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QUANTIFYING ENVIRONMENTAL EFFICIENCY THROUGH GENETIC MERIT (BW)

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Abstract

Nitrogen losses associated with cow urine patches and methane emissions from cow burps are demanding more attention due to their environmental effects, media interest, and regulatory change.

LIC has always focused on breeding and selecting for cows which efficiently convert the food they eat into milk production, while maintaining important attributes needed to maximise the productive life of the cow.

Since its inception as the national dairy animal evaluation system in 1996, Breeding Worth (BW) has been, and still is, a great indicator of environmental efficiency. This leads to the hypothesis that to improve both nitrogen and methane efficiency of cows, a key driver would be the animal's ability to maximise production output per kilogram of feed eaten.

The analysis indicates that BW shows a strong relationship with how much urinary nitrogen and enteric methane is produced by an animal per kilogram of milksolid produced.

An animal of $10BW higher genetic merit would be expected to produce 1.7g less urinary nitrogen per kilogram of milksolid over its lifetime. Similarly, 2.0g less enteric methane is produced per kilogram of milksolid. These results align with DairyNZ research, in which intake, output and partitioning were compared for high BW and low BW cows.[1]. High BW cows showed greater nitrogen efficiency, higher levels of nitrogen in milk protein and lower amounts of nitrogen in urine.

The environmental efficiency of LIC's Daughter Proven Premier Sires team (including Friesian, Jersey and KiwiCross®) has improved over time. Using the weighted average from the number of straws sold each year, the urinary nitrogen calculated per kilogram of milksolid has progressively decreased by 0.6% per year (16% over 30 years) as has calculated enteric methane per kilogram of milksolid by 0.45% per year (13% over 30 years).

These improvements in environmental efficiency have been made because BW is a sound measure of overall efficiency of a dairy animal. When making farm environmental recommendations, it is important to consider the environmental efficiency of the animals, which can be best indicated by the herd BW.

[1] Woodward et al (2011), *Are high breeding worth index cows more feed conversion efficient and nitrogen use efficient?*, In Proc. NZSAP 71 109-113

Introduction

Genetic gain in New Zealand dairy cattle has enabled consistent progress towards the most efficient cows for converting pasture into profit. Now that we have reached a stage where global pressures on the environment are requiring more focus on reducing the environmental impact of all human activities, including agriculture, we need to understand how genetics can contribute to improvements. The BERG report indicated that, by improving productivity per animal, dairy farms could reduce biological greenhouse gas emissions by 2-10%[2].

The purpose of this paper is to quantify the relationship between genetic merit (BW) and environmental efficiency, in terms of urinary nitrogen excretion and enteric methane emissions. Genetic gain occurs over a long period of time, therefore this paper analyses the animals environmental impact and productivity changes over the past 30 years.

Animal Evaluation

The New Zealand dairy industry breeding objective is: 'identifying animals which are the most efficient converters of feed into profit'.[3] This objective is based on the premise that New Zealand dairy farmers have a common goal of increasing farm profitability. The two biggest costs in New Zealand dairy farming are land and animals – the former to grow feed, the latter to convert feed into saleable product. In the case of dairy production this product takes four forms: milkfat, protein, milk volume and liveweight.

Animal Evaluation was launched in 1996, generating new across-breed indices which quantify the profitability of the animal per 4.5 tonne of dry matter eaten, compared to the genetic base animal. The new indices for evaluating dairy animals in New Zealand were Breeding Worth (BW), Production Worth (PW) and Lactation Worth (LW). These three indexes are calculated to generate the:

- Genetic merit – Breeding Worth
- Lifetime performance – Production Worth
- Seasonal performance – Lactation Worth

[2] *Report of the biological emissions reference group (BERG)*, (2018), Biological Emissions Reference Group, page 23.
[3] *New Zealand Dairy Industry Animal Evaluation Technical Manual*, Livestock Improvement Corporation Ltd, 1996.

Each index is calculated using trait evaluations and economic data to generate the index. The five original traits used in the indices were:

1. Milkfat
2. Protein
3. Milk Volume
4. Liveweight
5. Survival (now Residual Survival)

Three additional traits have been added to BW:

6. Fertility (added to BW in 2002)
7. Somatic Cell Score (SCS) (added to BW in 2004)
8. Body Condition Score (BCS) (added to BW in 2016)

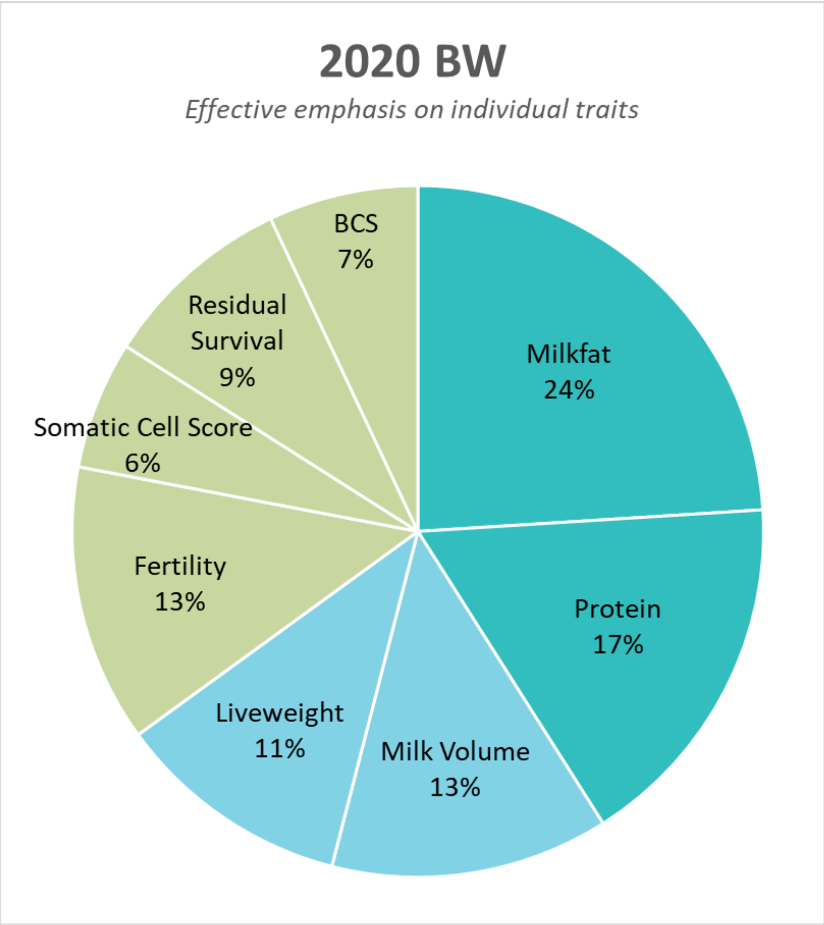

Figure 1: 2020 BW effective emphasis on individual traits

For Breeding Worth each animal has an individual calculated Breeding Value (BV) for each trait, based on information such as: genetic information, recorded events (calving, dry off, removal), herd test data, and weight data. The BVs are then multiplied by Economic Values (EV) which are generated at an industry level to reflect the current market values for dairy product and farm costs.

Breeding Worth = (Milkfat BV x Milkfat EV$) + (Protein BV x Protein EV$) + (Milk volume BV x Milk volume EV$) + (Liveweight BV x Liveweight EV$) + (Residual Survival BV x Residual Survival EV$) + (Fertility BV x Fertility EV$) + (SCS BV x SCS EV$) + (BCS BV + BCS EV$)

Breeding Worth has been used for this analysis as it is the index which expresses the genetic merit of an animal, and is used for selection and breeding decisions which impact on the future profitability and impact of the herd.

Quantifying emissions and excretion

Enteric methane emissions and urinary nitrogen excretion from dairy cows are two of the major contributors to the environmental impact of dairy production in New Zealand. It is extremely difficult and expensive to measure and assess actual emissions and excretion from dairy cows in a pasture based system. Therefore, a modelling methodology has been used to quantify the expected emissions and excretion.

The modelling uses six individual Breeding Values for each animal. These BVs are:

1. Liveweight
2. Milk Volume
3. Milkfat
4. Protein
5. Fertility
6. Total Longevity

These BVs are used to calculate the expected levels of production, calving events, and removal.

Calculations for energy requirements, partitioning and emissions were based on the 'Methodology for calculation of New Zealand's agricultural greenhouse gas emissions'[4]

An understanding of an animal's energy requirements was used to estimate dry matter intake from which emissions and excretion are calculated. In the inventory, energy requirements refers to the amount of energy that is needed for an animal to survive (maintenance) and produce animal products such as milk, meat, and conceptus (pregnancy)[5]. The inventory model currently assumes that dairy cattle consume only pasture to satisfy their energy requirements, and no supplementary feed is used.

All equations were run on a monthly time step accounting for every month of the animal's life from birth to removal.

The inventory methodology has been developed to calculate national emissions. To enable the model to be used for analysing individual animals, the following changes were made to the methodology:

1. Industry level production and population data was replaced by individual animal data.
2. National average monthly pasture quality values for digestibility, crude protein percentage and metabolisable energy were generated, replacing regional values.
3. Industry average growth rates were used for all growing animals.
4. Energy requirements were added to account for average body condition changes that occur for lactating cows.
5. A calving rate model, with supporting lactation production curves, were included.
6. A removal and replacement model were included.

The results from the modelling generate monthly, annual and lifetime values for production, emission and excretion. The following metrics are used for this analysis:

1. Milksolids production (milkfat + milk protein)
2. Enteric methane
3. Urinary nitrogen

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[4] *Methodology for calculation of New Zealand's agricultural greenhouse gas emissions (Version 5)*. (2019), Ministry for Primary Industries New Zealand, https://www.mpi.govt.nz/dmsdocument/13906-detailed-methodologies-for-agricultural-greenhouse-gas-emission-calculation
[5] *Methodology for calculation of New Zealand's agricultural greenhouse gas emissions (Version 5)*. Page 58.

Results

Urinary Nitrogen

There is a strong correlation between high genetic merit animals and calculated lifetime urinary nitrogen excretion per kilogram of milksolid produced, as shown in *Figure 2*. A key driver in achieving this improvement has been the increase in per cow production without increasing cow liveweight, which reduces the proportion of feed required maintenance relative to production.

This improvement shows that an animal of $10BW higher genetic merit, is expected to produce 1.7g less urinary nitrogen per kilogram of milksolid over its lifetime. The population used was 15,397 dairy breeding bulls. The criteria was that the bulls were registered with NZAEL; born on or after 1 January 1990; and registered before 21 February 2020.

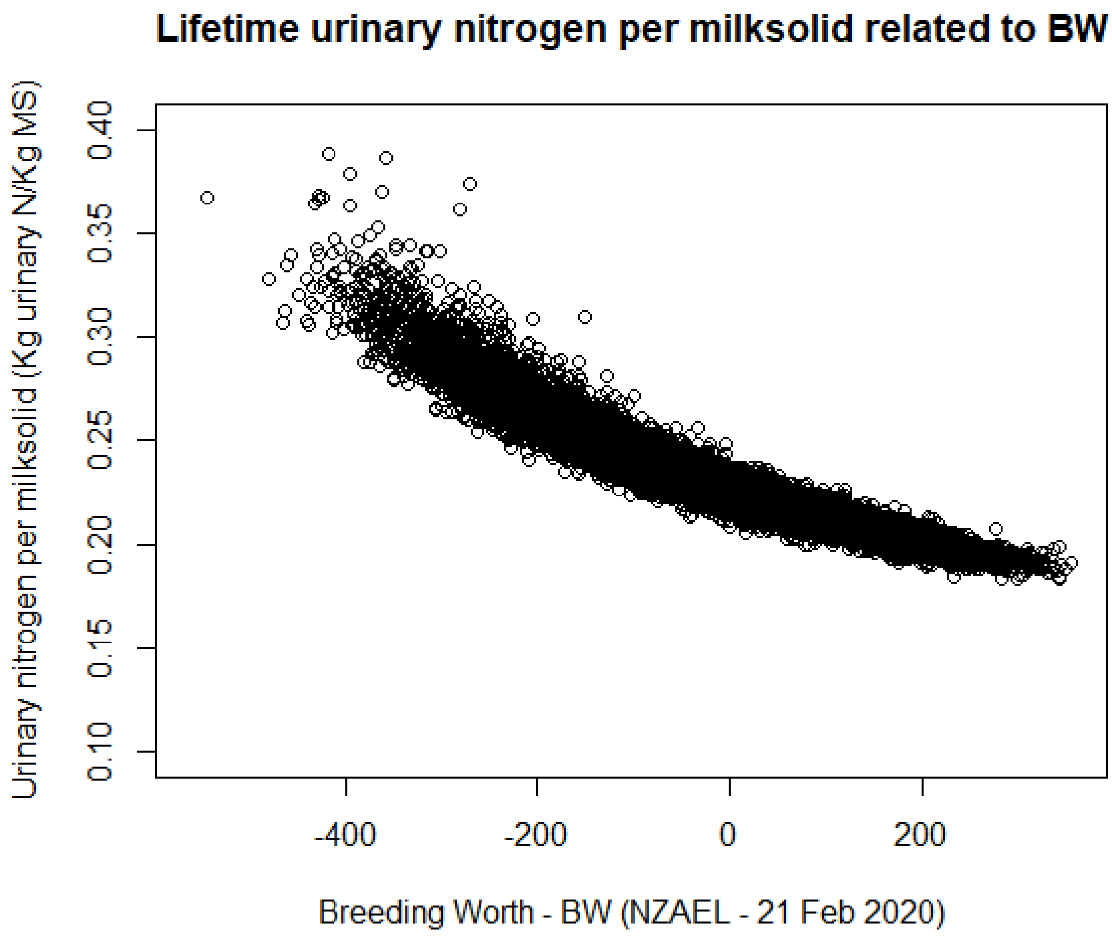

Figure 2: Lifetime urinary nitrogen per milksolid produced related to BW

A high producing cow requires more energy than a lower producing cow of the same liveweight. Therefore more urinary nitrogen is produced per cow, but this is in part offset with additional nitrogen being portioned to milk protein.

Stocking rate needs to be lowered as genetic merit increases if no changes are being made to feed supply. For per-hectare modelling a constant of 14 tonnes of dry matter per hectare eaten was used. Assuming a reduction in stocking rate occurred to match feed availability, a 1-2% reduction in urinary nitrogen per hectare was calculated. This reduction is not deemed significant, but importantly shows that there is no increase in total urinary nitrogen excreted, if feeding levels per hectare remain constant.

The reduced intensity of urinary nitrogen excretion per kilogram of product can be seen when assessing the breeding values of LIC's Premier Sires® Daughter Proven Team over the past 30 years (*Figure 3*).

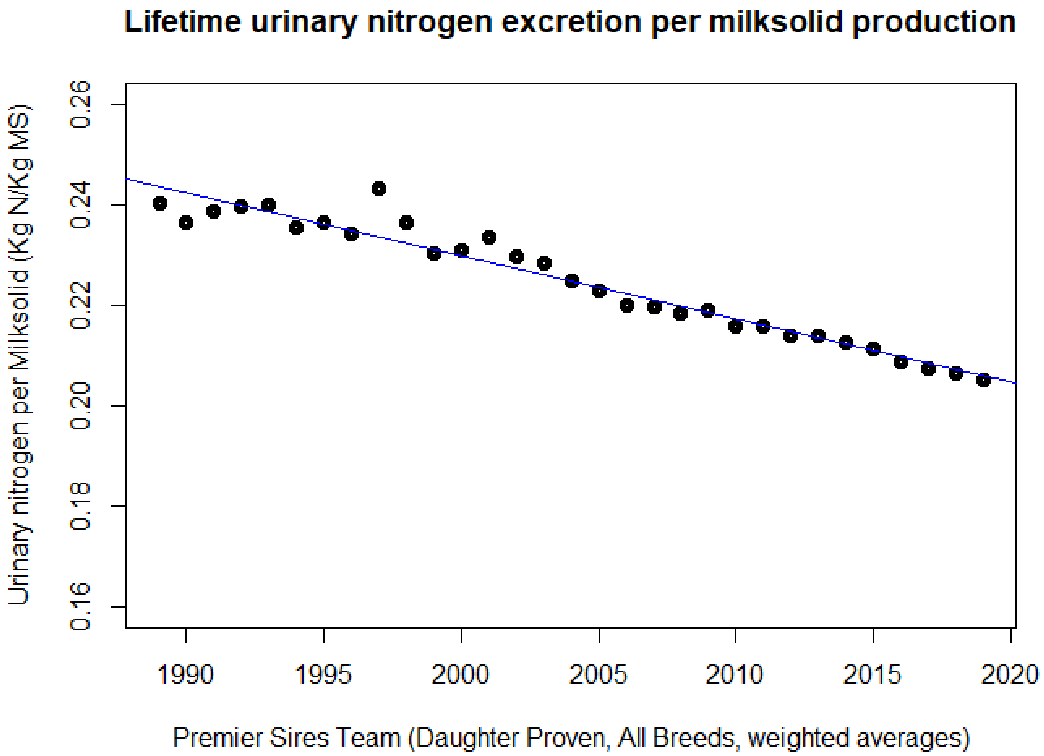

Figure 3: Urinary nitrogen: LIC Daughter Proven Premier Sires® Team over 30 years

Over 30 years there has been a 16% reduction in urinary nitrogen excreted per kilogram of milksolid, a 0.6% annual decrease.

Enteric Methane

Like urinary nitrogen excretion, there is a strong correlation between high genetic merit animals and calculated lifetime enteric methane emissions per kilogram of milksolid produced, as shown in *Figure 4*. Once again, a key driver in achieving this improvement has been the increase in per cow production without increasing cow liveweight.

This improvement shows that an animal of $10BW higher genetic merit is expected to produce 2.0g less enteric methane per kilogram of milksolid over its lifetime.

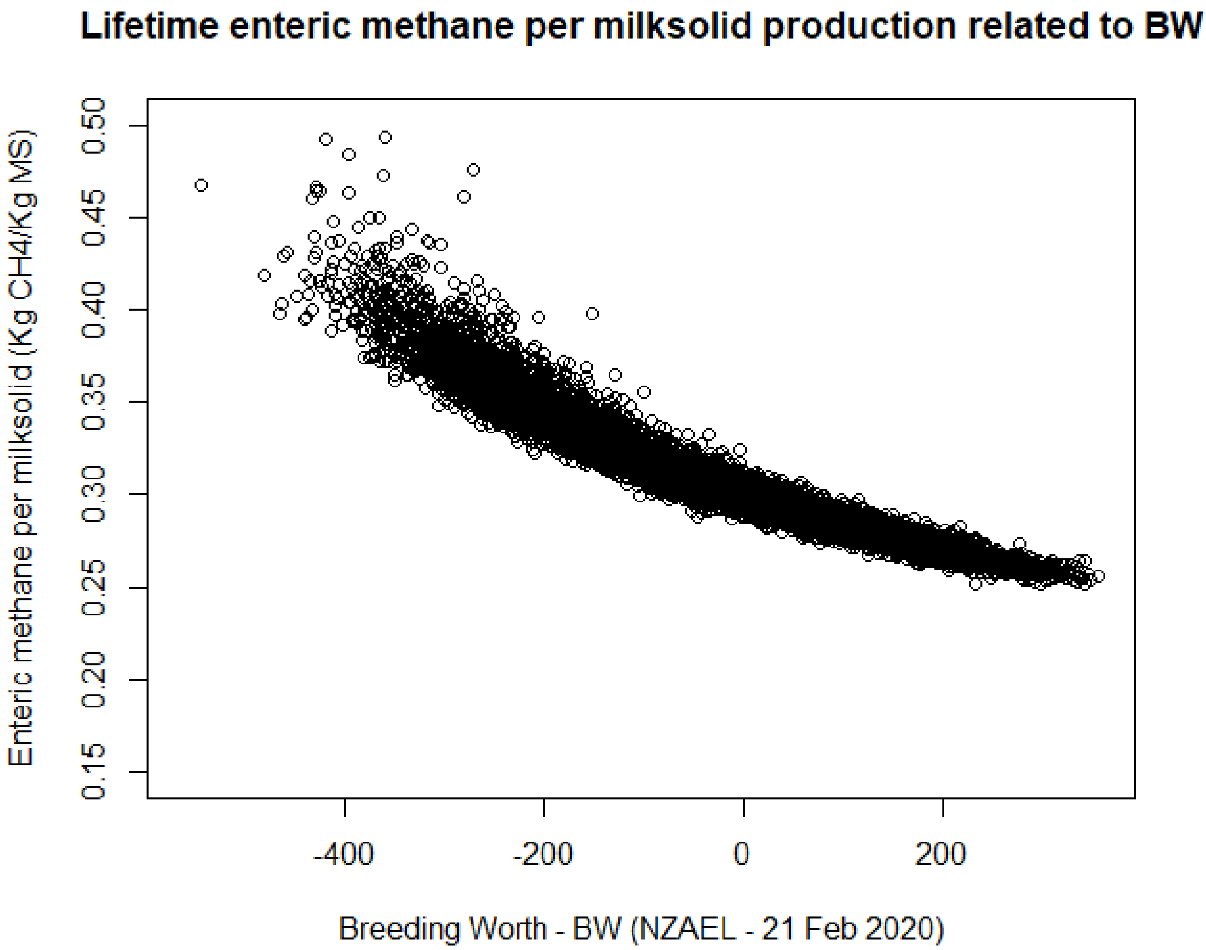

Figure 4: Lifetime enteric methane per milksolid produced related to BW

Assuming stocking rates were altered to meet the feed requirements of higher genetic merit cows using the constant of 14 tonne dry matter per hectare eaten, there would be no change in total enteric methane emissions per hectare. This is because the calculation for enteric methane emissions for all cattle classes in New Zealand is 21.6g of enteric methane per kilogram of dry matter eaten. Research is due to start in 2020 to assess genetic variance in enteric methane emission levels in New Zealand dairy cattle.

The reduced intensity of enteric methane emissions per kilogram of product can be seen when assessing the breeding values of LIC's Premier Sires® Daughter Proven Team over the past 30 years (*Figure 5*).

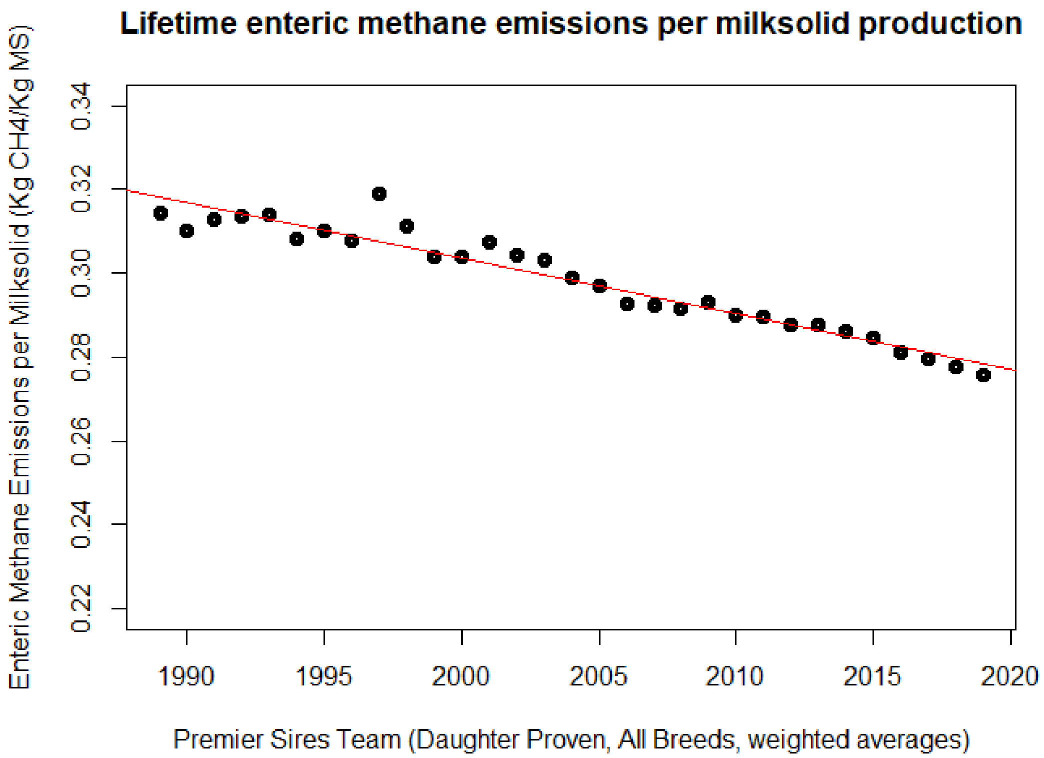

Figure 5: Enteric methane: LIC Daughter Proven Premier Sires® Team over 30 years

Over 30 years there has been a 13% reduction in enteric methane per kilogram of milksolid, a 0.45% annual decrease.

Conclusions

Breeding Worth is a good indicator of environmental efficiency, particularly regarding emissions and excretion intensity per kilogram of product. For an animal $10BW units higher than her peers, the environmental impact of one kilogram of milksolid is smaller by 1.7g urinary nitrogen and 2.0g enteric methane.

Striving to achieve the national breeding objective (to produce cows which are the most efficient convertors of pasture feed into profit) has reduced the urinary nitrogen load excreted per kilogram of milksolid by 16% over the past 30 years. Similarly the emissions intensity of enteric methane per kilogram of milksolid has reduced by 13% over the 30 year period.

When making recommendations on farm to reduce the environmental impact, it is important to consider the overall efficiency of the animals, which can be best indicated by the herd BW.