Identifying the pasture potential for New Zealand dairy farms

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Abstract
Higher amounts of pasture and crop eaten on farm are associated with higher profit, and it is likely that many dairy farms have an opportunity to improve their financial performance. Regional averages of pasture and crop eaten are readily available but locally relevant estimates of achievable potential pasture and crop eaten are not, so farmers do not know what improvement to pasture and crop eaten and profitability might be possible. The Pasture Potential Tool was developed to provide a locally relevant estimate of that potential. Data on pasture and crop eaten were sourced from DairyNZ's DairyBase farm performance database, and made available using an interactive web-based tool after testing with pilot groups of farmers. The tool defined a farm's potential pasture and crop eaten in a particular year as the 90th percentile of farms within a defined radius, or the level that is exceeded by only one in ten farmers, with the data being filtered for comparable soil type and elevation, and adjusted for nitrogen fertiliser application. The tool is available on the DairyNZ website, and has been accessed more than 1300 times in the first 5 months since it went live (as of May 2019).

Keywords: pasture production, pasture intake, crop intake, DairyBase, farmer data, online tool

Introduction
New Zealand dairy farms vary widely in financial performance, and a substantial proportion of this is due to variability in the amount of pasture and crops grown and eaten (PACE) on-farm relative to feeds purchased externally (Silva Villacorta et al. 2005; Neal et al. 2017). Analysis of the farm performance data in DairyNZ's "DairyBase" database (DairyNZ 2019a) suggests that each additional tonne (tDM) per hectare of PACE is associated with an increase of approximately $300 in net operating profit per ha (Neal et al. 2018).

It is likely that opportunities exist on many farms to increase PACE and, therefore, profitability. For example, grazing management may not follow best practice; McCarthy et al. (2014) estimated that around 25% of farmers were over-grazing, and 25% were under-grazing pastures, relative to recommended post-grazing residuals. Differences in production per-paddock also may not be identified or addressed; Clark et al. (2010) found that, even on research farms with consistent management and measurement, the best paddocks had twice the yield of the poorest paddocks, and a recent study by Woodward et al. (2019) suggested that the variation could be even greater in some cases. Some of these differences could be improved through better pasture management, soil fertility and drainage (Chapman et al. 2013).

Yield gaps, defined here as the difference between a farm's actual and potential PACE, have become an increasingly popular metric for assessing the scope for improvement in farm practice and subsequent yield (Van Ittersum et al. 2013). For example, Hochman et al. (2016) estimated the difference between district wheat yields in Australia and modelled maximum yields when only moisture was limiting, to highlight the opportunity for improvement. Recognising that this moisture-limited maximum may be difficult to achieve or uneconomical, they defined an "exploitable yield gap" as the difference between actual yield and 80% of the moisture-limited maximum. Neal et al. (2017) estimated that increasing PACE (closing the gap) could be worth approximately $200 million per year to the dairy sector, or on average, $17,000 per farm. Currently, no such measure of yield gaps exists for pasture-grazed dairy farms, although DairyBase does collect information on about 700 farms per year to report back regional benchmarks (average, top 20%) that indicate a farmer's performance relative to the benchmark. The limitation is that the benchmark data are not publicly available, and are often at a regional level that does not take into account differences in N fertiliser application, elevation or soil type that are likely to influence the achievable level.

The objective of the current study was to develop a tool to provide farmers with a locally relevant estimate of potential pasture production, to answer the question, "What is the potential amount of pasture and crop that could be grown and eaten on my farm?". The ability to identify a locally relevant and realistic target is highly valuable for motivating the diagnosis and improvement of pasture use and overall farm profitability.

Materials and Methods
New Zealand-wide data on PACE were obtained from DairyNZ's DairyBase dairy farm performance database (DairyNZ 2019a). In DairyBase, PACE is not directly measured, but is estimated from farm performance data based on the estimated energy requirements of animal

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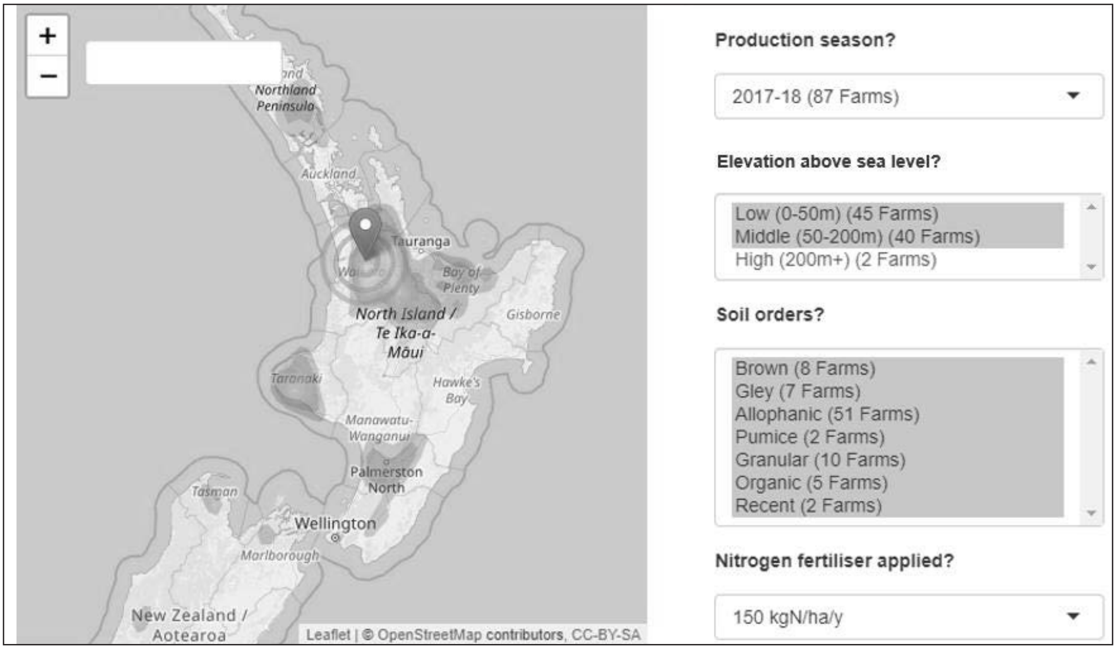

Figure 1 Pasture Potential Tool inputs. Selection of location, season and other local variables. Shaded areas on the map represent the density of available data.

maintenance and milk production, and subtracting the energy supplied by imported supplement. Crop areas are recorded but reliable measurements of crop yield are not generally available, so it is not possible to separate the contribution of pastures versus crops. Approximately 700 DairyBase farms each year collect the data necessary to calculate PACE, although this information takes several months to be collected before it becomes available for analysis. These data were also analysed in R (R Core Team 2019) to determine the association (if any) between greater areas of harvested crop to greater PACE, and greater profit. Waikato data were used for this purpose, given harvested crop (e.g. maize) is relatively common in that region.

Regional benchmarks for PACE can be generated from these data, by back calculation of energy supply and demand (Nicol & Brookes 2007). However, factors such as rainfall, soil type, elevation, terrain and fertiliser use vary widely within most regions, so that a regional benchmark is of limited relevance to any given farm. The advent of the digital electronic age has allowed a wider range of data to be collected spatially and temporally and related interactively. A range of data has been incorporated and developed into a new application called the Pasture Potential Tool. This tool defines pasture potential for a specified location as the 90th percentile of PACE on nearby farms with the same local factors. That is, the value exceeded by only one out of ten nearby farmers who are subject to the same local factors mentioned above.

The Pasture Potential Tool was written in R (R Core Team 2019) with the web interface developed and deployed using R-Shiny and shinyapps.io (RStudio 2019). Farm-performance data from DairyBase were linked with a representative soil type and elevation for each farm (as determined at the location of the farm milking shed) using the publicly available New Zealand Fundamental Soils Layer database from Landcare Research (2019) to find soil order, and Mapzen Terrain Tiles on Amazon Web Services (https://registry.opendata.aws/terrain-tiles/). The New Zealand Map interface was accessed from the Google Cloud Platform.

Early versions of the tool were tested with two pilot groups of farmers and DairyNZ consulting officers in the North Island (Bay of Plenty) and South Island (Canterbury) in 2018. The tool was then improved iteratively to take into account their feedback and to improve functionality. For example, adjustments or filters for nitrogen fertiliser, elevation and soils did not feature in the original version, and were progressively added in response to feedback.

Results

The Pasture Potential Tool is available at www.dairynz.co.nz/pasture-gap/. The tool allows farmers to select their location interactively on a map, or by entering an address (Figure 1). Coloured areas on the map indicate

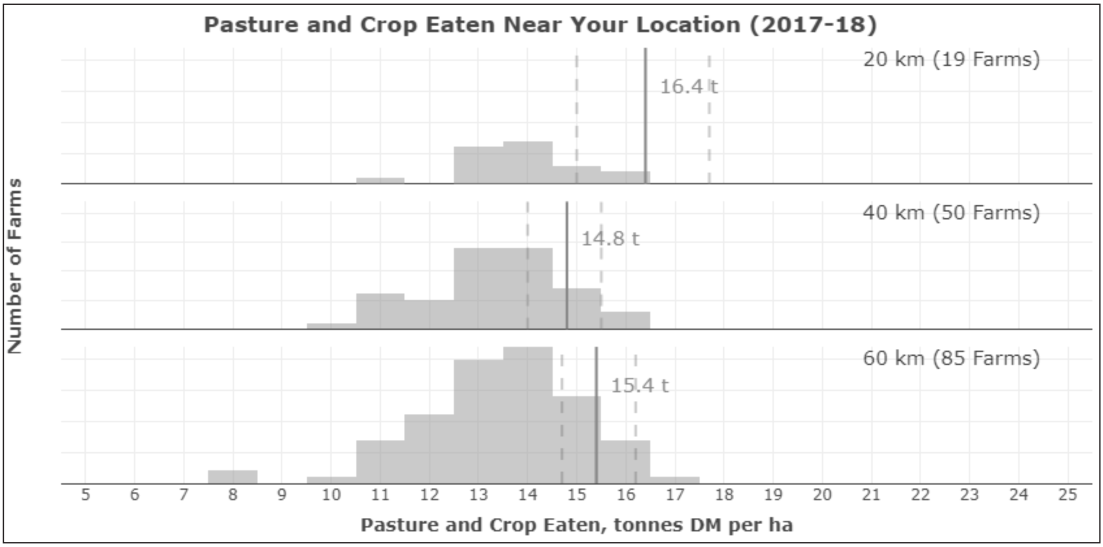

Figure 2 Pasture Potential Tool outputs. Distribution of pasture and crop eaten (tDM/ha/y) on farms within three distances (20, 40 and 60 km) from the user's farm, with estimated potential (90th percentile) indicated as a solid line, and dashed lines to indicate the 95% confidence interval of this estimate.

the availability of data, with green representing the locations with the most data. The year of interest can be selected from a dropdown menu, and an indication is given of how many farms with PACE data are within a 60-km radius of the selected point on the map (largest circle) with smaller circles representing a 40-km and 20-km radius. The farmer can then filter the data further by selecting the most relevant characteristics. For example, in Figure 1, farms with with low to mid elevations are selected, and any soil order. All observations can be adjusted to a selectable level of N fertiliser applied annually assuming a moderate response rate of 10 kg DM pasture per kg N fertiliser applied (DairyNZ 2019b).

In response to these inputs, the tool filters the relevant farms from DairyBase, and plots histograms of PACE for farms within a 20-km, 40-km and 60-km radius (Figure 2). These distances allow the user the opportunity to compare closer farms (e.g. 20 km), versus more distant farms (e.g. 60 km) where other factors such as similar elevation or soil type are more important to determine potential than spatial proximity. The pasture potential value is determined from this data by quantile regression, and a bootstrap method is used to estimate its uncertainty. These are shown as a vertical solid line, accompanied by the numerical pasture potential value, and dashed lines to indicate the uncertainty, respectively.

If a farmer wishes to determine the gap between a farm's potential and actual PACE, they may use the Pasture Potential Tool in conjunction with the estimated actual PACE calculated by DairyBase, or from DairyNZ's online tool for Pasture and Crop Eaten Assessment (www.dairynz.co.nz/pasture-and-crop-eaten).

The focus on closing the pasture component of a PACE gap is more likely to yield profits. For example, using 12 years' worth of DairyBase data for the Waikato, a regression analysis showed that farms with 10% more area in harvested crop would be expected to have approximately 0.6 t DM/ha more PACE ($P<0.05$), although there was no significant improvement in operating profit per hectare from the area allocated to high yielding harvested crop. This result is most likely due to an increase in costs outweighing the relative yield advantage of the crop.

Discussion

As of May 2019, the tool had been accessed approximately 1300 times, representing about 10% uptake given that there are fewer than 12,000 dairy herds in New Zealand (LIC 2018). It was publicised through a number of conferences and dairy sector email lists and publications (e.g. Neal et al. 2018; Neal & Woodward 2019; DairyNZ 2019c).

Quantifying the difference between potential and actual PACE is an important step in realising improved financial performance but the technical process for achieving this stage still needs to be developed. Such development is likely to require holistic consideration of the farm. For example, conversion of pasture into higher yielding crops (e.g. for harvest) will only improve the profitability of PACE if the additional costs outweigh the benefits.

DairyNZ has a number of resources to help farmers capture the potential financial opportunity of pasture. Such resources include the pasture component of Farm Gauge, a self-assessment tool for farm businesses (www.dairynz.co.nz/farm-gauge/), a range of information regarding best-practice feed management, and tools such as the spring rotation planner (https://www.dairynz.co.nz/feed/). The pasture potential concept may be refined in future to provide more customised reporting (for example in DairyBase), or via integration into existing farm dashboard tools to make them more comprehensive. New developments could see options for near-real-time comparisons for pasture harvest across relevant farms in the year to date, for example using remote measurement augmented by on-farm information (e.g. Woodward et al. 2019). However, there are a number of reasons why we would suggest using the tool only with appropriate consideration. For example, fewer data points are available in some regions. Terrain (apart from elevation) is currently not taken into account. Also, farmers may themselves be aware of factors that make a substantial difference to their PACE that are not accounted for in the tool (e.g. frequent waterlogging). Environmental or other regulations may also make it difficult to create appropriate farmer peer groups for estimating potential. For example, a peer group determined using the tool based on nearby farms could straddle two catchments with differing regulations on N loss and limitations on permitted activities that affect achievable pasture harvest.

Conclusions

The level of use and engagement with the Pasture Potential Tool (~10% of farmers) above the number of benchmark reports generated by DairyBase (~6%) suggest that considering potential has been a useful exercise for farmers as they look for opportunities to improve their pasture and crop eaten, and hence profitability.

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