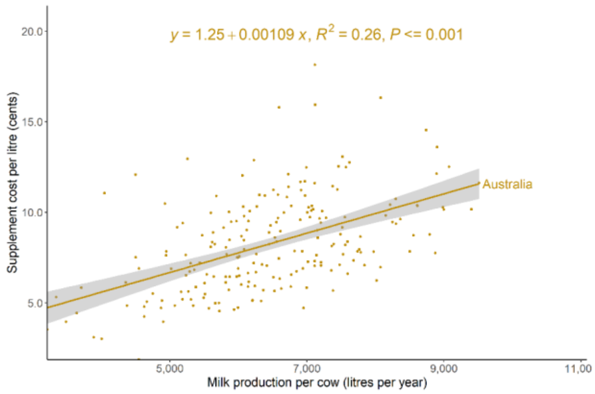


Figure 45. Milk production per cow impact on total feed cost per litre

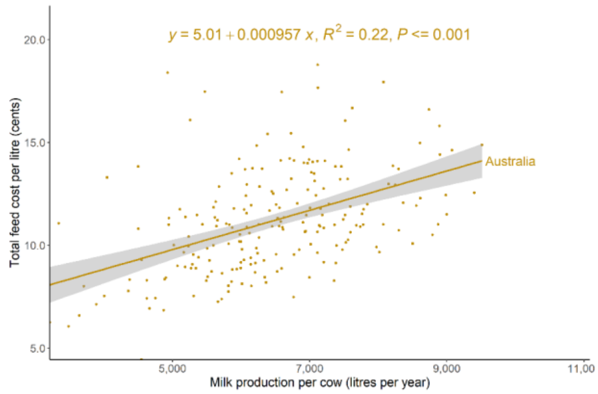


Figure 46 confirms that milk production per cow could explain 19 per cent of the variation in labour cost per cow. This positive correlation suggests that increasing milk production per cow does contribute to an increase in labour cost per cow. Figure 47 confirms that milk production per cow could explain 12 per cent of the variation in total pasture cost per tonne dry matter of pasture harvest. This positive correlation suggests that increasing milk production per cow does contribute to an increase in total pasture cost per tonne dry matter of pasture harvest.

Figure 46. Milk production per cow impact on labour cost per cow

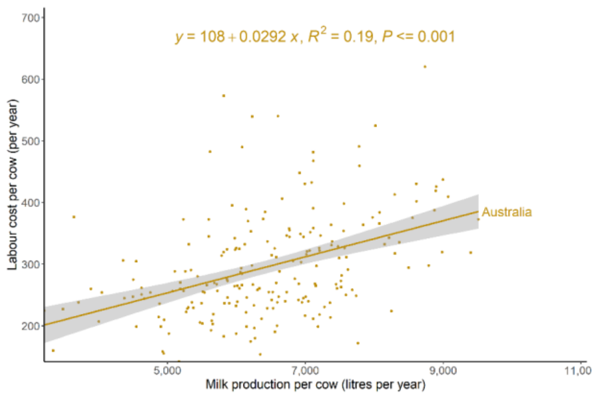


Figure 47. Milk production per cow impact on total pasture cost per tonne dry matter

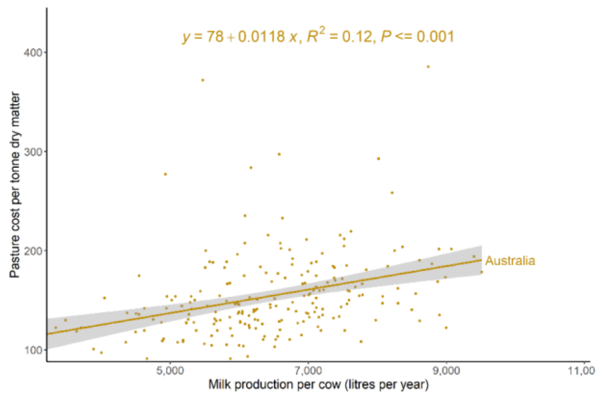


Figure 48 confirms that milk production per cow could explain 9 per cent of the variation in core per hectare cost per tonne dry matter of pasture harvest. This positive correlation suggests that increasing milk production per cow does contribute to an increase in core per hectare cost per tonne dry matter of pasture harvest.

Figure 48. Milk production per cow impact on 'core per hectare cost per tonne dry matter of pasture harvest'

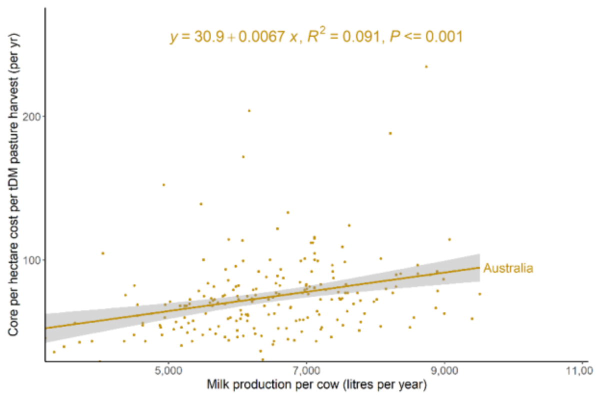


Table 3. Factors being impacted by milk production per cow

Primary factors being impacted by milk production per cow	As increases	R^2	P
Core per cow cost	Increases	0.28	<= 0.001
Supplement cost per litre	Increases	0.26	<= 0.001
Total feed cost per litre	Increases	0.22	<= 0.001
Labour cost per cow	Increases	0.19	<= 0.001
Pasture cost per tonne dry matter	Increases	0.12	<= 0.001
Core per hectare cost per tonne dry matter of pasture harvest	Increases	0.09	<= 0.001

In summary, the primary impacts of increasing milk production per cow on the performance of a pasture-based dairy business are from higher supplement and total feed cost per litre, higher core per cow cost, higher labour cost per cow, higher pasture cost per tonne dry matter, and higher core per hectare cost per tonne dry matter of pasture. The result is that increasing milk production per cow has *no* significant impact on ROC, profit per hectare or profit per cow other than at very low or very high levels of milk production per cow, where there is a negative impact on profit. These factors are outlined in Table 3.

What Does Change with the Production System as Percentage of Pasture in the Diet Decreases?

Dairy farm production systems can be defined by the percentage of pasture in the cow's total diet, with this percentage based on the proportion of energy supplied by pasture compared to supplements. Figure 22 confirmed that pasture as a per cent of the cow's diet could explain 8 per cent of the variation in profit. The relationship can be described as one where as pasture as a per cent of the cow's diet decreases, there is initially little variation or impact on profit, although a negative impact becomes increasingly evident as the per cent of pasture decreases. Figures 51-61 outline the primary factors that are being impacted by, or are impacting on, pasture as a per cent of the cow's diet and supporting the associated impact on profit that can be explained from decreasing pasture as a per cent of the diet.

Figure 49 confirms that variations in pasture as a per cent of the cow's diet could explain 7 per cent of the variation in profit per hectare. Figure 50 confirms that pasture as a per cent of the cow's diet could explain 12 per cent of the variation in profit per cow. These correlations to profit per hectare and per cow suggest that decreasing pasture as a per cent of the diet does increasingly contribute to a decrease in profit as the per cent decreases.

Figure 49. Pasture as per cent of diet impact on profit per hectare

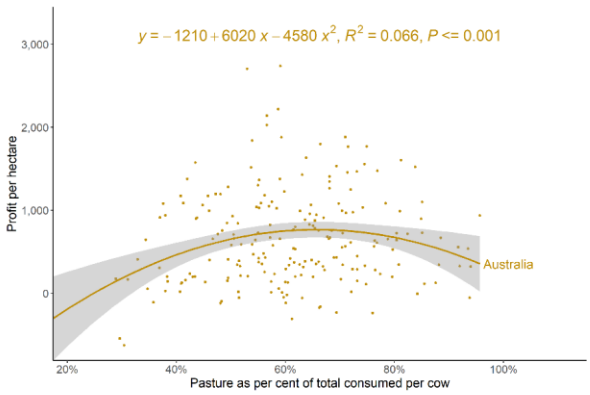


Figure 50. Pasture as per cent of diet impact on profit per cow

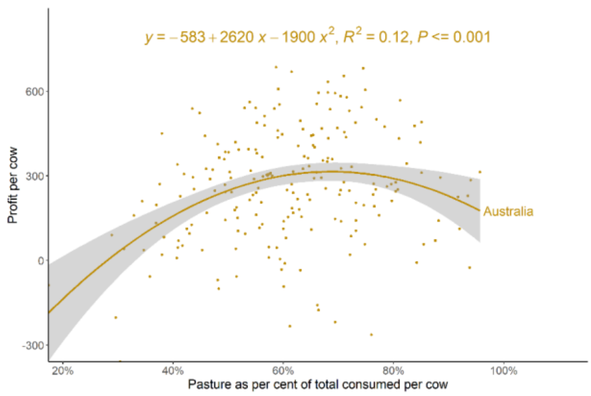


Figure 51. Pasture as per cent of diet impact on cost of production per litre

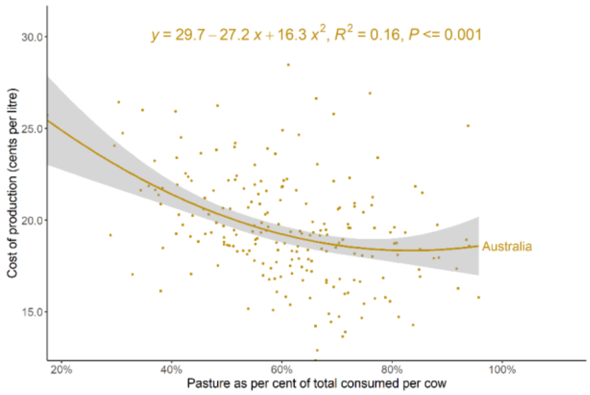


Figure 52. Pasture as per cent of diet impact on pasture consumed per cow

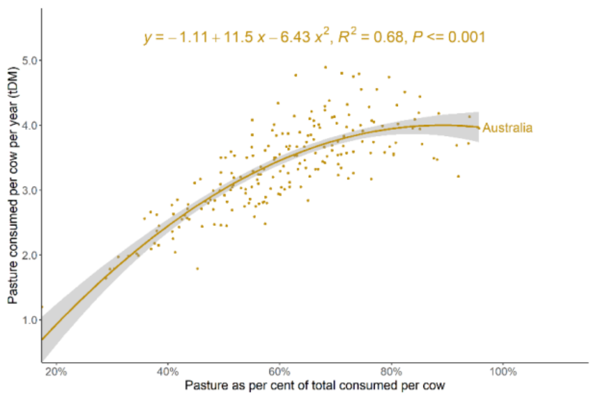


Figure 51 confirms that pasture as a per cent of the cow's diet could explain 16 per cent of the variation in cost of production. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in cost of production. Figure 52 confirms that pasture as a per cent of the cow's diet could explain 68 per cent of the variation in pasture consumed per cow. This positive correlation suggests that increasing pasture as a per cent of the diet is associated with an increase in the amount of pasture consumed per cow.

Figure 53 confirms that pasture as a per cent of the cow's diet could explain 58 per cent of the variation in supplement cost per litre. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in supplement cost per litre. Figure 54 confirms that pasture as a per cent of the cow's diet could explain 50 per cent of the variation in total feed cost per litre. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in total feed cost per litre.

Figure 53. Pasture as per cent of diet impact on supplement cost per litre

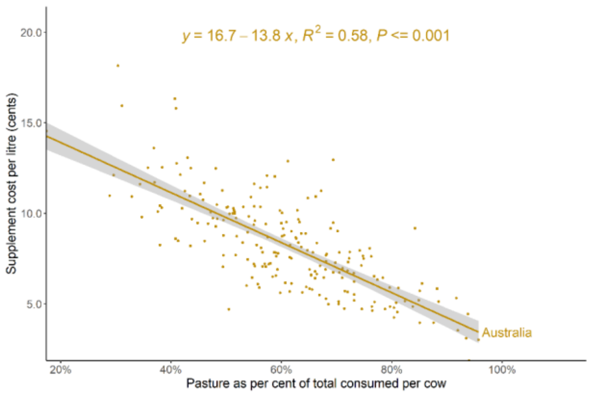


Figure 54. Pasture as per cent of diet impact on total feed cost per litre

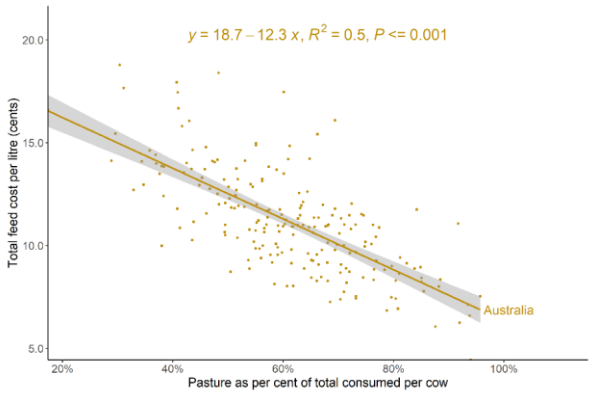


Figure 55 confirms that pasture as a per cent of the cow's diet could explain 49 per cent of the variation in core per hectare cost per tonne dry matter of pasture harvest. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in core per hectare cost per tonne dry matter of pasture harvest. Figure 56 confirms that pasture as a per cent of the cow's diet could explain 26 per cent of the variation in total pasture cost per tonne dry matter of pasture harvest. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in total pasture cost per tonne dry matter of pasture harvest.

Figure 55. Pasture as per cent of diet impact on 'core per hectare cost per tonne dry matter of pasture'

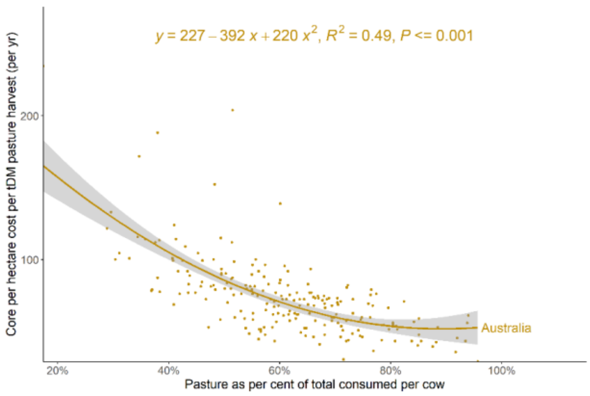


Figure 56. Pasture as per cent of diet impact on total pasture cost per tonne dry matter

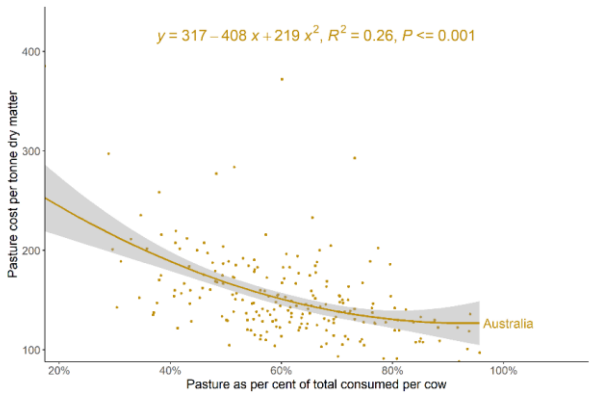


Figure 57 confirms that pasture as a per cent of the cow's diet could explain 10 per cent of the variation in pasture harvest. This positive correlation suggests that decreasing pasture as a per cent of the diet does contribute to a decrease in pasture harvest. Figure 58 confirms that pasture as a per cent of the cow's diet could explain 9 per cent of the variation in core per cow cost. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in core per cow cost.

Figure 59 confirms that pasture as a per cent of the cow's diet could explain 8 per cent of the variation in labour cost per cow. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in labour cost per cow. Figure 60 confirms that pasture as a per cent of the cow's diet could explain 32 per cent of the variation in milk production per cow. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in milk production per cow.

Figure 57. Pasture as per cent of diet impact on pasture harvest

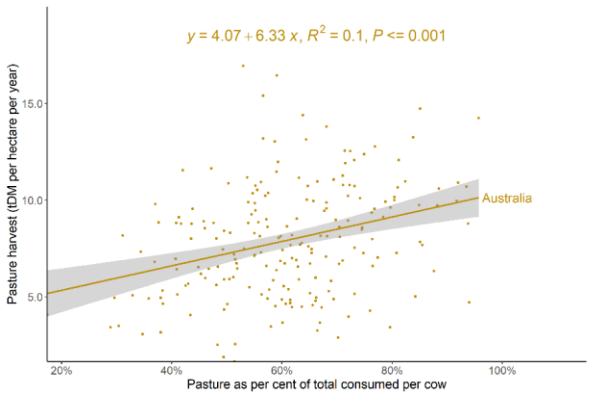


Figure 58. Pasture as per cent of diet impact on 'core per cow cost'

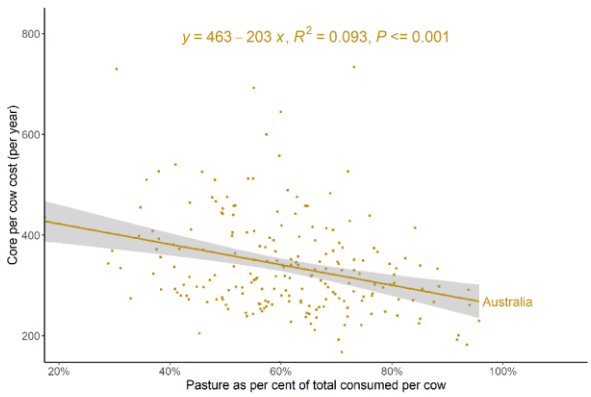


Figure 59. Pasture as per cent of diet impact on labour cost per cow

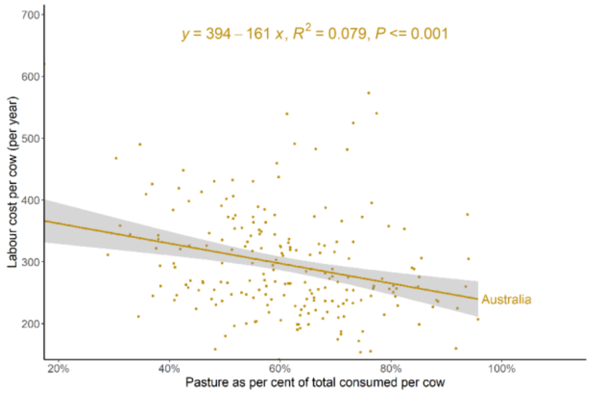


Figure 60. Pasture as per cent of diet impact on milk production per cow

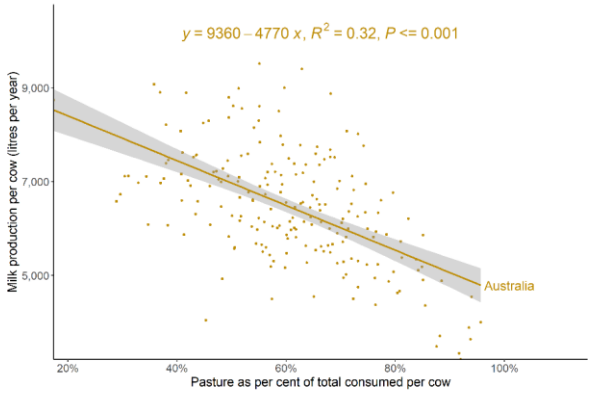
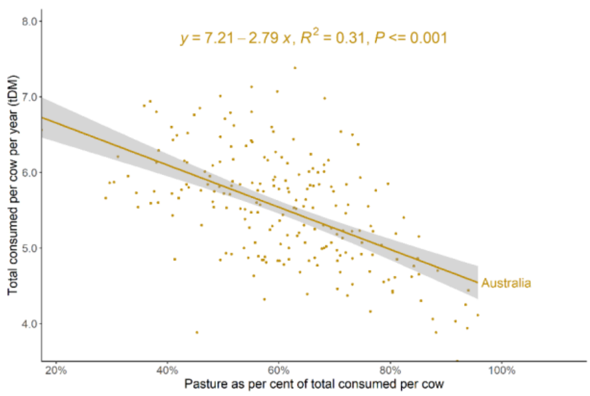


Figure 61 confirms that pasture as a per cent of the cow's diet could explain 31 per cent of the variation in total dry matter consumed per cow annually. This negative correlation suggests that decreasing pasture as a per cent of the diet does contribute to an increase in total dry matter consumed per cow.

Figure 61. Pasture as per cent of diet impact on total consumed per cow (tonne dry matter/cow/year)



In summary, the primary impacts of decreasing pasture as a per cent of the cow's diet on the performance of a pasture-based dairy business are from higher supplement and total feed cost per litre, higher core per hectare cost per tonne dry matter of pasture, higher pasture cost per tonne dry matter, higher core per cow cost, higher labour cost per cow, and *lower* pasture harvest. Changes in these ratios combine to increase the cost of production. Additional impacts of decreasing pasture as a per cent of the cow's diet include a reduction in pasture consumed per cow, and an increase in both total consumed per cow and milk production per cow. However, the benefits of producing more milk per cow do *not* compensate for the higher costs and lower pasture harvest, resulting in reductions in the level of profit with the rate of decrease increasing as pasture as a per cent of the diet decreases. These factors are outlined in Table 4.

Table 4. Factors being impacted by production system (pasture as per cent of cow's diet)

Primary factors being impacted by pasture as % of cow's diet	As increases	R^2	P
Cost of production per litre	Decreases	0.16	<= 0.001
Pasture consumed per cow	Increases	0.68	<= 0.001
Supplement cost per litre	Decreases	0.58	<= 0.001
Total feed cost per litre	Decreases	0.50	<= 0.001
Core per hectare cost per tonne dry matter of pasture harvest	Decreases	0.49	<= 0.001
Milk production per cow	Decreases	0.32	<= 0.001
Total consumed per cow	Decreases	0.31	<= 0.001
Pasture cost per tonne dry matter	Decreases	0.26	<= 0.001
Pasture harvest	Increases	0.10	<= 0.001
Core per cow cost	Decreases	0.09	<= 0.001
Labour cost per cow	Decreases	0.08	<= 0.001

Table 5 outlines the variation in cost of pasture versus concentrate and forage (excluding pasture) for this dataset. As reported previously by Beca (2020), where Australian datasets are analysed in a similar way through to 2018/19, then this confirms that pasture is usually around 25-35 per cent of the average cost of supplements. Conversely this can be expressed as the average cost of supplements usually being 200-300 per cent higher than the direct consumed cost of pasture.

Table 5. Pasture, concentrate and forage cost expressed in USD per tonne dry matter plus ratios of concentrate and forage cost as multiples and percentages of pasture cost. Forage cost excludes any pasture cost.

2005/06	Pasture Cost	Concentrate Cost	Concentrate to Pasture Ratio		Forage Cost	Forage to Pasture Ratio	
Australia	$60	$246	4.1	311%	$124	2.1	107%

These comparisons are calculated on the direct consumed cost of each feed category. With pasture, the direct costs include pasture maintenance and renovation (including green feed crops grazed in situ), fertiliser (including nitrogen), all pasture irrigation costs, and the direct silage and hay costs for pasture conserved on the dairy farm. With forages and concentrates, these costs include the purchase or production cost plus storage costs. Wastages are included in the calculations for forages and concentrates, whereas pasture is calculated on a consumed basis i.e. after wastage.

When concentrate cost on its own is compared to pasture cost, then in 2005/06 the ratio of concentrate to pasture cost of 4.1 is equivalent to describing concentrates as 311 per cent more costly than pasture. As reported previously by Beca (2020), for the period 2010-2019 in Victoria

(Australia), the ratio of concentrate to pasture cost was 3.4 which is equivalent to describing concentrates as 240 per cent more costly than pasture. The equivalent ratios for Tasmania (Australia) over the same period was 5.5 and 450 per cent. These comparisons in costs for pasture versus concentrate and forage (excluding pasture) further explain the impact of changes in production systems where pasture is replaced in the cow's diet by supplement and, in particular, concentrate. This impact is to significantly increase cost of production and increasingly reduce profit.

Discussion and Conclusions

Apart from partial or proxy profit ratios (e.g. profit per hectare, profit per cow) and business-wide risk ratios (e.g. operating profit margin, total expenses per litre, cost of production per litre), pasture harvest is the most important factor in determining profit in pasture-based dairy farming. In the dataset utilised for this paper, pasture harvest had a R^2 = 0.41 and the second most important factor had an R^2 = 0.25. This second ratio was stocking rate and it is directly involved with and supportive of pasture harvest. The third most important factor is total pasture cost per tonne dry matter of pasture harvest which has an R^2 = 0.23. This ratio is also linked to and supportive of pasture harvest. There are several other ratios in the next group of ranking ratios that are also positively influenced by pasture harvest, and all of these ratios in combination confirm that pasture harvest is the most important single factor determining profit.

There is another group of eight ratios that rank after the three outlined above, which have R^2 = 0.17-0.20. A majority of these ratios are significantly influenced by changes in production system, as defined by pasture as per cent of the cow's diet, with all of the following ratios increasing as pasture as a per cent of the diet decreases; cost of production per litre, supplement cost per litre, total feed cost per litre, core per hectare cost per tonne dry matter of pasture harvest, total pasture cost per tonne dry matter of pasture harvest, core per cow cost, and labour cost per cost. In addition, pasture harvest decreases as pasture decreases as a per cent of the diet. Although the direct impact on profit from changes in production system is not high (R^2 = 0.08), the significant impact of changes on a wide range of relevant ratios does confirm that the selection of a production system will significantly impact on the resulting level of business performance.

Although milk is the primary product sold from a dairy farm, the level of milk production per cow has no significant impact on return on capital, profit per hectare, profit per cow or cost of production per litre. At most it might be inferred that very low or very high levels of milk production per cow result in a higher cost of production and a lower level of profit. This absence of impact on profit from increasing milk production per cow is due to the increase in costs on a per litre, per cow, and per hectare per tonne dry matter basis when milk production per cow increases.

This highlights potentially the most significant challenge for pasture-based dairy managers in that many of the most important business performance relationships are counterintuitive due to biological efficiency in relation to milk production not correlating with profit. The explanation for this is that pasture-based dairy farm profit is primarily driven by pasture production and not milk production. Land is most often the largest asset category for a pasture-based dairy farm, with cows/livestock next largest followed by vehicles and machinery, and the productivity of that land through the maximising of low-cost pasture is the primary driver of profit. As a result, converting pasture into milk is the essential component for increasing profit, whereas feeding concentrates or other supplements to cows, other than where they contribute to increasing pasture harvest or maximising lactation days per cow, has little if any positive impact on profit.

There is also a commonly held view in the Australian and other dairy industries that the choice of production system by the farm operator is unimportant, and that it is proficiency in execution of management policies by the farm operator that is the dominant determinant of business performance and profit. It is understandable why this view may be commonly held, given the wide group of factors that significantly impact on profit and with only one of these, pasture harvest, having an R^2 greater than 0.25, and with many of these factors being inter-related and so confounded by each other. However, this view is incorrect and if pasture-based dairy farmers aspire to owning or managing a business with high levels of profit and low levels of risk then the following three factors are all important:

1. Excellence in execution of farm operational management; and
2. Comparatively high levels of pasture harvest per hectare; and
3. Comparatively high levels of pasture as a per cent of the cow's diet.

The complexity of pasture-based dairy businesses and the difficulty in identifying business performance ratios that correlate to profit results in two outcomes. Firstly, to fully understand the position of a farm business and to analyse alternate future strategies for that business requires people to use the "whole farm approach". This whole farm approach is described by Malcolm et al. (2005) and involves an acceptance that the outcomes from farm management decisions are the result of a combination of all things. So, to determine the solution to a problem related to part of the farm production system requires a solution to the whole farm system, and all inputs and their marginal contributions to output need to be considered when considering changes to a farm production system.

Secondly, there is a need to identify a suite of ratios that can be used to reliably analyse the whole farm business performance and identify which areas of a dairy farming business are performing well or poorly, and so which areas might require further analysis. An effective ranking of this core group of ratios has been identified and these were outlined in Table 1. In addition to these ratios, there should be added one or more solvency ratios, and if there is any significant debt funding, including quasi-debt through the leasing or renting of assets, then one or more debt servicing ratios added.

There is some evidence that significant numbers of farmers within several pasture-based dairy industries have decreased the per cent of pasture in the cow's diet over the last 10-20 years to the extent that these farmers may no longer be regularly profitable and their dairy industry lacking in international competitiveness. This has been reported previously by Beca (2020), with the Australia, Argentina and Uruguay dairy industries all potentially in this position, while the South Africa dairy industry, though presently profitable, may be forgoing the opportunity to improve its international competitiveness. In all these countries there has been widespread adoption of US genetics in their livestock breeding programs.

If the farmers in these countries wish to reduce their cost of production by changing their production system to one with a higher per cent of pasture in the diet, then the question arises as to whether they have an appropriate cow genotype to successfully make this change. The genotype of cow that suits a diet mostly comprising pasture, for example over 70 per cent of the diet, and which needs to walk to and from paddocks twice a day as well as harvest the pasture in the paddock themselves, is quite different to the genotype of cow that suits being confined in a feedlot and is provided all the feed it requires without moving outside its pen. These differences in genotype have been documented by Harris and Kolver (2001). The differences particularly pertain to traits relating to survival and fertility, which underpin a low cost of production pasture-based system where a great majority of the cows have a 365-day calving interval.

So if a farmer was looking to significantly increase pasture per cent of the diet, say by around 15 per cent of the total diet, and decrease supplement by the same proportion, then this might equate to a reduction in concentrate feeding rate of 2.0-2.5 kilograms per cow per day. For many farms, a reduction in concentrate feeding rate of this scale would result in the cows losing too much bodyweight and being unable to efficiently produce milk or get pregnant. As a result, the farmer would need to start breeding the type of cow that can efficiently produce milk with a high percentage of pasture in the diet, and this could take 5-10 years to undertake.

The implications of this change in diet composition and its impact on cow performance, along with other associated production system changes such as managing fewer cows per hectare to allow for the increase in pasture per cent in the diet, would result in significant business management challenges that could be worthy of further study.

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Red Sky Agricultural ('Red Sky') www.redskyagri.com; commercial provider of farm business analysis and benchmarking software that has primarily operated in Australia, New Zealand and South Africa. Red Sky's major shareholder is the author of this paper.

Appendix 1: Definitions

Energy Corrected Milk (ECM): determines the amount of energy in the milk based upon milk, fat and protein and adjusted to 4.0 per cent fat and 3.3 per cent protein. ECM formula = milk production x ((0.383 x fat% + 0.242 x protein% + 0.7832) / 3.1138). Converting all milk ratios to energy corrected milk is required due to the otherwise confounding impact of the wide range in fat and protein per cent as a result of differing cow types, diets and production systems. This formula is used by the Dairy International Farm Comparison Network, as outlined in the following: https://dairymarkets.org/PubPod/Reference/Library/Energy%20Corrected%20Milk.

Table 6. Definitions of operating revenue and expenses utilised in calculation of operating profit

Operating profit calculation	Definitions
Operating revenue	Milk sales + Livestock revenue[1] + Other non-milk revenue
[1] Livestock revenue	Livestock sales - livestock purchases + (closing numbers - opening numbers) x closing value per head
Operating expenses	Administration fees & overheads[2] + Animal health + Breeding & herd testing + Dairy shed expenses + Depreciation[3] + Electricity + Fertiliser + Freight + Irrigation + Pasture maintenance & renovation + Repairs & maintenance + Total supplement expenses[4] + Vehicle expenses + Management & labour expenses[5]
[2] Administration fees & overheads	Includes all office expenses plus professional fees plus rates, licences, levies and insurance
[3] Depreciation	Based on straight line depreciation over economic life of asset
[4] Total supplement expenses	Includes all concentrate and forage expenses (excluding pasture grown on dairy farm) fed to cows and growing heifers plus green feed crops grazed in-situ plus all expenses for grazing/support area utilised for cows and growing heifers as well as supplement production
[5] Management & labour expenses	Includes all direct labour expenses plus market salary value of any management provided by owner/family plus market hourly rate value of any labour provided by owner/family
Operating profit	Operating revenue - Operating expenses

Table 7. Calculations and definitions of ratios referenced in the statistical analysis

Ratios	Calculation / Definition
Core per cow cost	[100% x (Animal health + Breeding & herd testing + Dairy shed expenses + Electricity + Freight + Grazing/Support area expenses + Industry levies) + 70% x Vehicle expenses + 50% x (Depreciation + Repairs & maintenance)] divided by total cows in herd.
Core per hectare cost per tonne dry matter of pasture harvest	[100% x (Administration fees & overheads excl. industry levies + Fertiliser excl. nitrogen + Green feed crops grazed in-situ + Pasture maintenance & renovation) + 30% x Vehicle expenses + 50% x (Depreciation + Repairs & maintenance)] divided by effective dairy hectares divided by tonne of dry matter harvested per hectare.
Cost of production per litre	(Operating expenses minus livestock revenue minus other non-milk revenue) divided by total litres (ECM) produced.
Farm size (cow numbers)	Total number of cows in herd (milking plus dry cows).
Farm size (hectares)	Effective dairy farm area that is grazed by the cows.

Ratios	**Calculation / Definition**
Grams concentrate per litre	Grams of concentrate consumed per annum divided by total litres (ECM) produced.
Grams supplement per litre	Grams of supplement consumed per annum divided by total litres (ECM) produced, where supplement includes concentrates and forages but excludes pasture.
Income over feed costs per cow	(Milk revenue - concentrate costs - forage costs) divided by total cows in herd. This is an annual calculation and not a daily calculation.
Income over feed costs per litre	(Milk revenue - concentrate costs - forage costs) divided by total litres (ECM) produced. This is an annual calculation and not a daily calculation.
Labour cost per cow	Management & staff costs incl. imputed labour costs divided by total cows in herd.
Labour cost per litre	Management & staff costs incl. imputed labour costs divided by total litres (ECM) produced.
Labour efficiency - cows per full-time staff equivalent	Total cows in herd divided by number of 50-hour full-time staff equivalents.
Labour efficiency - litres per full-time staff equivalent	Total litres (ECM) produced divided by number of 50-hour full-time staff equivalents.
Operating profit margin	Operating profit divided by operating revenue.
Pasture harvest	This is the equivalent tonnage of standardised (11.0 MJ ME/kgDM) energy density pasture consumed per hectare. Any hay and silage conserved on the dairy farm is included in the total pasture yield. This is a back-calculation based on inputs and outputs.
Milk price	Milk price per litre (ECM).
Milk production per cow	Total litres (ECM) produced divided by total cows in herd.
Milk production per hectare	Total litres (ECM) produced divided by effective dairy hectares.
Pasture as per cent of diet	Percent of energy provided from pasture harvested on the effective dairy area as a percentage of total annual energy requirements of the cows.
Profit per cow	Operating profit divided by total cows in herd (milking plus dry cows).
Profit per hectare	Operating profit divided by effective dairy hectares (grazed by the cows).
Profit per litre	Operating profit divided by total litres (ECM) produced.
Return on (total) capital	Operating profit divided by the total value of all assets employed in the business (regardless of ownership/financing structure). Changes in asset values, including appreciation of land values, are not included in this calculation.
Stocking rate	Total cows in herd divided by effective dairy hectares.
Supplement cost per litre	(Concentrates + Forages + Grazing/Support area expenses) divided by total litres (ECM) produced.
Total consumed per cow (tDM/cow/year)	Total tonnes of dry matter consumed per cow in herd per year, where the energy supplied from pasture is standardised at 11.0 MJ ME/kg DM, the energy supplied from forages is standardised at 9.5 MJ ME/kg DM, and the energy supplied from concentrates is standardised at 12.5 MJ ME/kg DM.
Total expenses per litre	Operating expenses divided by total litres (ECM) produced.
Total feed cost per litre	(Concentrates + Forages + Grazing/Support area expenses + Green feed crops grazed in-situ + Fertiliser incl. nitrogen + Irrigation + Pasture maintenance & renovation) divided by total litres (ECM) produced.
(Total) Pasture cost per tonne dry matter	(Direct pasture cost plus variable pasture cost plus capital pasture cost) divided by total dry matter of pasture harvested. Direct pasture cost includes pasture maintenance and renovation (including green feed crops grazed in situ), fertiliser (including nitrogen), all pasture irrigation costs, and the direct silage and hay costs for pasture conserved on the dairy farm. Variable pasture cost includes an assessment of the proportion of repairs and maintenance, vehicle expense and wages including employment expenses that could be attributed to growing pasture. Capital pasture cost includes an opportunity cost of capital for the land and a proportion of depreciation on capital assets that could be attributed to growing pasture.