Defining the value proposition for using technology to improve pasture management and harvest more pasture

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Abstract

There is large variability in pasture grown and harvested on New Zealand dairy farms. Some of these differences are due to fixed factors such as rainfall, soil type, and temperature, while other factors could be remedied, for example improving pasture management, soil fertility and drainage. Of the aspects that could be remedied, it is expected that a substantial proportion would not be profitable to fix with current costs, knowledge, or technologies available in the near future. Of the proportion where it may be possible to fix cost-effectively, it was estimated that the net gain (after costs) is approximately $200 million per year to the dairy industry.

Background

There is a large variability in New Zealand dairy farm financial performance, and a significant proportion of this is due to the variability of pasture grown and harvested (Silva Villacorta et al., 2005). There are a number of approaches through which the gap between actual and potential pasture harvest may be reduced, which could include technology such as those that facilitate faster, cheaper or more accurate pasture measurement. However, taking into account the cost of “fixing” the problem or removing the limiting barrier, only some of these approaches will be profitable to adopt.

Yield gap analysis, the difference between a potentially achievable harvest and the actual harvest, has become an increasingly popular concept for assessing the scope for improvement in farm practice and subsequent yield (Van Ittersum et al., 2014). For example, in the context of wheat yields in Australia, Hochman et al. (2011) developed a methodology to estimate the difference between district yields and the modelled maximum yield when only moisture was limiting. However, they also use the term exploitable yield gap, recognising the difficulty in achieving the moisture-limited maximum. The exploitable yield gap was defined as the difference between actual and 80% of the moisture-limited maximum.

Beddow et al. (2014) criticise the over-reliance on yield gap analysis on the basis that, for example, farmers may not try to achieve the maximum yield as it may not be profitable under their circumstances. Indeed, from first principles of production economics, if inputs have a cost, and the production function has diminishing returns to the inputs, the optimal (profit-maximising) level of production per hectare will always be lower than the maximum possible (Debertin, 2014).

The first aim of this study was to determine the value of the pasture harvest yield gap between current farm performance and the best farm performance of New Zealand dairy farms. The second aim was to then determine what the net value of closing the gap was, where it was profitable to do so, after accounting for the costs of achieving it, noting that technologies may assist in closing this gap. This exercise helps to determine to what extent farmers should be encouraged to aim for increased pasture harvested, if at all profitable. Additionally, it can help clarify the value proposition for technology, while acknowledging that technology alone will not facilitate the capture of the opportunities.

Methods

An analysis was undertaken to determine the yield gap, which required a regional distribution of pasture harvest for farms across New Zealand. DairyBase, the New Zealand industry good database of farm-level physical and financial measures, was the primary data source for analysis (Shadbolt, 2009), with processing performed in R (R Core Team, 2013). Although farms do not usually have a reliable direct measure for the pasture they harvest, it can be estimated from herd-level energy balances. For example, an estimate of pasture harvested (eaten) can be back-calculated from that required to support milk production and animal maintenance, excluding energy supplied by imported feed.

These data were used to determine the relationship between pasture and profit. A preliminary spatial analysis was then carried out to identify cases, using expert opinion, on where differences might be plausibly determined as being due to either fixed factors or management factors. In the absence of further information, a Bayesian method (Kruschke, 2014) was applied to attribute these differences across the national data.

Results and discussion

Bridging the yield gap

At a regional level, the probability density function for pasture and crop eaten (t DM/ha) shows the variation between farms (Figure 1). Most regions had a difference between the median and 90th percentile of around 3 tonnes of dry matter per hectare.

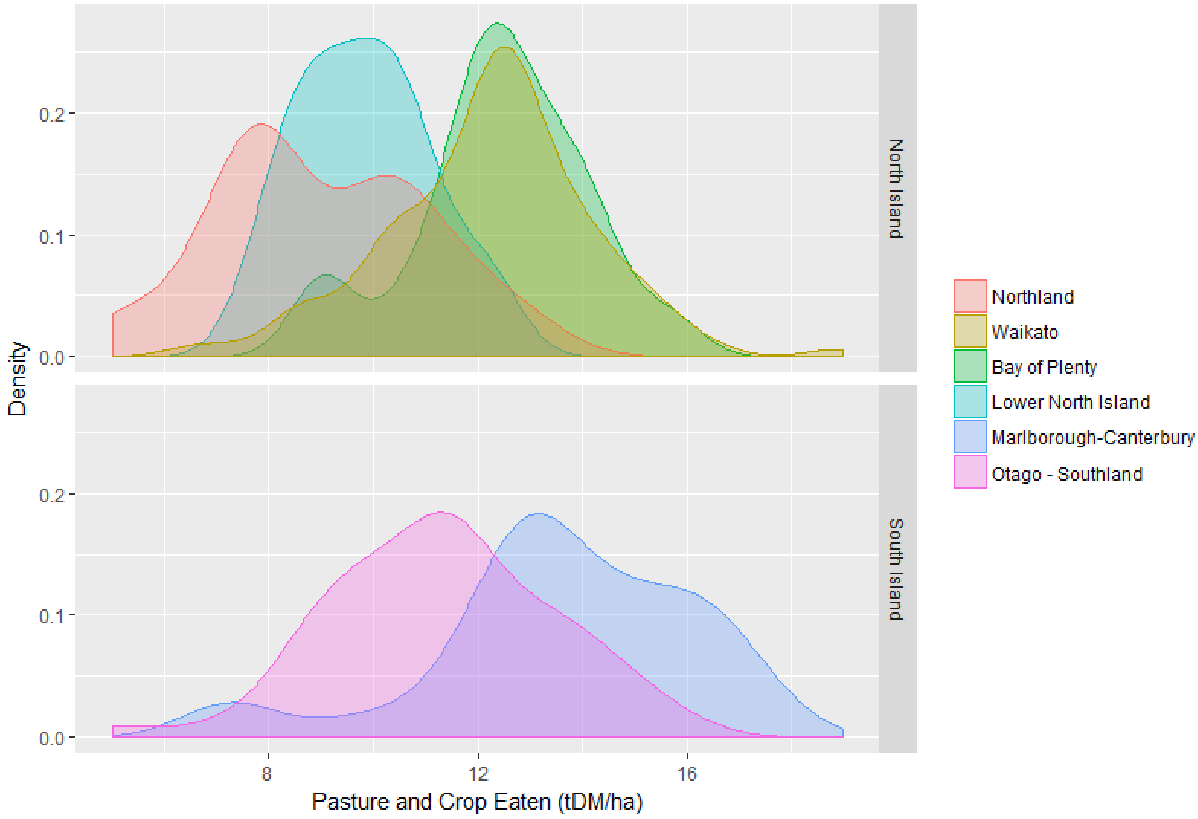

Figure 1. Distribution of pasture and crop eaten (tonnes of dry matter per hectare) by region, 2012/13.

The positive relationship between pasture and crop harvested and profitability was confirmed across ten years and all regions, with one example given in Figure 2. The coefficient of the regression equation implies that farms in that region harvesting an extra tonne of dry matter per ha generate an extra $382/ha of earnings before interest and tax. An aggregation of the regional yield gap (to the 90th percentile) was then multiplied by the regional value of pasture and crop to estimate the profit from closing the entire yield gap to that point. There is some evidence to suggest that managers can reduce the yield gap (e.g. McCarthy et al., 2014; Beukes et al., 2015). However, there is also clearly a number of fixed factors such as soil type and climate that vary within a region and cannot be changed, so not all farmers could reach the 90th percentile for the region.

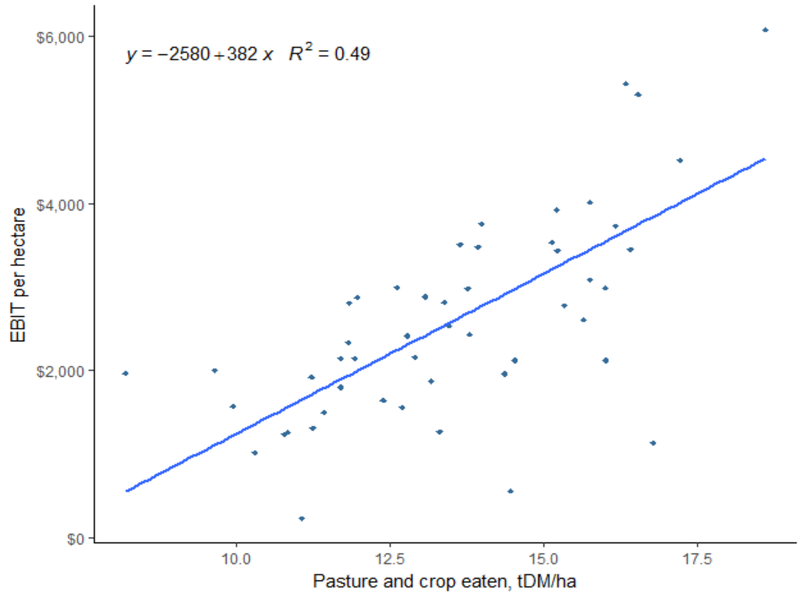

Figure 2. Positive association between pasture and crop harvest and earnings before interest and tax ($NZD), Bay of Plenty region, 2014/15.

Figure 3 shows an example of a kernel-smoothed pasture surface for the Bay of Plenty region of New Zealand. Expert knowledge of the geography, climate and soils of the region was used to identify an area (labelled A), where pasture and crop harvest was lower than the region average due to fixed factors, primarily contour and soil characteristics. A separate area (labelled B) was identified where fixed factors were likely to be similar within the area of the circle, with the lower yield in the centre of the circle likely to be due to different management. In the absence of more detailed information, a Bayesian approach (Kruschke 2014) was used. This entails making an initial supposition, that in the absence of information to the contrary, two mutually-exclusive alternatives can be considered equally likely, with further systematic updating of these prior beliefs when more data becomes available. For the current situation, this then justified the application of a uniform (relatively uninformative) prior across the national data, where 50% of the difference was due to fixed factors.

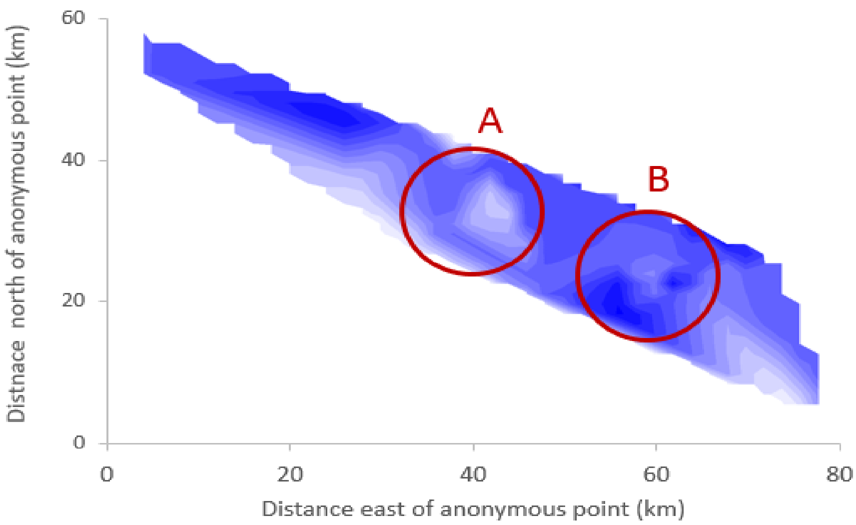

Figure 3. Spatial distribution of pasture and crop harvest per hectare (tonnes of dry matter per hectare), Within the Bay of Plenty region, 2012/13. Darker colours depict areas with higher yield, white = 9 tDM/ha, darkest blue = 18 tDM/ha.

While it was assumed 50% of the yield gap could be closed by changing operational management, strategy or additional investment on farm, it is unlikely that it would always be profitable to make the change. Conceptually this is shown in Figure 4, at point A, where there is very little cost to improve pasture harvest, but a significant gain. An example could be better adherence to good grazing practice such as monitoring residuals accurately (McCarthy et al. 2014). Point B is the point where marginal revenue from increasing pasture harvest equals the cost of increasing the pasture harvest. An example might be investment in artificial drainage that might approximately breakeven. Point C is a point where an increase in pasture harvest is much costlier than the revenue gained. This could refer to wholesale reshaping of the landscape, the use of expensive soil ameliorants, or sowing high yield species that require machine harvest and infrastructure to utilise. Again applying Bayesian reasoning, it was likely that 50% of the yield gap that could be closed was not actually profitable to close. Assuming a linear cost function starting at zero (as per Figure 4) this implies that the cost of closing the yield gap, when it was profitable (i.e. up to Point B), would be half of the revenue gained to that point.

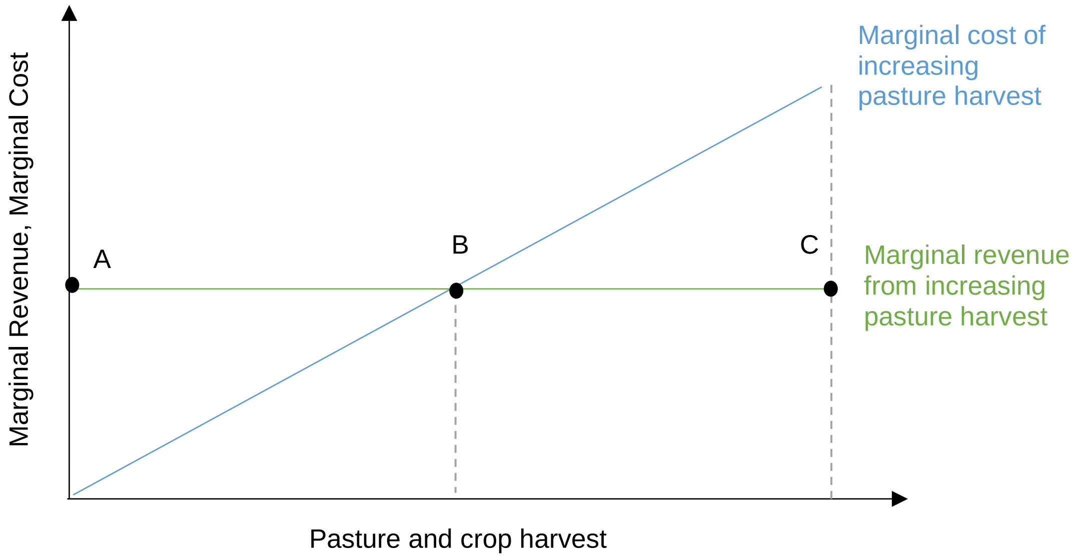

Figure 4. Economic representation of revenue and costs associated with increases in pasture harvest

The yield gap, when aggregated over regions over the ten year dataset, had an economic value totalled $1.7 billion per annum. However, applying the estimate that was due to fixed factors which could not be rectified reduced the value to $0.85 billion. Applying the estimate of the amount that could not be profitably rectified then reduced the value of the yield gap to just over $0.4 billion. Finally, after removing the cost of improving the pasture and crop harvest to the profitable point meant that the net value (profit) to be captured by New Zealand dairy farmers was only about $200 million per year, or 12.5% of the gross value of the yield gap when a regional potential was assumed. At a farm level, this translates to an average of $17,000 per farm of additional earnings before interest and tax.

Developing technology to close the yield gap

Identifying the most relevant technologies to improve profitability and sustainability is a major challenge to applied research in dairy farming (French et al., 2014; Garcia et al. 2014). Appropriate analysis of the value proposition of closing the yield gap provides scientists and technology developers more guidance around the most promising avenues for research and development, while keeping realistic notions of the cost at which the technology needs to be marketed to generate a net benefit for the farmer. Quantifying the gap may also provide sufficient motivation for the farmer to change current management practices.

While profit and yield gap analysis is currently popular across agricultural industries around the world, there is a tendency to overestimate the "size of the prize", or at least that which is profitably captured. The analysis in this study indicates that while the profit gap (due to yield shortfalls) between the best and the remaining farmers is well over a billion dollars per year, it is likely that no more than 25% of the value of the yield gap could be profitably closed using the currently available and potentially available technologies. Further, taking into account the cost of those technologies, the net benefit would then be in the order of 12.5% of the value of the gap.

Closing the yield gap will, in most cases, require an improvement in pasture management and this may be supported by measurement technologies. For example, allocating an appropriate and constant amount of pasture daily will result in approximately 10% higher milk yield (Garcia et al., 2007). However, King et al. (2010) indicated that only a small proportion, perhaps 20% of farmers, regularly and formally measure pasture. A key reason for the slow adoption of formal monitoring in grazing management has been reported to be the lack of clarity regarding economic benefits of pasture measurement (Parker, 1999). Yield gap analysis will potentially address this, in part, by quantifying the value that improved pasture measurement technologies could help capture.

In an attempt to estimate the value of feasible pasture measurement tools (specifically unmanned aerial vehicles operated beyond visual line of sight), Shelley and Andrews (2015) used a productivity approach to estimate $570 extra margin per hectare from “active pasture management”, and assuming an incremental take-up by 45% of New Zealand’s dairy farmers, this aggregated to $0.4 billion per year. However, their assumptions about the cost of change was relatively low, with costs of aerial survey being less than 10% of the additional margin, and no costs estimated for data processing or consultancy time. Despite a very different methodology, the magnitude of their numbers are similar to those presented in this paper in terms of the extra margin that could be gained. However, the cost of achieving it is likely to be underestimated by Shelley and Andrews (2015). This is because some costs, such as gaining more knowledge from a website and applying it on farm may carry a low cost, other options, such as extensive drainage, would be far costlier.

Conclusion

There is a value proposition for closing the pasture and crop yield gap, and some technologies may play a part in improving aspects of pasture management, allowing farmers to profitably harvest more pasture. However, this is easily overestimated, and is certainly yet to be fully realised.

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