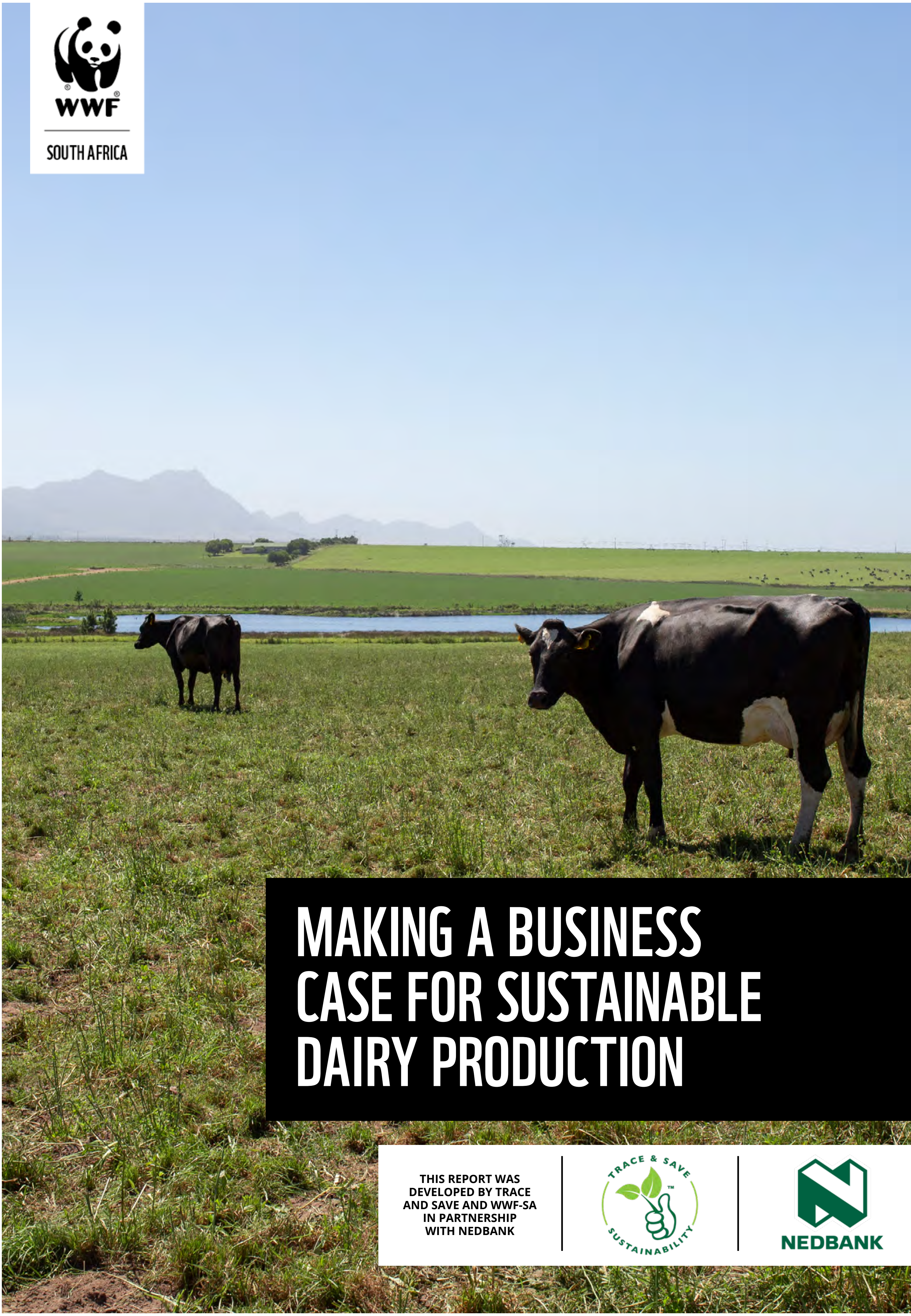

MAKING A BUSINESS CASE FOR SUSTAINABLE DAIRY PRODUCTION

THIS REPORT WAS DEVELOPED BY TRACE AND SAVE AND WWF-SA IN PARTNERSHIP WITH NEDBANK

CONTENTS

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EXECUTIVE SUMMARY

The purpose of this business case is to investigate the association between the economic and environmental facets of sustainability related to milk production on dairy farms in South Africa.

The data that was used is drawn from a case study of 62 pasture-based dairy farms between 2013 and 2019, largely from the Eastern Cape (55 farms), Western Cape (3) and KwaZulu-Natal (4) that are part of Trace & Save. Trace & Save is a sustainability assessment platform accompanied by a management system and online platform that measures, tracks and reports on sustainability at the farm level, and is designed for any soil-based form of agriculture. Given the lack of absolute measurements of sustainability performance and certification standards in the South African dairy sector, the Trace & Save system has been adopted as the guiding methodology for the business case.

An interrogation of the soil carbon levels, carbon footprints and nutrient utilisations of case study farms revealed that the best of South African pasture-based dairy farms have a comparatively low environmental impact compared to global averages. The soil carbon levels are also well above optimal. Even the medium environmental impact group reflects relatively well compared to global averages.

For agriculture to be sustainable, restoration of soil health is paramount, not just maintaining soil fertility. This is also the main goal of regenerative agriculture practices. The results revealed that sustainably produced milk relies on healthy soils that grow sufficient, good quality pastures. These pastures need to be well utilised and provide the largest proportion of feed. Farms that grow more food on the farm for their cows make more money. The bought feed that is necessary should be effectively converted into milk. Fertiliser inputs should be minimised, and nutrient efficiency optimised, which should also be associated with healthy soils. Achieving this while optimising milk production should result in more sustainable pasture-based milk.

In the statistical analyses conducted, soil carbon and nitrogen fertiliser application rates are negatively correlated. Healthy soils, which have optimal microbial life, fertility and structure, require lower fertilizer inputs to achieve optimal pasture and crop growth. This is due to the provision of nutrients to plants through natural nutrient cycling as supported by a healthy, balanced soil food web.

The gross margin of each farm was calculated as the total income per litre of milk minus the following variable costs per litre of milk - concentrates, roughage, fertiliser, electricity and fuel. This is obviously not an actual profit margin as there are costs which have been excluded e.g. labour, equipment, infrastructure, veterinarian and medical costs. However the costs which have been included to calculate the gross margin give comprehensive insight into which farms are more or less profitable than each other. One example farm increased their gross margin by 43% from R1.72/litre to R3.01/litre between 2013 and 2019 by implementing changes advocated by Trace & Save.

Higher margins are associated with a lower carbon footprint and higher nitrogen and phosphorous utilisation. The only environmental parameter not correlated with gross margin is soil carbon. Results showed that sustainability is influenced by efficiency of milk production (per hectare and per liveweight, but not per cow), both from an environmental impact and economic perspective.

This creates the distinction, where to limit environmental impact and increase profitability; milk production should probably not be pushed to the maximum per cow. It is about optimising, rather than maximising production.

It was found that rainfall did not significantly impact on environmental and economic performance. This shows that geographic location, climate and soil type do not necessarily limit or propel farm sustainability.

Projecting potential future impacts based on the results shown to be possible in this case study to all the farms in the Eastern Cape and KwaZulu-Natal provinces over the next 5 years could reduce the total carbon emissions by 10%, the excess nitrogen by 27% and the phosphorous excess by 19%. These would be significant reductions in the environmental impacts from dairy farming if farm management practices that contribute to sustainability can be implemented across all these farms.

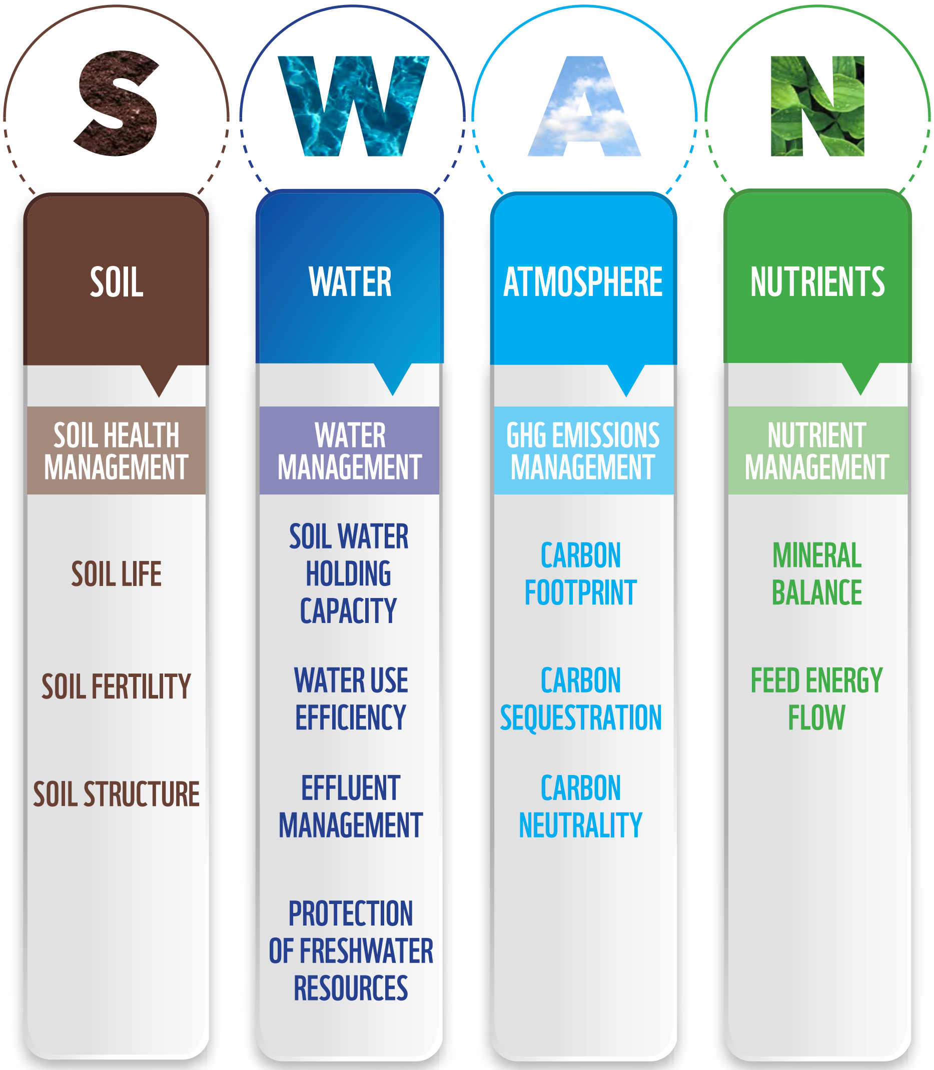
The overall conclusion drawn from the case study results is that implementing sustainable best practices should lead to more profitable milk production with a lower environmental impact. This is a win-win for farmers, for consumers, for milk processors and for the dairy industry in its entirety.

SECTION 1 - BACKGROUND

PURPOSE OF THE BUSINESS CASE

This business case document is a WWF attempt to motivate for regenerative farming practices in dairy production by using scientifically researched data on dairy farming practices to demonstrate that it should be financially advantageous to implement sustainability best practices on a pasture-based dairy farm. The business case approach centres on exploring the correlation between the economic and environmental facets of sustainability in dairy farming.

Figure 1. Indicators measured in Trace & Save's SWAN system



To these ends, the data set accumulated from 62 farms by Trace & Save between 2013 and 2019 has been used to provide a case study and the quantitative evidence for determining whether implementing sustainable production practices has financial benefit. Our investigation shows that no other data set as comprehensive or detailed exists in South Africa and there is no other sustainability assessment system, accreditation scheme or standard being used to measure and track sustainability performance on dairy farms in South Africa.

The sustainability indicators used and developed by Trace & Save are therefore the focus for the development of this business case.

The Soil, Water, Atmosphere, Nutrients (SWAN) system comprises measures of soil health, water management, greenhouse gas emissions and nutrient management. The indicators which are measured and make up the SWAN system are laid out in Figure 1.

RATIONALE FOR THE TRACE & SAVE SYSTEM

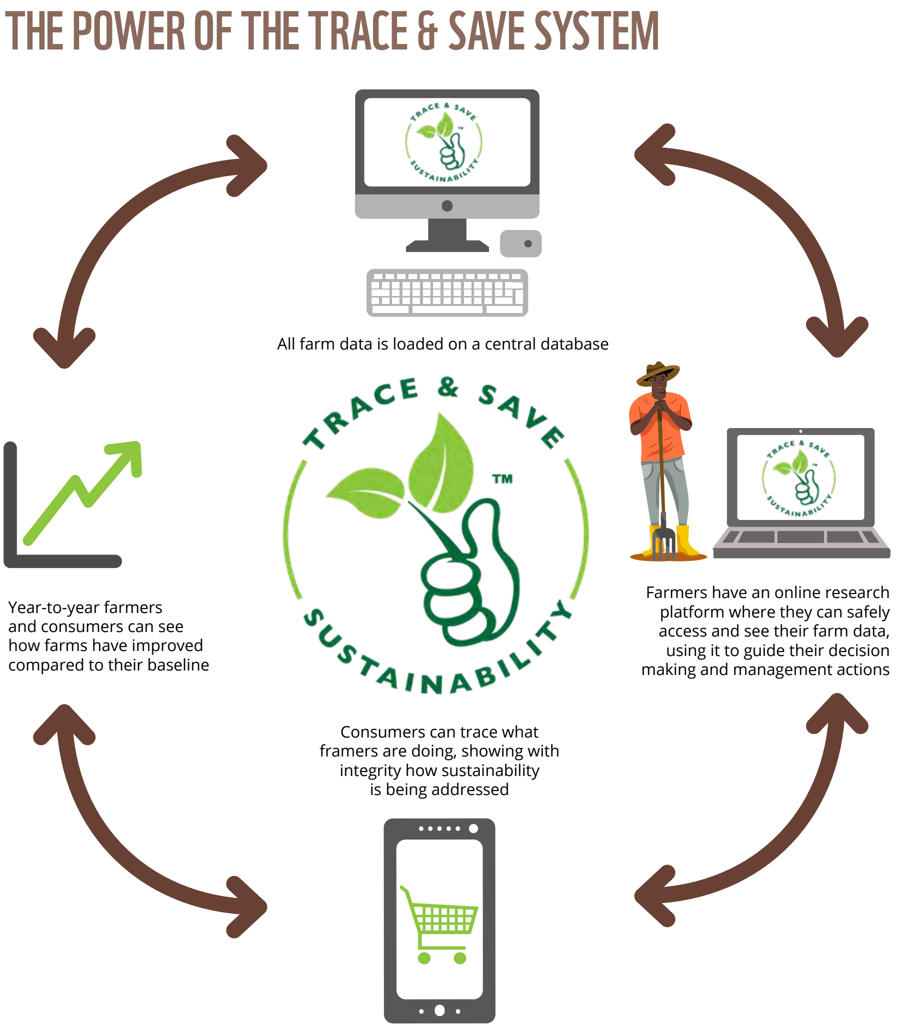
Given the lack of absolute measurements of sustainability performance and certification standards, particularly in the South African dairy sector, the Trace & Save guidelines have been adopted as the guiding methodology for the business case.

Trace & Save (www.traceandsave.com) is a sustainability assessment platform accompanied by a management system and data platform that measures, tracks and reports on sustainability at the farm level, and is designed for any soil-based form of agriculture. Trace & Save aims to encourage and assist the implementation of regenerative, sustainable agricultural practices on farms.

Measures of indicators of sustainability are provided, allowing farmers to track changes on their farm pertaining to sustainability, while being assisted and advised in how to become more sustainable in their practices. Trace & Save started in 2012 with pasture-based dairy production but can be adapted for other forms of farming such as vegetable, grain and fruit production, provided they are soil based considering soil sampling is a key focus of the system.

Trace & Save uses the on-farm measures and indicators of sustainability indicated above in Figure 1 to determine an integrated sustainability score for a dairy farm. The score is the average of the Soil, Water, Atmosphere and Nutrient (SWAN) scores, each of which is a composite of the various indicators used. The results are represented spatially through an online platform and database which provides traceability and allows the farmers and consumers to see year to year how farms have improved compared to their baseline (Figure 2).

Figure 2. Elements of the Trace & Save system and how it works.



The Trace & Save system is comprised of the following components:

1. **The SWAN system** - measures of soil health, water management, green house gas emissions (atmosphere) and nutrient management (SWAN).
2. **Biodiversity management** checklist (qualitative not quantitative assessment)
3. **People wellbeing**
4. **Animal welfare**

Each facet of the SWAN system is made up of several indicators, which include farm specific measures, providing insight for farm management decision-making. All the measures included are backed by sound, scientific principles and research. The system is also dynamic, constantly growing and evolving as new research and insights become available, or based on the needs of farmers and the dairy sector.

BACKGROUND ON THE CASE STUDY

The farms included in this case study are pasture-based dairy farms from the Eastern Cape (EC) predominantly, KwaZulu-Natal (KZN) and the Western Cape (WC) provinces of South Africa.

They are all farms that Trace & Save work with or have worked with since 2013. The majority (64%) of the farms have been working with Trace & Save through their participation in the Woodlands Dairy Sustainability Project (WDSP). The rest of the farms are private clients of Trace & Save.

Farms have also not provided data for the same periods of time, due to certain farmers being early adopters, while others have only had access to Trace & Save more recently. For this reason, a variable number of farms have been included in each analysis, which will be explained for each context.

There are 62 farms included in this case study in total. Although they only form 5.5% of the total dairy farmers in South Africa, they contribute 10% of the milk produced (Table 1).

When considering the main pasture-based dairy producing regions in South Africa (the EC and KZN), the farms included in the case study represent 18% of this milk production.

Most of the farms are in the EC (55) and represent 30% of the milk production in the EC. The farms in the case study are therefore well representative of pasture-based dairy production in South Africa.

There are four farms in KZN and three farms in the Western Cape included, as Trace & Save has only started working in these regions from 2018. Most of the farms are mixed irrigation and grain-fed (43), with six being irrigation only and 13 being rain-fed only farms."

The rest of the farms are distributed between the Tsitsikamma, Humansdorp, Oyster Bay, George, Underberg and the KZN midlands.

Table 1. Farms included in the case study relative to dairy farming in South Africa.

DAIRY FARMING FACTORS	SOUTH AFRICA	CASE STUDY
Number of dairy farmers	1 119	62 (*5.5%)
Total milk production (million tons)	3.4	0.35 (*10%)
Average cows in herd (cows in milk and dry cows)	439	1 003 (*223%)
Average milk production per farm (tons)	3068	5 736 (*207%)
Average farm area (ha)	400 od ha	424

Source: MPO (2020); Trace & Save (2020)

** Percentage of National*

CASE STUDY ASSUMPTIONS

Understanding the measures used

For the case study, each year of data for a farm has been included as a data point. Only farms where the heifers are raised on the farm are included in the assessment. Any farm which had less than 12% heifers (which was decided on as a threshold indicator of where not all heifers are raised on the farm) as a percentage of the total animals on the farm, were excluded from these analyses. It is not possible to compare farms where heifers are raised on the farm to those where they are not, as the amount of land, feed and other inputs are much higher where heifers are included, whereas there is no additional milk production. Farms which do not raise heifers on the farm either have a separate farm where they are raised or they outsource the raising of heifers to another farmer.

There are therefore 62 farms which have been included with an average of 3.2 years of data per farm. There is one farm with eight years of data, five with seven years, three with six years, nine with five years, eight with four years, six with three years, nine with two years and 21 with one year of data. This gives a total of 195 farm years included in the analyses. Since this is system-based research there are obviously no control farms included.

It is important to note that these scores are not an absolute performance assessment with regards to sustainability. It is not advised to directly compare farms scores and conclude that one farm is better than the other.

Farmers are encouraged to improve on their baseline scores and improve year-to-year. Becoming more sustainable is a process of improvement, and the measures used in the SWAN system give an indication whether that is happening on a particular farm.

The water component of the SWAN system has been excluded from this case study. Although water data has been collected by Trace & Save on farms over the past eight years, a large proportion of this data was based on estimated figures by the farmers. It was therefore decided to rather exclude this data, as unreliable data can lead to unreliable analyses and results. Rather than providing insight, this data could have the potential to confuse. Ideally, for future studies, water data must be included as water stewardship is such an integral part of sustainable farming. For this to be possible farmers need to install water meters and collect more accurate water use data on their farms.

Soil carbon has also been used as the indicator of soil health. Soil carbon levels are correlated with the overall Soil score used by Trace & Save (Spearman's rho = 0.71; $p < 0.01$). Since the soil score is complex, whereas soil carbon is a simple, straightforward concept that everyone can relate to, it was decided to use it to incorporate the soil health aspect of the SWAN system and sustainable farming.

Partial productivity measures are indicators of how efficiently farms are producing milk. Each of these measures indicates the efficiency of a certain aspect of farm management, for example fertiliser efficiency, or feeding efficiency. Together with the sustainability assessments, these measures provide insight into what the optimal farm system is for sustainable pasture-based milk production.

THE PARTIAL PRODUCTIVITY MEASURES INCLUDED ARE:

Milk production	**(litres per hectare)**: Making efficient use of the available land is important to a productive farm. This measure is not easily compared between farms though, as the value of one hectare of land is not always comparable, so this measure should be used with some caution.
Milk production	**(litres per cow per day)**: This is also a measure that needs to be used with caution, as production per cow is not a significant indicator of efficiency in and of itself. That said, it is still important that cows are producing milk efficiently.
Milk production	**(litres per 100 kilograms of live weight)**: This is the litres per cow per standardised lactation (litres per cow per day times 305 days) divided by the average weight of cows in milk (CiM) divided by 100. It is one of the most important milk production efficiency indicators. By removing many of the variables associated with milk production, for example cow size and breed, it gives insight on the actual performance in production efficiency.
Milk production	**(kilograms of solids per 100 kilograms of live weight)**: This is the measure described above, multiplied by the density of milk (1.028 kg/l) and multiplied by the percentage of butterfat and protein (which the farmer is paid for – lactose is part of the milk solids, but not economically important). Milk does not only have value in terms of quantity, but also in terms of the fat and protein proportion, and this measure gives an indication of how efficiently a farm is producing milk solids.
Concentrates to cows in milk	**(grams per litre)**: This is a measure of the total grams of concentrates fed to CiM throughout the year, divided by the total milk production on the farm. It is a simple measure of feed conversion efficiency. Concentrates are the most expensive form of feed; therefore the less efficiently concentrates are fed, the less profitable the milk production.
Bought non-pasture roughage	**(grams per litre)**: A similar measure to the one above but considering roughage rather than concentrates. It is therefore also a measure of feed efficiency. The calculation is the total grams of bought roughage fed to all animals on the farm divided by the total milk production on the farm.
All farm-grown feed	**(grams per litre)**: This is a feed-conversion efficiency measure focused on the irrigated pasture, dryland pasture and roughage grown on the farm. It is the total grams of this feed produced divided by the total milk production on the farm.
Fertiliser	**(kilograms of nitrogen, phosphorous and potassium per hectare per year)**: Nitrogen, phosphorous and potassium are the three most significant forms of fertiliser and therefore their efficient use is an important indicator of productivity.
Heifer replacement	**(percentage of heifers needed to maintain the milking herd each year)**: This figure is calculated as half of the total heifers on the farm divided by the milking herd size (CiM plus dry cows). It gives an indication of CiM longevity, breeding efficiency and general animal husbandry. There is a cost, both direct and opportunity, to raising heifers, so ideally the least possible amount should be raised. On certain farms this figure can be skewed if the farm is expanding, therefore extra heifers are raised for growth and not replacement plus breeding objectives, but this distinction is not made when the data is collected. The reality is that those heifers are an investment for the future, but accurately reflect as a cost for that particular year.
Soil carbon (%)	This is the average total soil carbon (LECO) for each farm from composite soil samples taken across the whole milk platform at a depth of 0-15cm. Soil samples were not taken every year at the beginning of the Woodlands Dairy sustainability project, so soil samples and other data have been aligned as closely as possible. Soil carbon is the best indicator of soil health. It helps to store water and nutrients, provides food to soil organisms, and contributes to improve soil structure.
Rain (millimetres per year)	Rainfall is not an efficiency indicator, but rather an explanatory factor that is important to include.

Since Trace & Save does not directly collect financial data from farmers, a gross margin was calculated for each farm as an indicator of profitability. **The gross margin has been calculated as the total income per litre of milk (income from milk and meat sales) minus the following variable costs per litre of milk: concentrates, roughage, fertiliser, electricity and fuel.** It is recognized that this is obviously not an actual profit, and that there are fixed and other costs which have been excluded (e.g. labour, equipment, infrastructure, veterinarian and medical costs), but the costs which have been included give comprehensive insight into which farms are more or less profitable than each other.

Effective management and implementation of sustainability best practices is an integral component of sustainable farming. Trace & Save does not have a direct measure of management effectiveness, but the measures in the SWAN system serve as indicators of how well best practices are being implemented. This is especially true as a farm works with Trace & Save over a period. Improvements in the SWAN system indicators are a very good indicator of effective implementation of sustainability best practices.

Examining sustainable pasture-based dairy farming

To better understand the intersecting goals of reduced environmental impact and long-term profitability, each goal is explored individually. Partial productivity measures are used to examine:

- Which farm system is associated with the lowest environmental impacts, and
- Which farm system is associated with the highest profitability.

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SECTION 2 - ENVIRONMENTAL IMPACT

ENVIRONMENTAL IMPACT OF CASE STUDY FARMS

The environmental impact of farms was determined using four indicators, namely carbon footprint, soil carbon, nutrient use efficiency and phosphorus use efficiency. Each of these measures have been categorised and scored for each farm according to the following criteria:

Carbon footprint	Farms have been categorised into terciles of low = 1 (0.814 – 1.101 kg CO_2e/kg FPCM), medium = 2 (1.103 – 1.247 kg CO_2e/kg FPCM), and high = 3 (1.249 – 2.444 kg CO_2e/kg FPCM) carbon footprints.
Soil carbon	Soil carbon norms differ according to texture. Trace & Save uses soil carbon norms based on the figures specified by Gugino et al. (2009). Farms have been categorised as good = 1 (sand: > 2.26%; loam: > 2.34%; silt: > 2.41%), average = 2 (sand: 1.29% – 2.26%; loam: 1.47% - 2.34%; silt: 1.64% - 2.41%), and poor = 3 (sand: < 1.29%; loam: < 1.47%; silt: < 1.64%).
Nitrogen use efficiency (NUE)	Farms have been categorised into terciles of high = 1 (65.0% - 30.0%), medium = 2 (29.4% - 22.4%) and low = 3 (22.3% - 7.9%) NUE.
Phosphorous use efficiency (PUE)	Farms have been categorised into terciles of high = 1 (94.5% - 35.6%), medium = 2 (35.2% - 26.0%) and low = 3 (25.9% - 8.9%) PUE.

Refer to Galloway et al. 2018 for how the carbon footprint, nitrogen use efficiency and phosphorous use efficiency measures were calculated. An overall environmental impact score was then calculated by adding the four scores together. The lower the overall score, the lower the farms environmental impact. Farms were grouped into three groups: low, medium and high impact categories, based on the criteria in Table 2.

Table 2. Criteria used to categorise farms into environmental impact groups.

	Score (as per the categorised scores described above)	**No. of farms**
Low environmental impact	4 – 6	66 (11 farms have a score of 4)
Medium environmental impact	7 – 8	68
High environmental impact	9 – 12	61

An overview of the average farm system for the three environmental impact categories can be found in Table 3.

Table 3. Average environmental impact and partial productivity measure scores for each environmental impact group. These scores can be used to better understand the average farm system for each group and what the differences are between the groups.

Parameters	Low environmental impact group		Medium environmental impact group		High environmental impact group		ANOVA	Correlation with enviromental impact
	Mean	*Std dev*	*Mean*	*Std dev*	*Mean*	*Std dev*	*F*	*Spearman's rho*
Carbon footprint (kg CO2e/kg FPCM)	*1.08*	*0.14*	*1.16*	*0.12*	*1.38*	*0.28*	***41.6*****	***0.64*****
NUE (%)	*36*	*9*	*25*	*6*	*20*	*4*	***89.4*****	***-0.77*****
PUE (%)	*42*	*13*	*32*	*15*	*25*	*4*	***29.8*****	***-0.57*****
Soil carbon (%)	*3.7*	*1.7*	*3.1*	*1.5*	*2.5*	*0.9*	***11.9*****	***-0.35*****
Stocking rate (kg weight/ha)	*1 633*	*571*	*1 506*	*605*	*1 501*	*680*	***0.9***	***-0.16****
Milk production (l/ha)	*16 198*	*5 934*	*14 923*	*5 801*	*12 928*	*6 452*	***4.6*****	***-0.26****
Milk production (l/cow/day)	*18.9*	*3.2*	*18.9*	*2.8*	*17.6*	*3.3*	***3.4****	***-0.12***
Milk production (l/100 kg weight)	*1 204*	*150*	*1 223*	*148*	*1 108*	*174*	***9.5*****	***-0.23*****
Milk production (solids/100 kg weight)	*95*	*13.5*	*96.2*	*14.8*	*85.4*	*17.4*	***10.1*****	***-0.27*****
Concentrates to CiM (g/l)	*321*	*60*	*346*	*75*	*399*	*92*	***16.6*****	***0.37*****
Bought non-pasture roughage (g/l)	*131*	*118*	*138*	*133*	*206*	*146*	***3.6****	***0.09***
All farm grown feed (g/l)	*943*	*248*	*972*	*292*	*1 039*	*347*	***1.7***	***0.12***
Farm grown feed contribution (%)	*60*	*10*	*60*	*10*	*57*	*10*	***2***	***-0.12***
Fertiliser (kg N/ha)	*163*	*91*	*241*	*121*	*250*	*132*	***11.0*****	***0.27*****
Fertiliser (kg P/ha)	*12.1*	*12.7*	*28.2*	*32.6*	*29*	*34.4*	***7.3*****	***0.21*****
Fertiliser (kg K/ha)	*61.8*	*78.3*	*77*	*70.5*	*77.3*	*89*	***0.8***	***0.02***
Heifer replacement (%)	*31*	*10*	*29*	*8*	*31*	*9*	***1.6***	***0.02***
Rain (mm/year)	*644*	*270*	*623*	*259*	*663*	*300*	***0.3***	***-0.02***

There are quite a few areas which distinguish the low, medium, and high environmental impact groups. Interestingly, stocking rate is not one of them. All the milk production efficiency indicators, except litres per cow per day, are negatively correlated with the environmental impact score. Optimal milk production is imperative to limiting environmental impact. What is important to note though is that production per 100kg live weight and solids per 100kg live weight are highest in the medium impact group, with production per cow being the same as in the low impact group. Production in litres and solids per 100kg live weight are also negatively correlated with environmental impact, and concentrates fed are positively correlated with environmental impact. This means that a lower environmental impact is associated with lower milk production and lower feeding with concentrates. Taking into consideration that the highest environmental impact group has the lowest milk production and the highest feeding (concentrates and bought non-pasture roughage) rates, with the goal of reduced environmental impact in mind, farmers should think about how to optimise, rather than maximise, milk production. Especially if maximizing production is reliant on using more bought feed.

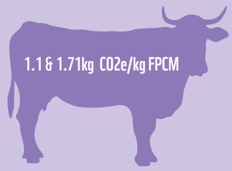
Feed conversion efficiency is an important component of reducing environmental impact. Concentrates, bought roughage and farm grown feed fed per milk production are all lowest on the low environmental impact farms. Concentrates and bought roughage are also positively correlated with low environmental impact scores. It is interesting that there is no difference in the farm-grown feed contribution between the groups. The average of 60% is quite low when considering the general consensus among farmers that the aim should be 70% plus on pasture-based dairy farms. This can be explained by the fact that four of the years included in this case study were drought years, and therefore farmers have relied heavily on bought feed.

Fertiliser is another one of the inputs that significantly contributes to the negative environmental impacts from agriculture. Lower nitrogen and phosphorous fertiliser application rates are associated with lower environmental impact. The concern with low fertiliser rates is often that it will result in insufficient pasture growth. When considering that the home-grown feed contribution is equal between the groups of farms and the milk production per hectare is highest on the low impact group farms and the feed conversion is optimal, there is no evidence of insufficient pasture growth.

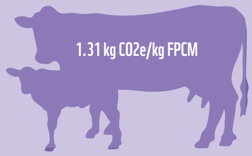
There is also no difference in rainfall rates between the groups, nor is there a correlation between rainfall and environmental impact scores. There are very high standard deviations in rainfall between the groups. There are also farms from each region in each of the groups – there was no observable grouping of farms according to region. **This is important as it indicates that low environmental impact is not necessarily associated with a specific geographic region, soil type or climate.**

IMPLICATION ON CARBON EMISSIONS

There is very little South African data available to compare the case study findings to. One life cycle analysis conducted in the Western Cape with five Ayrshire dairy producers obtained farm gate carbon footprints between 1.1 and 1.71kg CO_2e/kg FPCM (Dairy Mail, 2016).



Comparing the average carbon footprint of the case study farms to average carbon footprints globally, the low environmental impact group of farmers have a lower average carbon footprint than Oceania (1.31 kg CO_2e/kg FPCM),



Eastern Europe (1.34), North America (1.29) and Western Europe (1.37) in 2015 (FAO & GDP 2018).

The global average carbon footprint of dairy farms in 2015 was 2.40 kg CO_2e/kg FPCM.

Making direct comparisons for carbon footprints is not always easy, as one must compare apples with apples. These figures come from pre-farm-gate, lifecycle assessment. While there might be slight differences in methodology they should be comparable in principle.

IMPLICATION ON NUTRIENT EFFICIENCY

A nutrient efficiency score reflects the efficiency with which nitrogen, phosphorous and potassium have been used on each farm. Better nutrient use efficiency is associated with lower concentrates and bought roughage feed per litre of milk, a higher contribution from home-grown feed and lower nitrogen, phosphorous and potassium fertiliser application rates.

Comparing the average nitrogen use efficiency (NUE) of the case" and "Gourley et al. (2012) reports NUEs of between 8% - 50%, and an and an average Phosphorous Use Efficiency (PUE) of 32% on dairy farms in New Zealand, Australia, Europe and the USA. The averages for the farms in this case study are between 20% - 36% for NUE and 25% - 42% for PUE, which are comparable to the data from Gourley et al. (2012). None of this data reflects well on the environmental impact of dairy farming though and should be a goal for improvement by the dairy industry. The best NUE for farms in this case study is 65%, with three other farms having a NUE over 50%. The PUE's in the low environmental impact group are 10% higher than the average found in other parts of the world. No other South African NUE figures are available for comparison.

This data shows that the best of South African pasture-based dairy farms have a relatively low environmental impact. The soil carbon levels are also well above optimal. Even the medium environmental impact group reflects relatively well compared to global averages.

SECTION 3 - ECONOMIC IMPACT

IMPLICATION ON PROFITABILITY - FINANCIAL BENEFIT OF IMPLEMENTING SUSTAINABILITY BEST PRACTICES

To transform production and input data to financial data, and to calculate the gross margin, a number of calculations were used based on pricing data from 2020 and data from representative farm's data as indicated in Table 4 below. As discussed above, the gross margin is the income from milk and meat per litre and/or hectare, minus the costs of concentrates, bought roughage, fertilizer, electricity and fuel per litre and/or hectare.

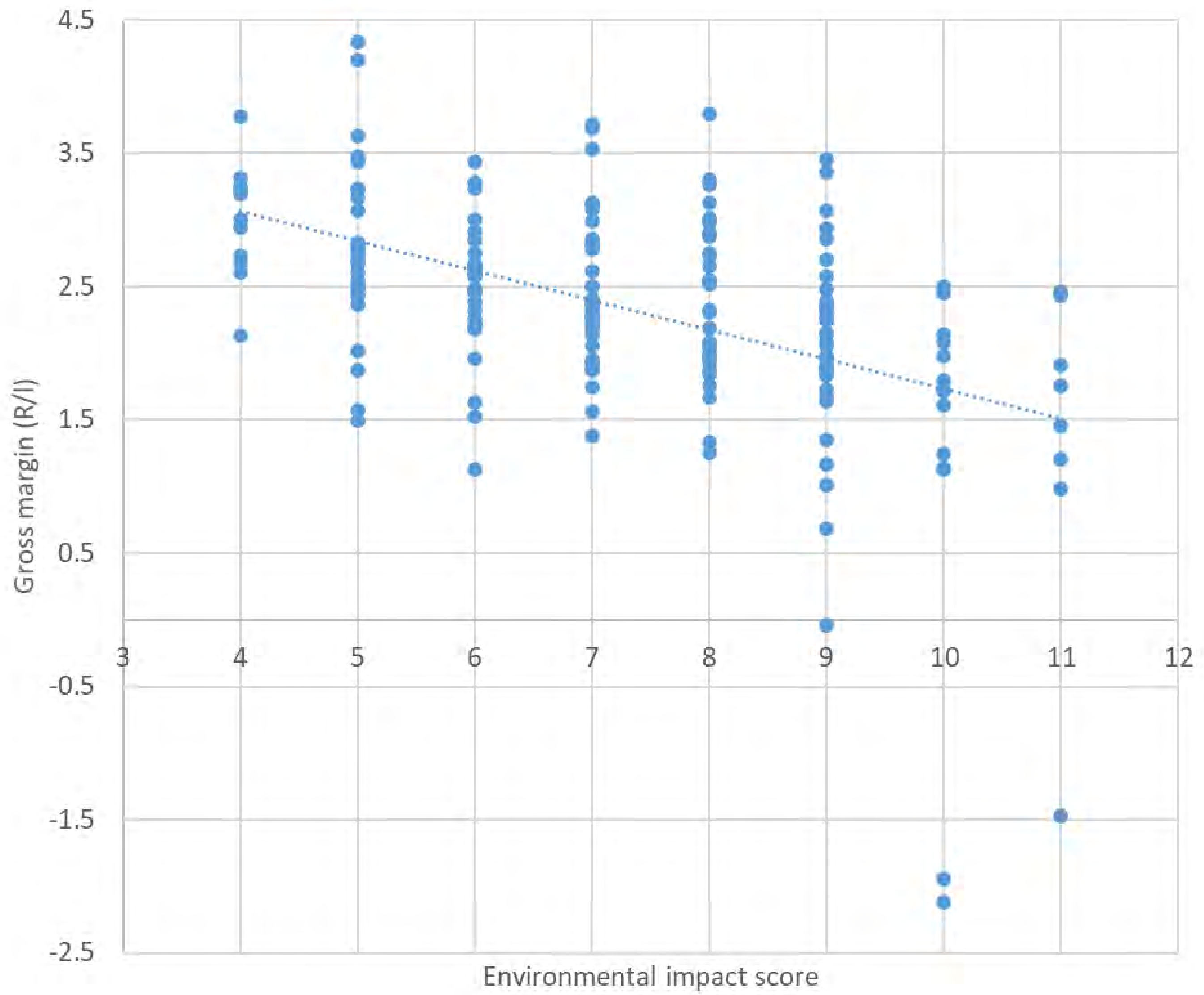
Table 4. Metrics and pricing used to transform production and input data to financial data in order to calculate a gross margin, which has been used as an indicator of farm profitability.

PRODUCTION AND INPUT DATA	METRICS USED FOR CONVERSION INTO FINANCIAL DATA	VALUES OR COSTS USED (R)
Milk income	Litres of milk production has been converted to kilograms of fat and protein corrected milk (FPCM), which is defined as raw milk with 4.00% fat and 3.30% protein. This allows for a standardised price per kilogram of milk, while giving the value to farmers who produce higher solids.	The milk price is relative to the year. Milk prices of R3.37 for 2012, R3.45 for 2013, R3.98 for 2014, R4.10 for 2015, R4.15 for 2016, R4.57 for 2017, R4.36 for 2018 and R4.38 for 2019 per kg FPCM have been used.
Animal sales income	The number and average weight of animals sold from the farm (milking cows, heifers, and bull calves) is recorded by Trace & Save.	Prices, obtained in the same manner as the milk prices, used are R15/kg for milking cows, R30/kg for bull calves and R30/kg for heifers for all years. These are rough estimate figures but are satisfactory in terms of placing a relative value on animal sales.
Cost of concentrates	Concentrates have been priced based on the total megajoule (MJ) contribution from concentrates on the farm for the year.	Prices of R0.29 for 2012, R0.29 for 2013, R0.28 for 2014, R0.29 for 2015, R0.38 for 2016, R0.26 for 2017, R0.32 for 2018 and R0.39 for 2019 per MJ have been used.
Cost of bought roughage	The same principle of pricing based on total MJ provided has been used as with the concentrates.	Prices of R0.15 for 2012, R0.17 for 2013, R0.17 for 2014, R0.18 for 2015, R0.27 for 2016, R0.26 for 2017, R0.31 for 2018 and R0.27 for 2019 per MJ have been used. The cost of lucerne was particularly high in 2016, 2017 and 2018.
Cost of fertiliser	The cost of fertiliser has been calculated on a price per kilogram of nutrient basis. A distinction has been made between chemical and organic nutrients. The costs per nutrient per year are provided in Table 6 in the Appendix.	
Cost of electricity	A standard cost of R1.00 per kilowatt hour has been used.	
Cost of fuel	A standard cost of R13.60 per litre of diesel has been used.	

There are some interesting relationships between economic and environmental parameters (the full correlation results can be found in Table 7 in the Appendix). The most important correlation is between gross margin (per litre and per ha) and the environmental impact score (Figure 3). It shows that higher margins are associated with lower environmental impacts (lower impact scores). Exploring this relationship further, higher margins are associated with a lower carbon footprint and higher nitrogen and phosphorous utilisation.

The only environmental parameter not correlated with gross margin is soil carbon, which is not surprising as gross margin varies each year, whereas soil carbon is accumulative. Although soil carbon is not correlated to margin, it is associated with lower fertiliser and fuel costs. It has already been noted that better soil carbon levels lead to reduced need for fertiliser. Fuel usage will also be lower where less fertiliser is applied.

Figure 3: Lower environmental impacts are associated with higher gross margins. The trendline shows that as the environmental impact of farms increases, the lower the gross margins are.



Case study farms have been further categorised into low, medium and high profitability groups based on gross margin data alone (Table 5).

Table 5. Average economic and partial productivity measure scores for each profitability group. These scores can be used to better understand the average farm system for each group and what the differences are between the groups

Parameters	High profitability group		Medium profitability group		Low profitability group		ANOVA	Correlation with gross margin
	Mean	*Std dev*	*Mean*	*Std dev*	*Mean*	*Std dev*	*F*	*Spearman's rho*
Gross margin (R/l)	*3.09*	*0.38*	*2.37*	*0.16*	*1.5*	*0.84*	***142.8*****	***1***
Gross margin (R/ha)	*48 052*	*18 666*	*37 006*	*14 673*	*21 280*	*13 924*	***46.6*****	***0.62*****
Income (R/l)	*5.1*	*0.35*	*4.78*	*0.4*	*4.56*	*0.44*	***29.9*****	***0.52*****
Cost (R/l)	*2.01*	*0.3*	*2.41*	*0.39*	*3.07*	*0.98*	***45.6*****	***-0.71*****
Stocking rate (kg weight/ha)	*1 575*	*556*	*1 583*	*606*	*1 484*	*704*	***0.5***	***0.14***
Milk production (l/ha)	*15 660*	*5 900*	*15 576*	*5 943*	*12 954*	*6 494*	***4.1*****	***0.22*****
Milk production (l/cow/day)	*18.1*	*2.5*	*19.1*	*3*	*18.3*	*3.9*	***1.9***	***0.02***
Milk production (l/100 kg weight)	*1 212*	*137*	*1 212*	*154*	*1 117*	*185*	***7.7*****	***0.21*****
Milk production (solids/100 kg weight)	*98.9*	*11.7*	*94.9*	*14.7*	*83.5*	*15.3*	***21.2*****	***0.44*****
Concentrates to CiM (g/l)	*307*	*62*	*343*	*64*	*413*	*84*	***37.4*****	***-0.59*****
Bought non-pasture roughage (g/l)	*104*	*100*	*144*	*116*	*223*	*251*	***8.2****	***-0.24*****
All farm grown feed (g/l)	*1 016*	*269*	*944*	*252*	*990*	*368*	***1***	***0.08***
Farm grown feed contribution (%)	*65*	*8*	*59*	*8*	*54*	*11*	***24.4*****	***0.46*****
Fertiliser (kg N/ha)	*216*	*122*	*243*	*128*	*193*	*113*	***2.8***	***0.1***
Fertiliser (kg P/ha)	*23*	*20*	*28*	*36*	*18*	*29*	***2.1***	***0.21*****
Fertiliser (kg K/ha)	*74*	*64*	*84*	*86*	*58*	*87*	***1.7***	***0.18****
Heifer replacement (%)	*29*	*8*	*30*	*9*	*33*	*10*	***3.7****	***-0.16****
Rain (mm/year)	*660*	*256*	*687*	*288*	*592*	*280*	***2.6***	***0.15****

*** p ≤ 0.01 and * p ≤ 0.05 Bold values indicate a significant correlation*

Trace & Save estimates that the costs included in calculating the gross margin make up about 55 - 65% of the total cost of production on pasture-based dairy farms. The costs included are the most important, management impacted variable costs on a farm. Of course, costs which have been left out, for example labour, veterinarian and medication costs, will be lower on some farms and higher on others, but the relative difference between farms is not as big as the costs included in this case study. The distribution of average costs in this case study were 64% (± 11%) for concentrates, 15% (± 13%) for roughage, 11% (± 6%) for fertiliser, 5% (± 3%) for electricity and 5% (± 2%) for fuel.

The results in Table 5 show that costs are more negatively correlated with gross margin than the positive correlation between income and gross margin (higher Spearman's rho value), and costs are more significantly different between the profitability groups than income (higher ANOVA F value). Therefore, cheaper milk production is more important than higher income. That said, the more profitable farms are also getting a higher income per litre. This comes from these farms producing higher solids, as animal sales only make up 7% of the income per litre.

As with environment impact, gross margin is correlated to milk production and therefore the similarity in systems is that milk production must be optimised for high profitability and low environmental impact. The one aspect of milk production that gross margin is not correlated to is production per cow. This emphasizes how little importance this measure has – it does not indicate optimisation, nor is it associated with profit. Optimal production should be measured relative to the size of the cow and relative to the area used for milk production.

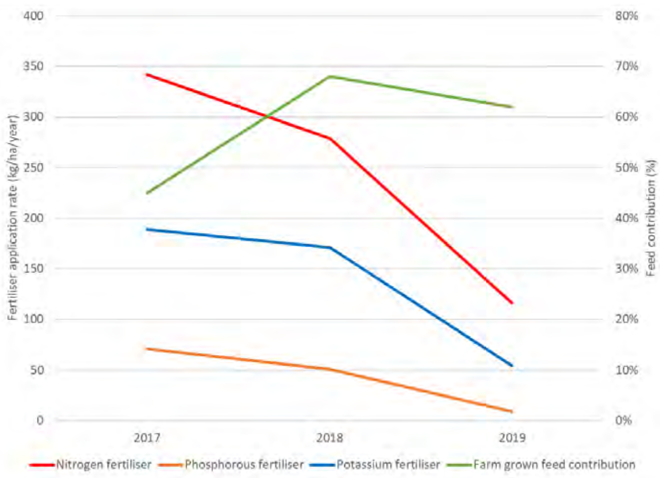
It is interesting to note that there are no significant differences in fertiliser application rates between the profitability groups, although there is a positive correlation between phosphorous and potassium fertiliser application rates and gross margin. There is not enough data to definitively say this, but it would appear the greater contribution in home-grown feed comes from a higher fertiliser application rate on high profit farms than on low environmental impact farms.

This means that the negative environmental impact from fertiliser application is more significant than the costs of applying fertiliser to grow feed on the farm. That said, nitrogen and phosphorous use efficiency are positively correlated with gross margin. This association can be mainly explained by feed conversion efficiency rather than fertilisation. Farmers do often make the argument that it is worth using the extra fertiliser to grow the extra feed on the farm and the results would agree with them purely from a financial perspective. When incorporating the environmental goal of sustainability, it is imperative to reduce fertiliser inputs. The only way to achieve this, without losing out on farm-grown feed, is to continue improving soil health so that there is no drop in production – which has been successfully achieved on a number of farms.

SUSTAINABILITY IMPROVEMENTS ON EXAMPLE FARM

An example is provided in Figure 4 below of a farm working with Trace & Save for only three years, which is not a long history of data, but in that time noticeable improvements were achieved. The full data for the farm is included in the Appendix, Table 8.

Figure 4. Sustainability improvements on a farm working with Trace & Save since 2017 showing a decrease in fertilizer application rates and an increase in the proportion of home-grown feed produced.



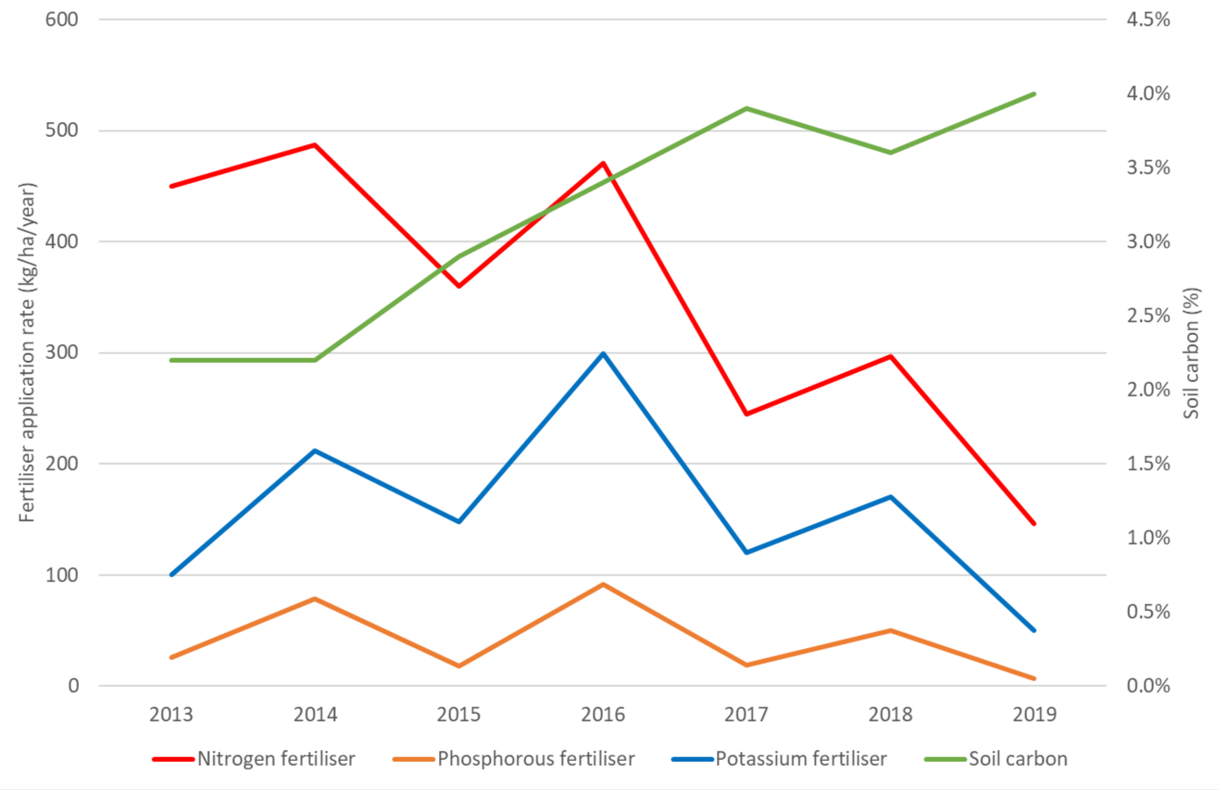
The area of greatest improvement has been in fertiliser application rates. Nitrogen, phosphorous and potassium rates in 2019 are less than a third of what they were in 2017. This has been linked to improved soil health, as represented by the increase in soil carbon from 2018 to 2019. How to achieve lower fertiliser rates through improved soil health is discussed in the best practices section below.

Of further interest on this farm is that between 2017 and 2018, an extra area of land was included in the farm. This is why the stocking rate and milk production per hectare have decreased so much. Where the feed was previously bought in (see very high bought feed for 2017), it could now be grown on farm. The percentage contribution from home-grown feed increased drastically from 2017 to 2018, but then reduced again in 2019. However, the increase in feed in 2019 was associated with higher milk production. Farm profits also increased by 7% over the three years from R2.99 to R3.22/litre.

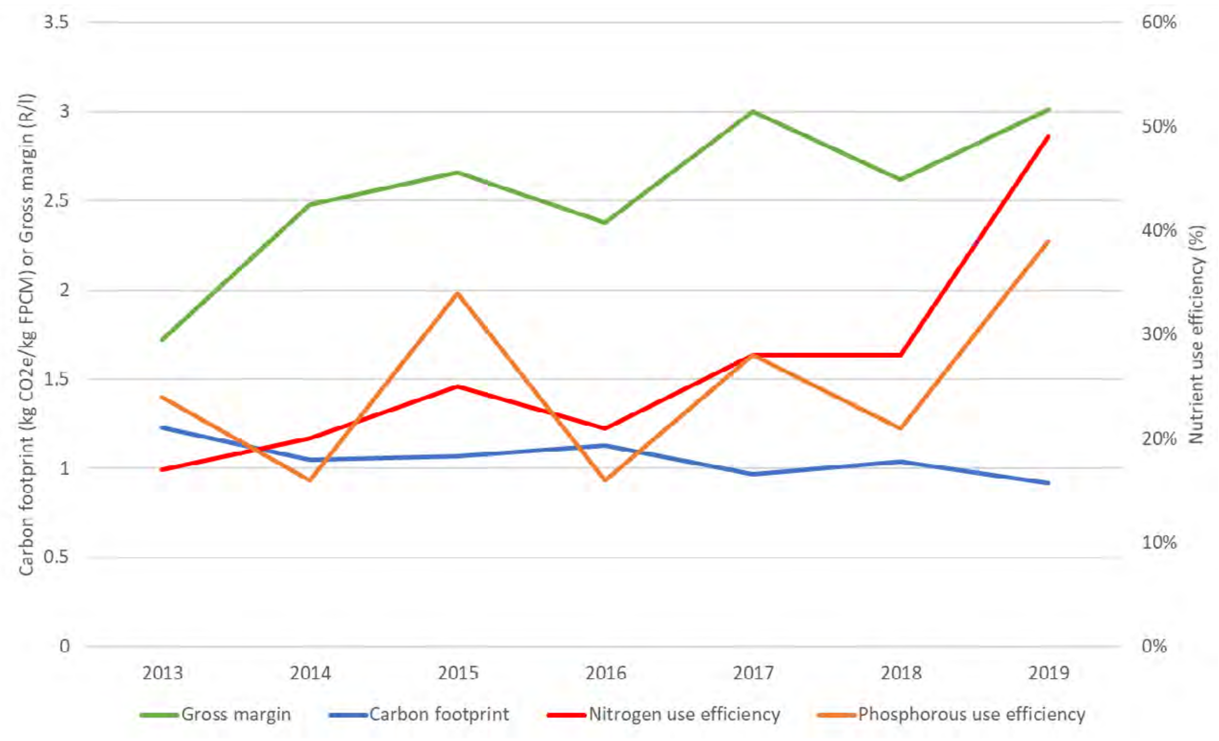
The farm in Figure 5 (the full data is included in the Appendix, Table 9) below has been participating in Trace & Save since 2013. This farm has drastically increased their gross margin over the past seven years, and the environmental impact has reduced significantly at the same time. The year 2019 was an especially impressive year on this farm. The soil carbon improvement is especially notable.

This farm is a very high milk production system with moderate inputs and has done an excellent job of becoming more efficient with the inputs used. Milk production has increased dramatically in all aspects. Nitrogen fertiliser application rates have more than halved between 2013 and 2019. This is associated with the improvement in soil health. Feed efficiency has also improved significantly, especially with regards to concentrates fed per milk produced. The years 2017 and 2018 however were especially challenging drought years, which pushed the bought roughage figure higher than it should normally be. Further opportunity for improvement on this farm lies in increasing the proportion of feed that is farm-grown.

Figure 5. Sustainability improvements on a farm working with Trace & Save since 2013.
5a. Improved soil carbon levels with decreases in fertiliser application rates over the seven years



5b. Increase in gross margin, increase in nitrogen use efficiency, increase in phosphorous use efficiency and decrease in carbon footprint on the farm over the seven years




EMERGENCY PULL STOP

SECTION 4 – APPLICATION AND IMPLICATIONS

BEST PRACTICES FOR IMPROVED SUSTAINABILITY

The data in this case study shows that dairy farms are complex and multiple factors influence the sustainability of pasture-based milk production. It requires an integrated, holistic approach to improve the sustainability of the whole farm system. When examining the farm systems which lead to lower environmental impact and increased profitability, there are a few practices which can be identified as contributing to more sustainable milk production.

Before discussing the details of the practices, it is important to understand that these practices are not just part of a checklist that will lead to more sustainable farming. The farms which have showed improvement on Trace & Save have implemented these practices effectively as part of good management of the farm system. Two farms can implement the same practices broadly, but one can succeed and the other not. The explanation of this is purely down to management and implementation. Farmers who want to improve the sustainability of their farms need to carefully consider whether they are implementing the practices below, how well they are implementing them, and thereby figure out how to create a more sustainable farming system on their farm. It takes hard work and commitment to achieve this.

1 Soil health management - maintaining soil health is about ensuring the continued capacity of soil to function as a vital, living system within the ecosystem and land use boundaries to sustain biological and agricultural productivity. The premise of pasture-based dairy farms is that milk production is driven by the grazing of pastures grown on the farm. There are two ways to grow sufficient pasture to meet the need for pasture-based milk production;

1.) Conventional methods rely on tillage and high fertiliser inputs.
2.) Sustainable and regenerative methods aim to restore and maintain soil health which promotes an active, diverse and functional soil biology, well-structured soil, nutrient cycling and balanced soil fertility. This is what then supports productive growth. These two approaches are mutually exclusive and farmers need to decide which approach they will follow.

2 Multi-species pastures - Multi-species pastures, which are mixtures of grasses, legumes, herbs and brassicas, provide the necessary diversity of organic matter in the soil to feed a diverse soil food web. The legume component also creates habitats for nitrogen-fixing bacteria. To build carbon, these pastures then need to be managed optimally (Conant et al, 2001). Optimal grazing management, from a carbon building perspective, is about maximising photosynthesis on the farm, as this is what pumps carbon into the soil. During photosynthesis organic compounds are produced (along with oxygen) which are used for plant growth (Keliher et al, 2015). A large portion of these compounds are also released through the roots into the soil as exudates. Root exudates attract and support soil organisms which protect and feed the roots in return, and are necessary for healthy and optimal soil life and plant growth.

Multi-species pastures have the additional benefit of being resilient, more stable and sustainable pastures (Woodward et al, 2013). The risks to dairy pastures include climate change (especially drought), pests and disease. Pastures with few species are vulnerable to climatic changes, whereas a multi-species pasture will have species that perform well under each condition. For example, chicory and lucerne are more resilient to drought conditions, whereas ryegrass grows favourably with high rainfall and cool weather. Multi-species pastures also support higher, better quality milk production than monoculture pastures (Roca-Fernández et al. 2016).

3 Effective fertilisation strategies - Fertilisers should only be used where needed and in the correct quantities. The only way to know this is through soil testing (Paustian et al, 2016). Soils which are healthy require less nitrogen fertiliser, as there will be higher mineralisation rates. Farmers who have been critical of the approach of reducing nitrogen fertiliser often misunderstand that nitrogen can only be significantly reduced on soils which are healthy. This is something farmers need to work towards and achieve, it does not happen overnight. Restoring soil health is a process, and needs to be approached as such, while using the available technology and data to assist this journey.

4 Pasture management - The importance of planting perennial, multi-species pastures for soil health has already been discussed. The mixture of species results in more nutritious pastures and therefore each ton grown makes a greater contribution to milk production. This is one of the most important opportunities for farmers to reduce bought feed. Through growing sufficient pasture, discussed above, having resilient pastures, and growing higher quality pastures, milk production can be predominantly supported by farm-grown feed. This approach has been shown to be the most sustainable, especially from an economic perspective, in this case study.

5 Effluent management - Effluent is generated in the milking parlour and, where applicable, from a feeding pad. On most farms this effluent is collected in ponds before being spread back onto pastures through various mechanisms. From an environmental perspective, effluent must be managed effectively and not allowed to enter surface and groundwater sources, which would lead to pollution (Longhurst et al. 2000). From an economic perspective, effluent is a beneficial waste product that can be used in place of fertiliser to build soil fertility. What is surprising is that farms often spread effluent onto the same areas of pasture for prolonged periods. This is not only a waste, because after some time these areas no longer need the nutrients, but it also becomes detrimental to soil health when the nutrient levels become excessive; as is often the case, especially with sodium, magnesium and phosphorous levels.

Effluent management is therefore a key component of efficient nutrient use. Nitrogen and phosphorous efficiency are important aspects of a sustainable farm system. For effluent to contribute to efficient nutrient use, areas should be identified, through soil testing, where there are deficiencies in phosphorous, potassium and other nutrients and effluent should be spread on those areas.

6 Optimal grazing management - Grazing management affects two aspects of pasture-based dairy: soil health and pasture-growth and -utilisation. To limit the reliance on bought feed (concentrates and roughage), and thereby farm more sustainably, pasture-based farmers need to grow sufficient, quality pastures which are effectively fed to the animals (Hills et al. 2016). Although it has been pointed out that longer periods of rest are good for soil health, pastures which are left for too long diminish in quality. Thus, optimal grazing management needs to ensure sufficient rest, but also ideal quality. This is a balance that farmers need to determine for each multi-species mixture, for each season and for each geographic and climatic region. It cannot be prescribed, but rather the principles of rotational, high density grazing with sufficient rest need to be applied relative to each context.

7 Irrigation efficiency - Water is one of the most limiting resources on pasture-based dairy farms and needs to be used more efficiently. Effective irrigation management is imperative both to efficient water use and soil health. Irrigation scheduling, which considers the soil and pasture requirements, relative to the climate, should be implemented. Large amounts of water are wasted on farms due to over-irrigation, and through uneven application of water (Martin et al. 2006). Some of this can be improved upon purely through better management practices such as avoiding irrigating during windy conditions and more informed scheduling (a number of tools and technologies now make this easier, but nothing beats visual field inspection and closely monitoring the weather forecast). Other improvements rely upon upgrading or maintaining irrigation systems and regularly checking whether they are still operating according to their design specs. Many of the irrigation systems currently employed on pasture-based dairy farms are highly inefficient. These include draglines, pivots which are not properly calibrated and where the nozzles are high above the ground, incorrect drop sizes and more. Every farmer should evaluate their irrigation systems to identify inefficiencies.

8 Efficient feed conversion - this has been identified as one of the most important aspects of a sustainable pasture-based dairy system in this case study. There are two main areas which influence efficient feed conversion: feeding practices and the animals. Incorrect feeding practices lead to large amounts of wastage which is costly. Feed should always be mixed effectively and fed in a manner that allows each animal to eat enough to support optimal production.

This especially includes providing enough space at troughs for all the animals to eat and sufficient shade for maximum cow comfort, which promotes milk production. Feeding out on the ground on pastures also leads to high wastage percentages, especially with bought roughage. Yet, this is a common practice on pasture-based dairy farms. Further to this, providing animals with a sufficient, well balanced diet is imperative along with ensuring animals are comfortable and not stressed while eating.

From the animal perspective, many factors influence feed conversion (Capper et al, 2009). Breeding is a factor with a big impact. Therefore, farmers should take care to select breeding traits which are conducive to optimal pasture utilisation. Raising heifers effectively also plays a big role, although this case study has shown it not to have a significant effect. Raising heifers will be discussed below. Ensuring that animals are healthy positively contributes to milk production and effective feed conversion.

9 Breeding efficiency - Breeding efficiency has a huge impact on milk production efficiency. For cows to achieve optimal production per 100 kilograms of live-weight over a lactation, the farm cannot afford to carry cows which have higher than 305-day lactations. This leads to inefficient milk production. The reason why so many farms have cows with longer than 305-day lactations is due to inefficient breeding. Systems should be put in place for effective heat-spotting and artificial insemination to ensure efficient breeding.

10 Raising heifers effectively - High heifer replacement rates, in theory, will also negatively influence efficient feed conversion. A decrease in the number of heifers required to replace culled cows each year results in a need to rear less heifers, where an emphasis can be placed on optimally rearing only the best heifers. The effective raising of heifers ensures that when these heifers become milking cows, they can produce milk productively. The most important aspect of this is monitoring target weights for heifers throughout their growth. If heifers are not reaching target weights, measures should be put in place to bring them back on track. This goes along with reducing mortality rates among young calves through effective calf care. This includes having clean pens, sufficient space and early detection and treatment of illnesses. The whole process of raising calves needs to result in healthy, productive young cows, without costing the farm excessively, caused by inefficiencies through mortality and unproductive feeding.

BARRIERS TO ACHIEVING SUSTAINABILITY

01

Misconceptions about sustainability and how to go about achieving it.

There is a great misconception that by implementing sustainable practices and becoming more environmentally friendly, farmers need to sacrifice productivity.

02

Being willing to go against convention and sometimes "go it alone"

When peers might criticize or forecast doom and caution to play it safe.

03

Multiple voices which confuse farmers and are sometimes directly contradictory

This causes farmers to lose confidence in implementing newer, less conventional practices. Often, when farmers implement more sustainable practices, they are questioned by many people, which can cause all but the most resolute farmers to waver. This often leads to half-implemented sustainable best practices, leading to them not working and therefore the farmer losing even more confidence.

04

Lack of accurate, readily available information and education.

The thread that runs through these barriers is that they are all based on incorrect perceptions and lack of information. Farmers cannot be expected to implement sustainability if they do not have clarity on what that means and how to go about implementing sustainable practices. Education is the most powerful weapon to overcome this.

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FUTURE POTENTIAL

What could be possible in the dairy industry in the next five years? This section is going to make some quite broad assumptions, for the sake of imagining a future with more sustainable milk production if we assume that the pasture-based dairy farmers of the EC and KZN are well represented by those included in this case study.

An additional assumption is that all the dairy farmers in the EC and KZN should be able to achieve more sustainable milk production. Some may argue that different regions may have different thresholds, but the Trace & Save data shows that farms have been able to improve their sustainability, and to be in the most sustainable groups, across a wide range of climatic and soil conditions.

Therefore, extrapolating the data from the average per farm in the case study, to all the farms in the Eastern Cape and KZN provinces, the total carbon emissions for milk production in these two provinces would be currently 2.53 million tons CO2e. Furthermore, there are 38 000 tons of excess nitrogen and 5 500 tons of excess phosphorous being generated collectively by these farms each year in these two provinces.

If every pasture-based dairy farmer could implement the sustainability best practices discussed in this case study, the current impact from these farms could be greatly reduced. Assuming that farms which currently have a high environmental impact could improve to a medium environmental impact, that farms with a medium impact could improve to a low impact and that farms with a low impact could improve to the levels of the lowest impact farms, what would the impact be?

The total carbon emissions would reduce by 10% to a total of 2.26 million tons CO2e. The excess nitrogen would reduce by 27% to an excess of 27 500 tons. The phosphorous excess would reduce by 19% to an excess of 4 400 tons. These are significant reductions in the environmental impacts from dairy farming.

As has already been established, along with this reduction in environmental impact would be an improvement in soil health. Storing carbon in the soil is the only way to mitigate the negative effects from GHG emissions; not only GHG emissions produced from dairy farming operations, but from all sources. Implementing sustainable best practices, such as optimal soil health and grazing management, will lead to increases in soil carbon levels. It would be reckless to predict the extent to which this could happen, but Trace & Save has observed drastic increases in soil carbon levels. It is realistic to think that, through the implementation of best management, farms can increase their soil carbon levels in the 0-30cm profile by 0.2% carbon. Extrapolating this to all the farms in the EC and KZN would lead to around 15.75 million tons of CO2e being stored in the soil over five years. That is the equivalent of 6.3 years' worth of emissions from the same farms based on current emission levels. It might seem like a crazy notion, but it would make pasture-based dairy farming carbon neutral.

The final impact of sustainable best practices being implemented on all pasture-based dairy farms would be an improvement in these farms' profitability. This would alleviate the pressure many of these farms feel and make the dairy industry more resilient.

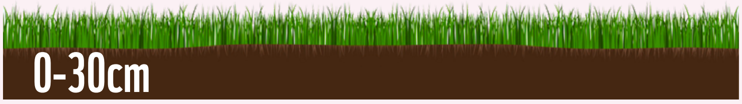
EXTRAPOLATING DATA FROM AVERAGE PER FARM TO ALL THE FARMS IN THE EC AND KZN...

CARBON EMISSIONS -22%

EXCESS NITROGEN -27%

EXCESS PHOSPHORUS -19%

(PROVIDED SUSTAINABLE FARMING PRACTICES ADVOCATED ARE IMPLEMENTED)



INCREASED SOIL CARBON BY 0.2%

±15.75 MILLION TONS OF CO2e STORED IN THE SOIL OVER 5 YEARS → EQUIVALENT OF 6.3 YEARS' WORTH OF EMISSIONS → WOULD EFFECTIVELY MAKE DAIRY FARMNING CARBON NEUTRAL

CONCLUSION

The data and analyses of information in this business case demonstrate that implementing sustainable best-practices will lead to more profitable milk production with a lower environmental impact. This is a win-win for farmers, for consumers, for milk processors and for the dairy industry in its entirety. Sustainably produced milk relies on healthy soils that grow sufficient, good quality pastures. These pastures need to be well utilised and provide the largest proportion of feed. The bought feed that is necessary should be effectively converted into milk. Fertiliser inputs should be minimised, and nutrient efficiency optimised, which is also associated with healthy soils. Achieving this while optimising milk production will result in more sustainable pasture-based milk.

It is therefore directly in the financial interests of dairy farmers to aggressively pursue goals of becoming more sustainable and achieving a lower environmental impact as there is a clear business advantage, as has been outlined in this business case.

The challenge with sustainability is in identifying which changes or practices need to be made and are relevant to the unique context of each farm, financing and implementing those practices and figuring out whether those practices are working. It must be remembered that sustainability is a journey, not achieved overnight. There still seems to be a perception that farmers need to make immediate, wholesale changes to their farms to be more sustainable. This is not the case. There are obviously certain costs involved with adapting any farm system, but these do not need to be incurred all at once. Practices can be implemented as they are possible. The important decision for every farmer is the mental shift, change in goals and being willing to “go it alone” sometimes, when peers might criticize or forecast doom for going against convention. That is where the journey starts.

SECTION 5 – REFERENCES AND APPENDIX

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APPENDIX

Table 6. Prices used to calculate fertiliser costs

Nutrient costs (R/kg of nutrient)	Chemical N	Chemical P	Chemical K	Organic N, P or K
2012	R9.89	R25.33	R11.00	R7.70
2013	R11.85	R34.53	R13.62	R10.40
2014	R10.43	R26.15	R10.96	R7.14
2015	R14.78	R34.36	R11.40	R8.07
2016	R11.74	R27.08	R12.40	R8.17
2017	R10.81	R26.07	R13.11	R13.10
2018	R11.24	R26.61	R11.86	R11.09
2019	R12.08	R26.23	R12.66	R7.95

Table 7. Spearman's correlations (Spearman's rho) showing the relationships between economic and environmental measures on 62 pasture-based dairy farms between 2012-2019 (n = 195)

Parameter	Gross margin (R/l)	Gross margin (R/ha)	Income (R/l)	Concentrate cost (R/l)	Bought roughage cost (R/l)	Fertiliser cost (R/l)	Electricity cost (R/l)	Fuel cost (R/l)	Carbon foot-print (kg Co2e/ kg FPCM)	NUE (%)	PUE (%)	Soil carbon (%)	Environmental impact score
Gross margin (R/l)	1	**0.62****	**0.52****	**-0.68****	**-0.23****	-0.07	0.05	-0.11	**-0.46****	**0.45****	**0.23****	0.08	**-0.50****
Gross margin (R/ha)			**-0.34****	**-0.43****	-0.1	-0.12	**0.17****	**-0.29****	**-0.56****	**0.38****	**0.16***	-0.06	**-0.41****
Income (R/l)				-0.07	**0.35****	-0.13	0.08	0.02	**-0.39****	**0.29****	-0.03	-0.02	**-0.32****
Concentrate cost (R/l)					0.05	0.01	-0.06	0.00	**0.19****	**-0.24****	**-0.15***	-0.05	**-0.20****
Bought roughage cost (R/l)						**-0.30****	-0.01	0.01	0.03	-0.06	-0.09	0.03	0.07
Fertiliser cost (R/l)							-0.1	0.14	**0.18****	**-0.62****	**-0.54****	**-0.16***	**0.56****
Electricity cost (R/l)								**0.15****	**0.21****	0.12	**-0.14***	-0.11	0.01
Fuel cost (R/l)									**0.35****	**-0.17****	-0.12	**-0.17***	**0.29****
Carbon footprint (kg Co2e/ kg FPCM)										**-0.44****	-0.05	-0.06	**0.64****
NUE (%)											**0.37****	0.14	**-0.77****
PUE (%)												0.02	**-0.57****
Soil carbon (%)													**-0.34****
Environmental impact score													1

Table 8. Sustainability improvement on a farm working with Trace & Save since 2017 showing the economic, environmental and partial productivity measure scores for the farm and how they have improved over three years.

Parameters	2017	2018	2019
Profit (R/l)	2.99	2.98	3.22
Gross margin (R/ha)	72 207	42 649	45 678
Income (R/l)	5.76	5.21	5.42
Cost (R/l)	2.77	2.23	2.2
Carbon footprint (kg CO2e/kg FPCM)	1	1.17	0.89
NUE (%)	22%	24%	42%
PUE (%)	14%	17%	43%
Soil carbon (%)	2.40%	2.40%	2.80%
Stocking rate (kg weight/ha)	2 160	1 307	1 399
Milk production (l/ha)	24 148	14 300	14 171
Milk production (l/cow/day)	17.1	16.9	17.4
Milk production (l/100 kg weight)	1 291	1 234	1 252
Milk production (solids/100 kg weight)	110	104	105
Concentrates to CiM (g/l)	250	235	254
Bought non-pasture roughage (g/l)	480	185	226
All farm grown feed (g/l)	724	1 104	903
Farm grown feed contribution (%)	45%	68%	62%
Fertiliser (kg N/ha)	342	279	116
Fertiliser (kg P/ha)	71	51	9
Fertiliser (kg K/ha)	189	171	54
Heifer replacement (%)	24%	29%	28%

Table 9. Sustainability improvement on a farm working with Trace & Save since 2013 showing the economic, environmental and partial productivity measure scores for the farm and how they have improved over seven years.

Parameters	2013	2014	2015	2016	2017	2018	2019
Gross margin (R/l)	1.72	2.48	2.66	2.38	3	2.62	3.01
Gross margin (R/ha)	25 711	46 356	56 587	46 391	68 713	59 369	70 090
Income (R/l)	3.85	4.67	4.73	4.84	5.15	4.82	4.97
Cost (R/l)	2.13	2.19	2.07	2.45	2.15	2.21	1.96
Carbon footprint (kg CO2e/kg FPCM)	1.23	1.05	1.07	1.13	0.97	1.04	0.92
NUE (%)	17%	20%	25%	21%	28%	28%	49%
PUE (%)	24%	16%	34%	16%	28%	21%	39%
Soil carbon (%)	2.20%	2.20%	2.90%	3.40%	3.90%	3.60%	4.00%
Stocking rate (kg weight/ha)	1 506	1 894	2 002	1 907	1 743	1 801	1 900
Milk production (l/ha)	14 989	18 722	21 300	19 395	22 899	22 703	23 323
Milk production (l/cow/day)	14.1	15.7	16.4	17.4	21.1	22.2	23
Milk production (l/100 kg weight)	1 075	1 141	1 218	1 291	1 459	1 455	1 473
Milk production (solids/100 kg weight)	88	93	98	107	116	115	117
Concentrates to CiM (g/l)	403	399	344	346	366	267	247
Bought non-pasture roughage (g/l)	18	48	119	47	203	219	157
All farm grown feed (g/l)	1 039	934	789	800	587	769	741
Farm grown feed contribution (%)	65%	60%	57%	61%	46%	58%	60%
Fertiliser (kg N/ha)	450	487	360	471	245	297	146
Fertiliser (kg P/ha)	26	79	18	92	19	50	7
Fertiliser (kg K/ha)	100	212	148	299	120	170	50
Heifer replacement (%)	18%	25%	25%	23%	22%	19%	25%

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