# Assessment of the potential financial benefits and risks of adopting improved effluent management

trace&save

## Contents



## Acknowledgements


**Trace & Save:** Lomé Smit; Craig Galloway

**WWF-SA:** Sue Viljoen

**External Reviewer:** Pieter Swanepoel, Stellenbosch University

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# Introduction

The management of livestock manure is an important consideration for sustainable agriculture on dairy farms. Manure is both a waste product with the potential to pollute, and a potential fertiliser. Whether it trends more towards the one or the other depends largely on how it is managed.

Livestock manure is the faeces and urine generated by animals. It contains organic material and is nutrient rich (Moreki and Chiripasi 2015). The intensification of animal production systems in recent years has led to significant amounts of manure being produced in concentrated areas (Malomo *et al.* 2018). This has resulted in the necessity to collect and dispose of this manure in a responsible manner.

Since manure is rich in nutrients such as nitrogen, phosphorus and potassium, it has value as a fertiliser (Moreki and Chiripasi 2015; Niles *et al.* 2022). The properties of manure, like the nutrient concentrations, will impact the potential use thereof, especially when it is used as a replacement for chemical fertiliser.

One of the major challenges in dairy production is managing the manure in a way that is advantageous for agricultural production, while minimising the potential negative impact on the environment and public health. Manure, and the management of effluent has a big pollution potential. There are high greenhouse gas emissions associated with manure management, and the repeated application of effluent in the same areas might also cause nutrient build-up. Nutrient excesses in the soil might lead to the loss of environmentally important nutrients like N and P. These nutrients may leach into, and degrade, water sources or be lost to the atmosphere. Manure and effluent should also not be allowed to enter water sources as this has serious health and environmental implications.

Systems for handling, storing, and applying manure are known as manure management systems (MMS) (Niles *et al.* 2022). Manure on dairy farms can be managed appropriately using a variety of strategies, ranging from straightforward, low-cost systems to more intricate ones. The most common MMS in South Africa is the use of anaerobic lagoons/ponds (Moeletsi and Tongwane 2015). Animal waste is mostly handled as a liquid and these ponds contain manure that is typically diluted with water, namely effluent. Manure is washed down from the dairy parlour and holding yard. The effluent does not only contain manure and water, but will also contain milk solids and all kinds of detergents that are washed from the dairy parlour.


*A typical effluent storage pond.*

This MMS can include single or multiple ponds where the effluent is stored under anaerobic conditions for prolonged periods. Anaerobic ponds are typically not aerated or mixed, most of the solid particles settle to the bottom via gravitation, and the liquid portion is then fed directly into the irrigation systems (where a single pond system is used), or overflows into a second/third pond (if multiple ponds are used), and only then fed into the irrigation system.

Mechanical separators also exist, where the solid portion of the manure in effluent is separated from the liquid portion. This reduces the volume of solids that enter the effluent storage lagoons. The solids can then be used to make compost, or be spread out on pastures or croplands, whereas the liquid portion is fed into the irrigation system as with the anaerobic lagoon system. These systems are less common in South Africa due to the high capital input cost thereof.

There are many variations of the above-mentioned MMSs, and the handling, storage and spreading of effluent is highly dependent on farming circumstances, such as water availability, storage capacity, effluent distribution capacity, ease of management and cost of storage and distribution.

Efficient manure management offers the opportunity to expand on the idea of nutrient circularity in livestock production, which encompasses the improved recovery of nutrients from organic material, whilst reducing nutrient losses (Sefeedpari *et al.* 2019; Harder *et al.* 2021). This may change how manure is perceived - from generally being considered as a problem to being seen as a valuable resource (Sefeedpari *et al.* 2019). The nutrients in effluent may have a direct financial benefit if less fertiliser is purchased and applied due to better, more optimal effluent management.

# Aim

The aim of this study is to investigate the potential financial benefits and risks of adopting improved manure management systems on pasture-based dairy farms through undertaking a cost-benefit assessment.

# Materials & Methods

Five willing farmers, who work with Trace & Save, were selected for this study, who either have recently upgraded their MMS, or are looking to upgrade their MMS. Trace & Save (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.

Descriptive data of the selected farms are summarized in Table 1.

**Table 1** A summary of the location, size and production of the five farms included in this study.

| Farm | Province | Region | Irrigated area (ha) | Dryland area (ha) | Stocking rate (kg LW/ha) | Adult cows (CiM + DC) | Heifers |
|---|---|---|---|---|---|---|---|
| 1 | EC | Hogsback | 46 | 121 | 632 | 186 | 150 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2 | WC | George | 525 | 624 | 1 071 | 2 300 | 1 189 |
| 3 | WC | George | 351 | 244 | 963 | 1 139 | 552 |
| 4 | EC | Tsitsikamma | 236 | 278 | 1 150 | 1 336 | 586 |
| 5 | EC | Oyster Bay | 24 | 1173 | 974 | 1 107 | 564 |

EC = Eastern Cape, WC = Western Cape
CiM = Cows in milk, DC = Dry cows
LW = liveweight

Since the five farmers participating in this case study work with Trace & Save, numerous applicable data for each farm was available from the Trace & Save database, such as the information available in Table 1, the soil nutrient levels of the farms, fertiliser recommendations and all other information stated. These five farms are a good representation of the 101 dairy farms that Trace & Save have worked with, and are also representative of a general highly-productive dairy-pasture farm in South Africa.

The farmers were interviewed (Appendix I) to gather information about their current or previous MMSs, which was then compared to their new and improved systems, or the systems they would want to upgrade to. This information was then used to provide an overview of the context, as well as the MMS on each of the farms. A description of the previous, current, and/or upgraded MMS is given in Table 2.

**Table 2** A summary of the manure management systems on the participating farms.

| | |
|---|---|
| **Farm 1:** | |
| Previous system | Multi-pond system with three ponds. The first pond allowed for the solids to settle where the liquid portion then moved to the second and then third pond before it was fed into the irrigation system.<br>This system caused the farmer a lot of problems due to blockages from solid portions of the manure.<br>Ease of management was the main reason for this farmer to change their MMS. The farmer also emphasized that the problems associated with blockages cost them a lot of money and time over the years. |
| Current system | This farm recently changed their MMS to a simple single pond system. A trench has been dug which leads the effluent directly to the original third pond. From there, the effluent is distributed to the dryland areas through a single pipeline, which is manually moved. The effluent gets diluted with application. The capital input of this system was R38 100 (cost of trench and new pipeline), and the farmer states that the operating costs are about one fourth of what it used to be. This system is much easier to manage, and the farmer is very happy with this system. The current system is compared to the previous system in the calculations. |
| **Farm 2:** | |

Current system

This farm has two dairies, therefore two MMSs, that both functions similarly. Both have multi-pond systems with two anaerobic lagoons each. The majority of the solids are separated by a concrete trap before the effluent flows into the first pond. The solids are scraped up and spread on pastures. From the first pond, the effluent is either pumped, or allowed to overflow (depending on the dairy) into the second pond whereafter it is then fed into the irrigation system for distribution. The current system is compared to the planned upgraded system in the calculations.

Upgraded system

The improved system will function on the same principles (i.e. multi pond system) but the effluent will be distributed to new pivots and therefore increasing the distribution area of the effluent.
The upgraded system will only require the laying of a new pipeline. Management and running costs are going to be very similar to what they currently are.

**Farm 3:**

Previous system

This farm had a multi-pond system. The effluent was distributed to the pastures through the irrigation system. The farmer, being very close to a town, had immense pressure from the public regarding environmental and social concerns, i.e., bad odors, greenhouse gas emissions, and pollution. The main reason for upgrading the system was due to these pressures. The farmer also had trouble with sediment buildup in the effluent pond which had to be cleaned every four years, adding costs.

Current system

*Part of a mechanical separator system with the separated solids.*

The current system has a mechanical separator where the solid and liquid portions of the effluent are immediately separated using a screw-press separator.

The liquid portion (with minimal solids) is stored in an effluent pond and irrigated onto pastures regularly. The solid portion (with minimal moisture content) is spread onto the pasture once a week.

The cost to upgrade to the mechanical separator system was R1 014 000, all costs included. The farmer states that this system results in a higher quality product, both solid and liquid manure. The farmer also says that this system results in manure which is very easy to distribute and manage compared to the previous system.

This farm is also planning on upgrading the current system to increase the effluent distribution area, which will cost around R200 000. The total cost of the upgrading will therefore be
R1 214 000.

**Farm 4:**

| | |
|---|---|
| Current system | This farm has a multi-pond system. There is a pre-trap from which the effluent is filtered into the second pond. The effluent is distributed through the irrigation system to four of the seven pivots on the farm. The farmer states that this system works for them due to the easiness of spreading a lot of effluent. However, the farmer has a lot of problems with sediment buildup in the pond. |
| Upgraded system | Ideally this farmer would want to have a mechanical stirrer and a floating pump, as the effluent is currently pumped from an ineffective distance of ± 20m. The effluent will then be pumped to the top of the farm and then be gravity fed through the irrigation system to all the pivots on the farm. This will allow for more nutrients to be distributed over a much larger area. The cost of the new floating pump and the new pipeline, will be between R200 000 and R300 000. The distribution of the current system, compared to the distribution of the upgraded system will be compared in the calculations. |

**Farm 5:**

| | |
|---|---|
| Current system | The current system makes use of a single pond system. The effluent is directed through a trap before landing in the lagoon, whereafter it is pumped to certain points on the farm where an effluent irrigator/gun can be connected. |

*The effluent irrigator/gun used by Farm 5.*

This is then used to irrigate the effluent on the drylands. This farm also makes use of a tanker to spread effluent to camps that are not covered by the irrigator and camps further away from the dairy. The farmer states that this system is simple. The effluent irrigator, however, is only set up to work on a small area, and the spreading of effluent with the tanker is more expensive and labour intensive.

Upgraded system

The improved system will function on the same principle (i.e. single pond system) but the effluent will be distributed further, to new dryland areas and therefore increasing the distribution area of the effluent. The main motivation for the upgraded system is to be able to spread more nutrients to a bigger area. The new distribution will only need a new pipeline, which will cost between R100 000 and R200 000. This farmer believes the effluent is very valuable and states that these costs are easily justifiable and are worth it. The farmer states that the management and maintenance of an upgraded system will be the same as currently.

Farm 1 and 3 changed their manure management system completely. Further, farm 1 changed the spreading area entirely whereas the rest of the four farms extended the distribution area of the effluent as part of the upgrading process.

The area of distribution of effluent for the previous or current system, and the distribution area of the new, upgraded systems are shown in Table 3.

**Table 3** The area of effluent distribution on the farms.

| Farm | Previous or current system | Improved system |
|---|---|---|
| 1 | 6.7 ha | 21.6 ha |
| 2 | 171.2 ha | 320.8 ha |
| 3 | 180.8 ha | 318.6 ha |
| 4 | 127.8 ha | 231.8 ha |
| 5 | 189.5 ha | 315.1 ha |

It should be noted that none of these farms have meters installed that determine the influx and outflow of effluent, which is a legal requirement in South Africa. Trace & Save is not aware of any farms which have a proper volume monitoring system for effluent. This makes it impossible to accurately determine the actual amount of effluent that gets generated and spread. We recommend measuring the effluent as this forms part of proper effluent management.

According to Chastain and Camberato (2004), where effluent is generated only at the milking parlour, which is true for all five farms included in this case study, the total solids content of effluent ranges between 0.6 and 1.7%. This is a very small percentage, and the effluent generated are therefore completely dependent on the amount of water used to wash the dairy parlour and holding yard. Trace & Save collects this data from farmers, and therefore we have assumed that the total effluent generated per farm is the litres of water used to wash the dairy per day multiplied by 365 days (Equation 1). This gives a more realistic, farm specific figure. The figures from literature often have very different contexts than South African dairy farms. Obviously, there will be loss from evaporation from the effluent ponds, but the rate/amount of evaporation is completely unknowable with the data currently available. Therefore, rather than making large assumptions, we have chosen to exclude evaporation from these calculations.

$$\mathrm{EG\ (L) = WU\ (L) \times 365}$$

Equation 1

Where;
EG = Effluent generated per year
WU = Water used to wash the dairy and yard per day

The amount of effluent that is available to spread per hectare was calculated by Equation 2.

$$\mathrm{EAH\ (L/ha)} = \frac{\mathrm{EG\ (L)}}{\mathrm{A_t\ (ha)}}$$

Equation 2

Where;
EAH = Effluent availability per hectare
$A_t$ = Total area where effluent is spread

The nutrients that are available, through the spreading of effluent, could then be determined using Equation 3. Only the macronutrients (nitrogen [N], phosphorous [P] and potassium [K]), were used in the calculations of this case study. Farmers rarely use effluent as a source of other nutrients. Although, it is acknowledged that there is much greater value to effluent than purely the N, P and K nutrients, for the sake of the case study, we thought it best to calculate effluent value based on these three, most abundantly fertilised nutrients. Sodium and magnesium are also briefly discussed as they can negatively impact soil health and crop production.

The nutrient values of effluent samples from the Trace & Save research database (taken on various farms in the EC between 2016 and 2022), for the particular MMS on each farm (Table 7), was used for all the calculations in this study. A sample, taken from the storage pond of each farm, was also taken and sent for analysis to determine the nutrient contents of the effluent (Appendix II).

$$\mathrm{NAH\ (kg/ha)} = \frac{\mathrm{ENC\ (mg/L)\ \times\ EAH\ \ (L/ha)}}{\mathrm{1\,000\,000\ \ (mg/kg)}}$$

Equation 3

Where;
NAH = Nutrients available to spread
ENC = Effluent nutrient content

Finally, the nutrients that are possible to be spread per camp was determined according to Equation 4.

$$\mathrm{NSP\ (kg)} = \mathrm{A_p(ha)\ \times NAH\ (kg/ha)}$$

Equation 4

Where;
NSP = Nutrients spread per paddock
$A_p$ = Area of the paddock

An important condition of the assessment of effluent value in this case study is that effluent only has value on camps where the nutrients are needed. This is based on soil health testing. Soil samples are taken on each camp of the participating farms each year by Trace & Save. Based on these soil samples, Trace & Save recommends capital and maintenance P and K fertilizer requirements. All five participating farms had soil samples taken in 2022. The Trace & Save fertiliser recommendation, per paddock for each farm, was used in conjunction with Equation 4 to determine the realised value of the effluent. All of the N in the effluent has value, and was treated as such, since it is not possible to determine a specific N requirement (although we do not believe all of this N is required in the soil [because pasture soils are very high in total nitrogen], we have included it as having value for the sake of the case study). For the P and K, a value was only given if the fertiliser recommendation was above 0 kg/ha for each specific paddock.

It should be noted that the nutrients in effluent are different to those of chemical fertiliser. The nutrients in effluent are mostly in the organic form whereas the nutrients in fertiliser are in the inorganic form. Inorganic nutrients can readily be taken up by plants but organically bound nutrients will first have to be mineralised before the nutrients will be available for plant uptake. For this reason, it is more difficult to manage and use effluent as a fertiliser source as the mineralisation process is influenced by various, mainly incontrollable, factors. On the other hand, there is value in the naturally “slow releasing” nature of the nutrients in effluent.

The nutrients from the effluent that are actually required (realised value), across the entire area that it is spread, was then compared to the total amount of nutrients in the effluent generated (potential value). A Rand value was determined, using chemical fertiliser prices of R33 per kg of N, R54 per kg of P, and R30 per kg of K (as per January 2023). These calculations will obviously change relative to the price of fertiliser, and that should be taken into account when reading this case study.

Lastly, a repayment period (RP) for the cost of the upgrade of the MMS was calculated according to Equation 5.

$$RP = \frac{CU}{realised_{(upgraded)} - realised_{(current)}}$$

Equation 5

Where;
CU = The cost of upgrading to the improved/upgraded system (R)
$realised_{(upgraded)}$ = The realized value of the upgraded or improved system (R)
$realised_{(current)}$ = The realized value of the current or previous system (R)

The Trace & Save research database was used to acquire all additional data for this study.

A list of all assumptions made in this case study can be found in Appendix III.

# Results & Discussion

## The effluent generated and the nutrient contents of effluent samples

The effluent generated per year, is shown in Table 4. The amounts for farm 2 are so much larger since it is taking into account two dairy parlours.

**Table 4** The amount of effluent generated per farm.

| Farm | Water used (l/day) | Effluent generated (l/year) |
|---|---|---|
| 1 | 13 750 | 5 018 750 |
| 2 | 120 000 | 43 800 000 |
| 3 | 50 000 | 18 250 000 |
| 4 | 70 000 | 25 550 000 |
| 5 | 55 000 | 20 075 000 |

The nutrient concentration of the effluent, for the samples taken on each farm, is shown in Table 5. The full analyses can be found in Appendix II.

**Table 5** Nutrient concentrations of effluent from samples taken on each farm.

| Farm | Unit | N | P | K |
|---|---|---|---|---|
| 1 | mg/l | 480 | 90 | 584 |
| 2 | mg/l | 300 | 66 | 627 |
| 3 | mg/l | 210 | 133 | 499 |
| 4 | mg/l | 101 | 29 | 333 |
| 5 | mg/l | 270 | 53 | 550 |

A summary of the total N, P and K for each MMS relevant to this study, calculated from the available data on the Trace & Save database, is shown in Table 6.

**Table 6** A summary of the N, P and K concentrations for each manure management system from the Trace & Save database.

| | N (mg/L) | | P (mg/L) | | K (mg/L) | |
|---|---|---|---|---|---|---|
| **Type of system** | **Value ± SD** | **n** | **Value ± SD** | **n** | **Value ± SD** | **n** |
| Mechanical separator | 380 ± 477 | 20 | 65 ± 37 | 23 | 465 ± 178 | 22 |
| Multi-pond | 465 ± 475 | 181 | 39 ± 27 | 191 | 420 ± 300 | 199 |
| Single-pond | 406 ± 475 | 52 | 25 ± 21 | 41 | 245 ± 246 | 44 |

SD = standard deviation
n = number of observations (i.e., number of farms)

From inspecting both Table 5 and 6, it is clear that there is massive variation between the samples. This is especially apparent from the high standard deviation values (Table 6). Standard deviation is a measure of variability in a dataset, and in this case, the high standard deviations mean that the data points are spread out over a large range of values.

These variations are also observed in literature (Ali *et al.* 2006; Hawke and Summers 2006). Nutrient concentrations in both liquid and solid manure differ greatly between dairies, within dairies, and over time. This is a result of changes in animal diet, the age and breed of the cows, and manure handling and storage practises (Hawke and Summers 2006; University of California, Davis 2010). Different environmental conditions are also responsible for different degrees of nutrient losses, which will affect the nutrient concentrations in the effluent (Oenema *et al.* 2007). This is why we have carried out all of the calculations for the case study using the averages from a larger dataset from similar MMS, where the samples have been taken in different months over a number of years, providing a more robust average. This is as opposed to using the values from the single samples taken in January 2023 on each farm.

These variations in effluent nutrient content and quality are what makes it important for farmers to analyse their effluent on a regular basis, at least once a month, in order to have proper insight as to what is being applied to pastures. This is along with the recommendation mentioned previously that the volume of effluent generated and spread should also be recorded.

<u>The potential versus the realised value of effluent for current and upgraded systems</u>

The potential nutrient values and the realised values, are shown in Table 7 and 8, both for the current and the upgraded systems of each farm.

The potential represents the total amount of nutrients in the effluent, using the values obtained from the Trace & Save database, whereas the realised values represent the amount of nutrients that are deficient in the soil (i.e., what is required to satisfy the Trace & Save fertiliser recommendation). The N is treated a bit differently than the other two nutrients. All of the nitrogen in the effluent has value and is treated as such. However, an 8% loss has been accounted for, which includes volatilisation and nitrous oxide emissions that occur when the effluent is spread on the pastures (IPCC, 2006).

The values for the potential and realised value of the effluent for the upgraded system (Table 8), is lower than for the current systems (Table 7). This is because of the increase in hectares from the extension of effluent spread which leads to a lower kg/ha value (Table 3).

**Table 7** The potential of the effluent compared to the realised value thereof for the current manure management systems, in kilograms per hectare.

| Farm | Potential N | N after loss | Potential P | Realised P | Potential K | Realised K |
|---|---|---|---|---|---|---|
| 1 | 307 | 282 | 18.9 | 0.0 | 185 | 185 |
| 2 | 119 | 110 | 10.1 | 2.9 | 108 | 25 |
| 3 | 38 | 35 | 6.6 | 0.2 | 47 | 29 |
| 4 | 93 | 93 | 7.9 | 0.0 | 84 | 31 |
| 5 | 42 | 39 | 2.6 | 0.0 | 25 | 7 |

**Table 8** The potential of the effluent compared to the realised value thereof for the improved manure management systems, in kilograms per hectare.

| Farm | Potential N | Realised N | Potential P | Realised P | Potential K | Realised K |
|---|---|---|---|---|---|---|
| 1 | 94 | 87 | 5.8 | 0.0 | 57 | 55 |
| 2 | 64 | 58 | 5.4 | 0.8 | 57 | 27 |
| 3 | 22 | 20 | 3.7 | 2.1 | 27 | 21 |
| 4 | 51 | 47 | 4.3 | 0.4 | 46 | 32 |
| 5 | 26 | 24 | 1.6 | 0.0 | 15 | 6 |

It is very important to note that although there is value to be gained by applying effluent, it can also lead to the oversupply of nutrients, especially regarding P on dairy farms. The differences between the potential and the realised values for both P and K above (Table 7 and 8) will lead to the oversupply of those nutrients, thereby causing nutrient imbalances in the soil. From a soil health perspective, it is therefore advantageous to increase the distribution area of the effluent. This will result in a more uniform distribution of effluent over the farm, thereby reducing the speed of soil nutrient build-up in concentrated areas. Further to the build-up of nutrients in the soil, the application of unnecessary and excessive nutrients greatly increases the risk of leaching and pollution of fresh water sources by these nutrients.

Along with the build-up of nutrients, other elements like sodium (Na) and magnesium Mg) (Mg is also a plant nutrient) will build up in the soil. Sodium causes salinity and can severely affect soil health and crop production. On average, across these five participating farms, 70 kg/ha of Na are applied through effluent application on the current application areas and 31 kg/ha for the increased area. Although this is not insignificant, at Trace & Save, we don’t necessarily see big salinity issues due to effluent application. The salinity problems observed are more commonly due to poor quality irrigation water (with very high Na levels). We often rather see Mg build-ups from effluent application, even though less Mg is applied per hectare, Mg leaches less easily from the soil and therefore builds up quicker. On average across these five participating farms, 24 kg/ha of Mg are applied through effluent application on the current application areas and 10 kg/ha for the increased area. Excess levels of Na and Mg might necessitate the use of gypsum to remove these elements from the soil profile, which is an additional input cost on farms.

Trace & Save recommends P maintenance fertiliser on camps with P Bray I levels of less than 40 mg/kg, and capital fertiliser on camps with P lower than 30 mg/kg. For K, maintenance K fertiliser is recommended when soil levels are less than 220 mg/kg, and capital fertiliser is recommended on camps where the K level is less than 150 mg/kg. Capital fertiliser is the fertiliser needed to build a soil’s nutrients status to the optimal range, whereas maintenance fertiliser is the amount needed to keep the soil within this optimal range, considering the removal from pasture harvest.

Table 9 shows the average soil nutrient levels for the five farms from the latest soil samples taken by Trace & Save, which were all taken in 2022.

**Table 9** The soil nutrients status of the old/current and the upgraded manure management systems, for the five farms.

*P Bray I analysis

The average P levels in the soils from all of these farms, across both the current and upgraded areas, are very high, and much higher than the norms for which P fertiliser is needed. This is a common occurrence on dairy farms in South Africa. The K levels are not as excessively high as the P levels. Some of the farms will have maintenance K recommended, and only farm 3 will have capital K fertiliser recommended.

Total N levels in the soil above 0.256 % are viewed as very high. Although total N is an analysis of both organic (not plant available) and inorganic (plant available) forms of N in the soil. Trace & Save views N fertiliser as a management tool, and there are no specific recommendations for N application rates. Trace & Save rather promotes optimising N fertiliser usage through good management practices. Hence, for this case study we have treated all the N as valuable, because it would be too complicated to treat it any other way. And farmers generally perceive effluent as a form of N fertilisation.

| | Current/previous system | | | Upgraded and improved system | | |
|---|---|---|---|---|---|---|
| **Farm** | **Average N** | **Average P*** | **Average K** | **Average N** | **Average P*** | **Average K** |
| **1** | 0.22 % | 95 ppm | 113 ppm | 0.16 % | 64. ppm | 110 ppm |
| 2 | 0.24 % | 76 ppm | 276 ppm | 0.23 % | 84 ppm | 255 ppm |
| 3 | 0.27 % | 116 ppm | 203 ppm | 0.21 % | 91 ppm | 146 ppm |
| 4 | 0.26 % | 77 ppm | 252 ppm | 0.24 % | 69 ppm | 200 ppm |
| 5 | 0.34 % | 86 ppm | 317 ppm | 0.33 % | 91 ppm | 322 ppm |

Since Trace & Save takes soil samples on 101 pasture-based dairy farms across South Africa, it presents the opportunity to point out the bigger-picture challenge of managing effluent. Of the 10 929 camps on the 101 farms, 23% of the camps require P fertiliser, 49% require K fertiliser and only 14% of the camps require either P or K.

Therefore, when applying effluent on 86% of the camps, either P or K will be excessive. This is deeply problematic. It is important to note that the farmers cannot be completely blamed for this. It is a challenging situation that they are placed in, and reflects the reality of the greater challenge that the industry faces. This is not a dilemma that should be thrown back at the farmers, but rather would be better solved through a collaborative effort between farmers and the dairy industry.

Financial indications of effluent value and the repayment period for upgrading current systems

The kg/ha values from Tables 8 and 9 were further used to determine Rand values for the effluent. These values were obtained by multiplying the amount of nutrients in the effluent (potential and realised) by the current prices of N, P and K fertilisers.

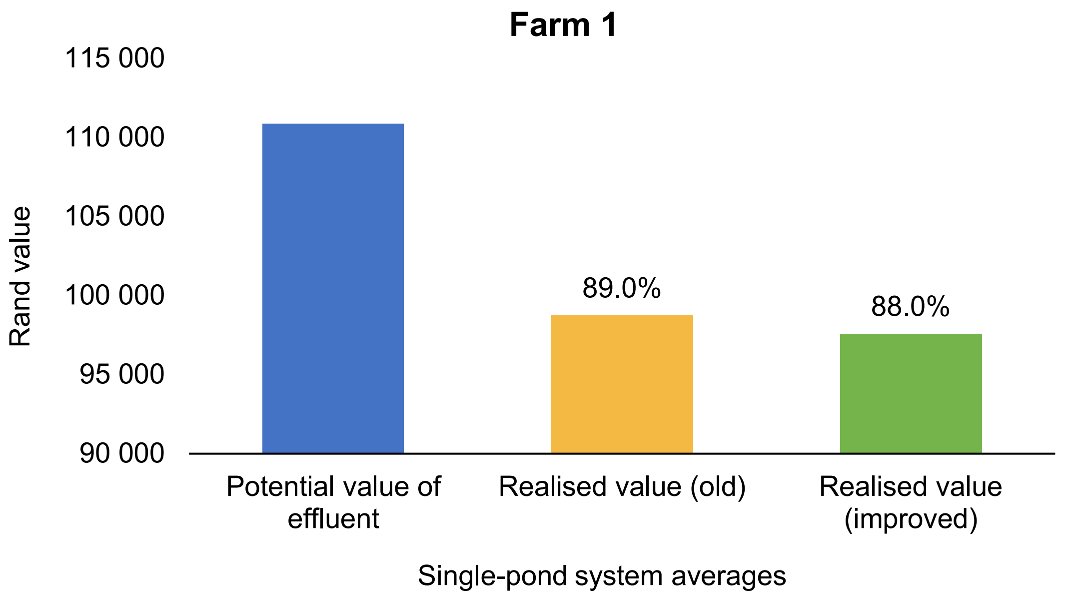


**Figure 1** Financial value analysis of effluent, comparing the potential value of the effluent with the realised value, for the current and for the improved system of farm 1. The percentage is the realised value as a percentage of the potential value.

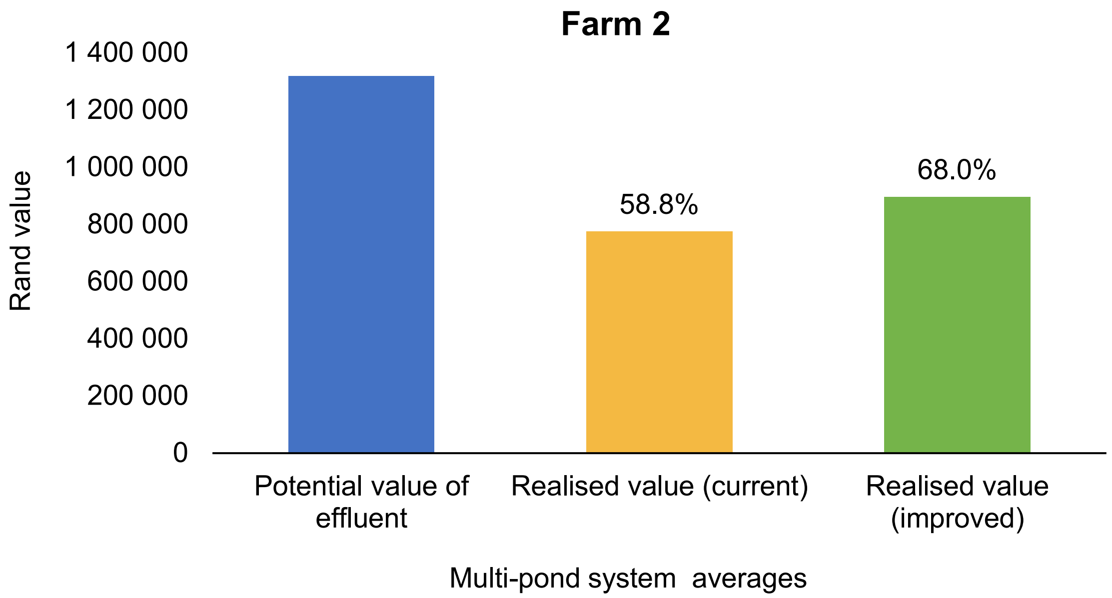


**Figure 2** Financial value analysis of effluent, comparing the potential value of the effluent with the realised value, for the current and for the improved system of farm 2. The percentage is the realised value as a percentage of the potential value.

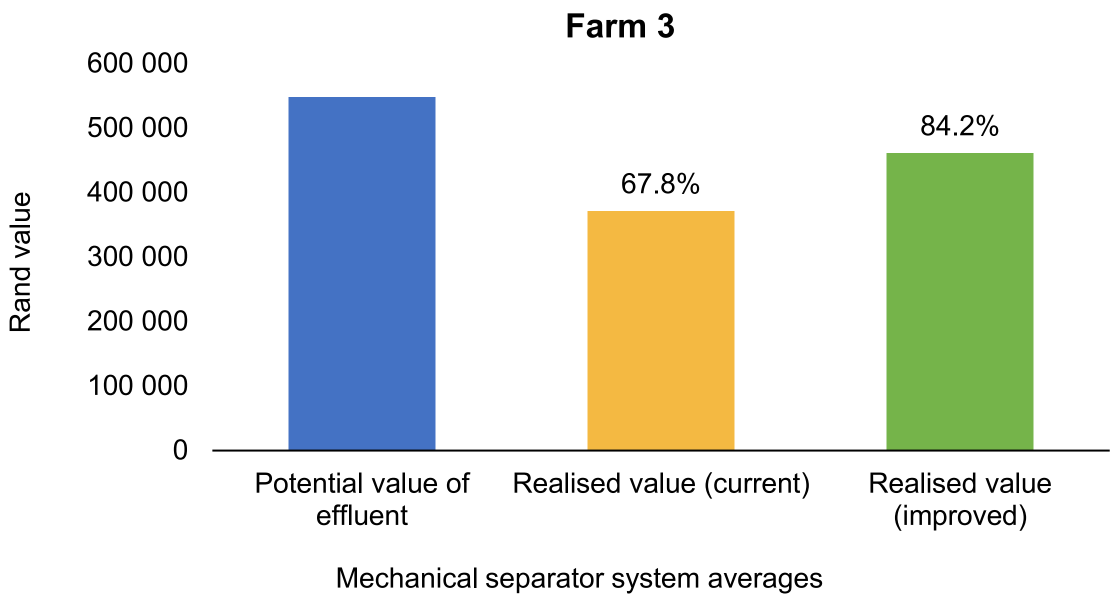


**Figure 3** Financial value analysis of effluent, comparing the potential value of the effluent with the realised value, for the current and for the improved system of farm 3. The percentage is the realised value as a percentage of the potential value.

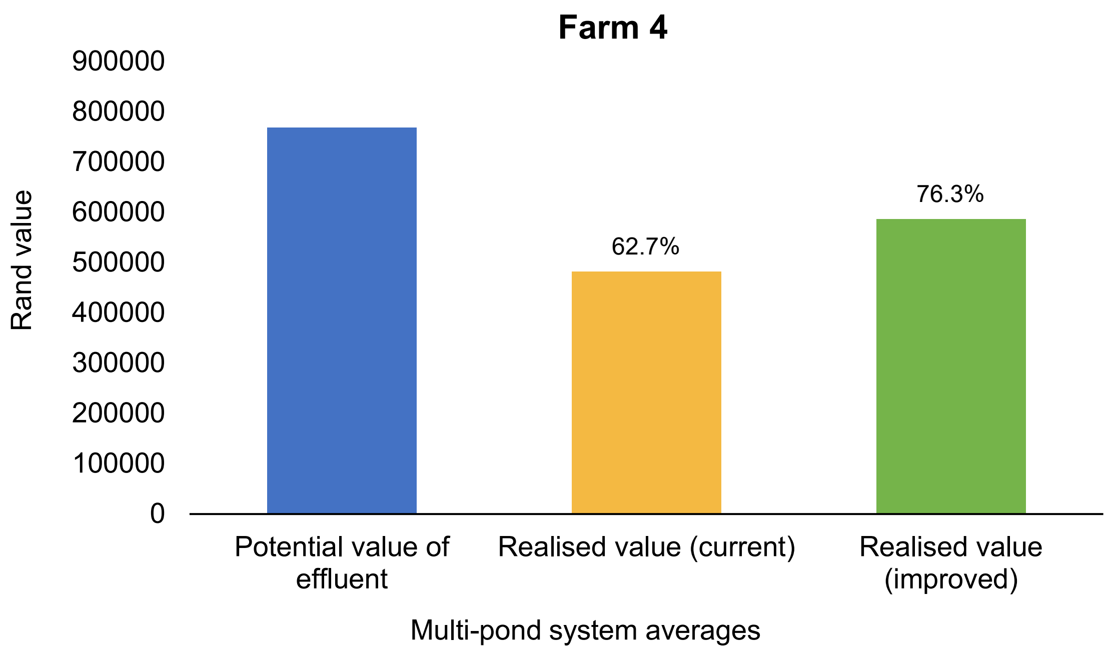


**Figure 4** Financial value analysis of effluent, comparing the potential value of the effluent with the realised value, for the current and for the improved system of farm 4. The percentage is the realised value as a percentage of the potential value.

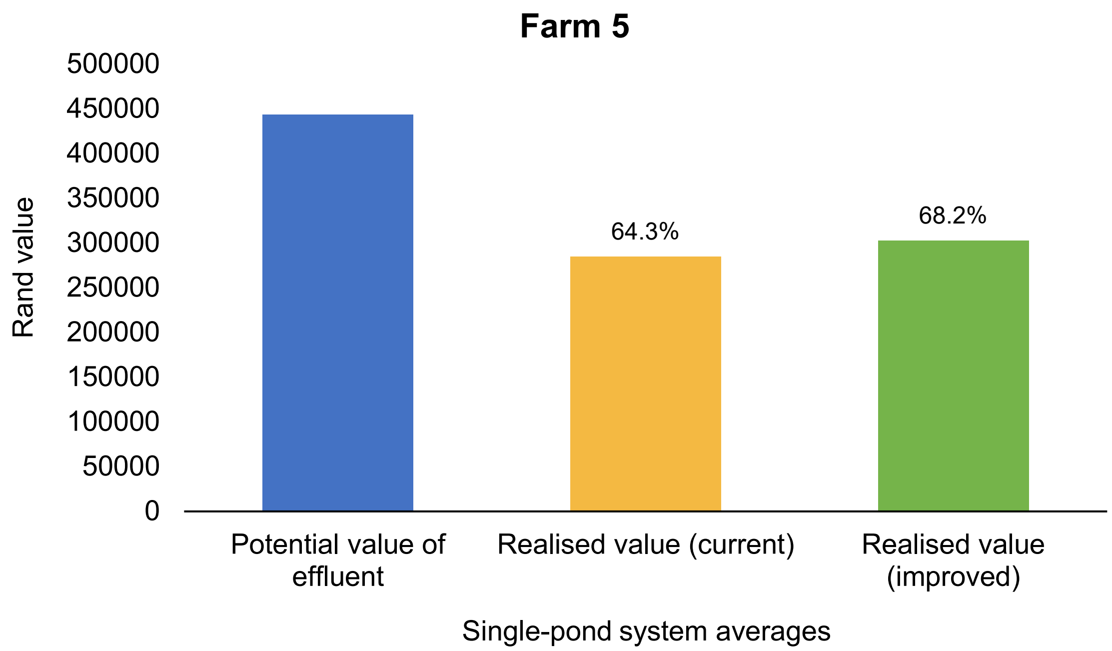


**Figure 5** Financial value analysis of effluent, comparing the potential value of the effluent with the realised value, for the current and for the improved system of farm 5. The percentage is the realised value as a percentage of the potential value.

The potential value of the effluent represents the Rand value of all the nutrients present in the effluent, whereas the realised values are the monetary value given to the effluent when only the nutrients that is required, from a soil fertility perspective, is taken into account. The percentages on the graphs indicate the realised value as a percentage of the potential value.

Farm 1 has the highest realised, compared to potential, values of all the farms (Figure 1). This is due to the high K requirements across both the current area and upgraded area. The realised value compared to the potential value is similar for the old and the current/upgraded system. This is due to 100% of the effluent K that can be utilised across the old spreading area, and 97% across the improved spreading area. Table 7 and 8 reinforces this statement.

Farm 2, which has the worst realised to potential percentage values of these five farms, have high soil P and K levels (Table 9). This results in a very low fertiliser requirement for both these nutrients leading to a low realised value, compared to the potential value. This will also lead to greater potential leaching resulting from the spreading of effluent on Farm 2.

Farm 3 has the highest percentage of increase in realised value with an increased effluent distribution area. Out of all the farms, this farm therefore has the highest value to be gained from spreading the effluent nutrients to new areas. Farm 4 also has quite a big increase in realised value. This increase observed from the upgraded system is mainly driven by the realised P, which is 55% of the potential P – the highest realised P increase across all the farms. The data in Table 8 support this statement.

Farm 5 has the lowest increase from the current to the upgraded system. This is due to the soil nutrient levels for both P and K being very similar across both spreading areas (Table 9).

The percentages are affected by two main parameters. Firstly, the higher the nutrient content of the effluent, the higher the potential value will be. Secondly, the higher the P and K fertiliser requirement, the higher the realised value will be.

Upon inspection of all these graphs, it’s evident that for majority of the farms, with the exception of farm 1, an improved MMS will increase the realised value of the effluent. Farm 1’s realised value of effluent decreased by 1.0%, whereas the increase was 9.2%, 16.4%, 13.6% and 3.9% for Farms 2 – 5, respectively, when the MMS is upgraded to increase the distribution area. This is a positive observation that emphasises the need to spread effluent to areas where there are not excessively high levels of nutrients.

Table 10 shows the Rand value of the increase in realised values that are expected when the farms increase their effluent distribution area by upgrading their MMS.

**Table 10** The increases in realised value from the improvement of the current system, the cost of upgrading, and the repayment period.

| Farm | Increase in realised value | Cost of upgrading MMS | Repayment period |
|---|---|---|---|
| 1 | -R 1 164 | R 38 000 | N/A |
| 2 | R 121 298 | R 150 000 | 1 year, 3 months |
| 3 | R 89 840 | R 1 214 000 | 13 years, 6 months |
| 4 | R 104 729 | R 200 000 | 1 years, 11 months |
| 5 | R 39 198 | R 150 000 | 5 years, 9 months |

It is worth noting that although the realised value of the effluent decreased with the upgraded system for farm 1, the overall costs for the system decreased. This is due to reduced pumping costs and reduced maintenance costs. The new system is also much easier to manage.

Farm 2 has the highest increase in realised value from extending the effluent distribution. Although having the worst realised values compared to the potential (Figure 2), the size of the farming operation and the massive amounts of effluent generated allows for this. Due to the cost of upgrading not being excessively high, coupled with the high increase in realised value, the repayment period for the upgrading of the MMS on this farm is the quickest.

Farm 4 has the second highest Rand value of increase when upgrading the system to increase the effluent distribution. This results in this farm also having a relatively quick repayment period. Farm 2 and Farm 4 by far has the quickest repayment periods from all the farms.

The cost of a mechanical separator is very high, as is seen from farm 3 (Table 10). Farm 2 previously had a multi-pond MMS, and upgraded to a mechanical separator system (Table 2). With a mechanical separator system, there is no anaerobic storage conditions of effluent solids which results in a much lower greenhouse gas (GHG) emission. The reduction in manure management emissions from this improved MMS is 2 503 to 1 928 tons $CO_2e$ (carbon dioxide equivalents) and 0.32 to 0.26 kg $CO_2e$/kg FPCM (fat protein corrected milk) (data from the Trace & Save database). Although this system has lower GHG emissions, the huge capital input makes this system unrealistic for most farmers.

Farm 5 has the lowest increase in realised Rand value from upgrading the system. This is due to the low percentage of increased realised value discussed above (Figure 5).

Farms 2, 3, and 5 all have viable payback periods and is not too risky financially, it therefore will be worthwhile to upgrade and extend their system. These upgrades are not capital intensive and huge capital inputs do not necessarily result in huge gains. Better value from the effluent can be gained from proper effluent management by selecting the correct areas (from a soil fertility perspective) which would most benefit from effluent. Further to this, ensuring the regular spreading of effluent, rather than letting it sit in a pond for long periods of time, limits the amount of loss of nutrients from volatilisation and leaching. Thus, pollution is also limited. Using effluent to replace fertiliser application, through a proper understanding of the nutrient levels in the effluent, and the nutrient requirements of the soil and pasture, will also maximise the return of spending on effluent distribution.

In the process of this case study, we have found that there is not an ideal effluent management system, but rather that the ideal effluent management system is relative to the goal of the farmer, and the context of the farm. In addition, having optimal management is more important than having the perfect system. There is a greatly likelihood of increasing the return on investment on manure management when a farmer selects the system which suits their context, and then focuses on getting the manure onto areas on the farm where it will have the greatest value.

The value of effluent in replacing fertiliser

One of the opportunities that is often discussed with regards to the value of effluent is that the application of effluent could lead to a reduction in fertiliser use due to the nutrients present. Assessing the value of this is highly complex though, since the spreading of effluent is not the only factor contributing to a reduction in fertiliser. The five case study farms are good examples of this.

Farm 4 skips fertilisation about half of the time that they apply effluent, but the application of fertiliser also depends on the growth rates of the pastures as the farmer fertilises according to this. Farm 3 also skips fertilisation with the application of effluent, and the farmer states that they use around 75% less fertiliser on the areas where effluent is applied, compared to the rest of the farm. On farm 5, they do not skip fertilisation events, but they did reduce their fertiliser from 30 kg N/ha to 23 kg N/ha per application in the previous year. The farmer does not attribute this reduction to the use of effluent alone though. Further, he believes that effluent is more valuable than the inorganic fertiliser of the same macronutrient rates that are generally applied on the farm. This is due to the valuable micronutrients present in the effluent (see the Table A in Appendix II) and the fact that micronutrients are not commonly fertilised on this farm.

In contrast, farm 2 does not skip any fertilisation events, and considers the nutrients added from the application of effluent as extra. Lastly, farm 1 spreads the effluent on an area where they would not normally fertilise in anyway, so they have seen huge value in the growth and health of the pastures where it is now spread.

Alternative effluent options

An MMS which has become popular on some pasture-based dairy farms is the use of a contractor to spread effluent. These contractors have all the necessary equipment to empty an effluent pond and spread the effluent. The advantages of such an arrangement are that the farmer does not have to carry capital costs, and has reduced labour and maintenance costs; they can get the contractor in only when needed to empty the ponds; and they can select exactly where to spread the effluent, since it is not a permanent set-up.

The challenge with evaluating the cost effectiveness of using a contractor is that they charge per hour, and depending on where the effluent is spread, the amount of effluent spread per hour varies greatly. If camps close to the dairy are selected, there is a high amount spread per hour, whereas a lot fewer loads are spread each hour when camps far from the dairy are selected. The irony of this is that generally, the camps with the lowest soil nutrient levels, and therefore the most ideal for effluent, are furthest from the dairy.

*A mechanical pond stirrer and an effluent tanker drawing up effluent. This is a similar setup to what the contractors use to distribute the effluent.*

Further, when assessing the cost of the contractor, it is highly complex to work out exactly what it would cost for a farmer to set themselves up to do the job. They would have to buy a new tractor and spreader, and then operate their own spreader every day. The distance of the camps being spread from the dairy makes a big difference. The size of tractor and spreader makes a big difference. Factoring in overtime, and other labour costs is challenging. But the farmer from farm 5 gave us an indication of how he would cost spreading, and it worked out to R429/ha for labour, maintenance and fuel. Obviously, in his context, where he already has the equipment, this is a relatively low cost.

Further to this, we calculated a per hectare cost of buying a new R290 000 spreader, and a new R800 000 tractor which would be dedicated to this job. Paying these back over 3 years, it works out to R738/ha. Obviously, this is highly dependent on the interest rate, and on how many hectares can be spread each month. We used a conservative figure of a standard work week. This exercise resulted in a figure of R1 167/ha to spread effluent, at 27 500 litres/ha.

In contrast to this, we explored the cost of using a contractor to do a similar job. We worked on an average, having spoken to three farmers that use different contractors in the Tsitsikamma area. On average, these contractors can spread 28 000 litres per hour, and it costs R1 000 per hour.

Based on the average nutrient values from the Trace & Save database for a multi-pond system average analysis, this works out to a cost of R38.65 per kilogram of N, P and K effluent spread, and R52.83 per kilogram of N, P and K effluent spread for the single-pond systems average analysis. When comparing this to a weighted average (based on N, P and K proportions of effluent) for chemical N, P and K of R32.60 per kilogram, it is cheaper to spread chemical fertiliser. Interestingly enough, at farm 5, where there is a single pond, the average cost of N, P and K spread works out to R23.08/ha. But as soon as this farmer needs to replace a tractor and/or spreader, it may be a better option to consider using a contractor.

This is an argument often made by farmers – why spread effluent with a spreader/contractor when it is cheaper to spread fertiliser. Spreading effluent is not an optional practice, it is imperative that the effluent is removed from the ponds and disposed of in a responsible manner. As we have established, relying on irrigation systems to spread effluent on pasture-based dairy farms is not a sustainable system. Therefore, short of figuring out a way to get effluent off of dairy farms, and onto crop farms (which are where a large amount of the nutrients on dairy farms come from in the first place – through the bought feed fed to cows). It is important to have an MMS and an effluent distribution system that results in the effluent being spread onto areas that most require it, and across as big of an area of the farm as possible. due to the excessive levels of P (most cases) and K (in some cases) in pasture soils.

Farmers cannot just choose the cheapest option to spread effluent. This will result in excess nutrients in the soil, and pollution of fresh water resources from excessive nutrients applied. This is not a sustainable option for the dairy industry.

## Conclusion

As a result of the intensification of animal production systems, significant amounts of manure are generated on dairy farms. This has led to the requirement to responsibly store, manage and dispose of this waste. Dairy effluent contains, among others, the macronutrients nitrogen, phosphorous and potassium. These nutrients are important for crop production and have value when used as a fertiliser source.

This study assessed potential financial benefits and risks of adopting improved manure management systems. Five farms that either recently changed their manure management system, or are planning to change it, were selected. The current and/or previous system was then compared to the improved and updated system. Farm 1 and 3 changed their manure management system completely, whereas the upgrading of the other three farms only consists of extending the distribution of the effluent.

The value of effluent is often exacerbated and only calculated according to the nutrients present in the effluent. This, however, is not an accurate representation of the value. Due to the nature of dairy farming, the soils often have excessive nutrient levels, especially in areas where effluent is, or has been, spread. If there is no further requirement for nutrients, they have no value. Furthermore, adding nutrients to soils with high nutrient levels, will lead to excessive nutrient contents. This results in nutrient imbalances that adversely affect the functioning of healthy soils. Excessive levels of nutrients in concentrated areas can also lead to nutrient losses and pollution.

The realised value of the effluent, determined according to the Trace & Save fertiliser recommendation, was much lower than the potential value of the effluent, determined according to the nutrients present in effluent. By increasing the distribution area of the effluent, and spreading it on areas where effluent has not been spread historically, the realised value of the effluent generally increased, except on farm 1. This is due to a lower K requirement of the soil on the new distribution area. The increases observed for the other farms increased between 3.9% and 16.4%. These increases are entirely driven by the higher nutrient requirements of the new areas.

The repayment period for the upgrading of manure management systems ranges from 1 year and 3 months (extending the distribution area of a multi-pond system) to 13 years and 6 months (upgrading to a mechanical separator system). For most farms, it is financially viable, and would be advantageous to increase and expand their effluent distribution area as this would result in the effluent being spread in areas where it has more value (i.e. higher nutrient requirements). The cost of upgrading and the benefits of an upgraded system would need to be assessed from farm to farm. For example, upgrading to a mechanical separator system reduces your greenhouse gas emissions significantly, and improves ease of management, but for the majority of farmers, this technology is unaffordable due to the hefty capital input. More importantly than the ideal system, is optimal management. A greater return on spending will be realised through good management, than having the perfect system.

This case study has not been an exhaustive study on all MMS on dairy farms. Alternative manure management systems exist, and using a contractor to spread effluent is gaining popularity among some dairy farmers. This system is especially advantageous due to it being a non-permanent setup and the farmers can spread effluent exactly where they want.

From our perspective, these effluent spreader systems present a good option, allowing farmers to spread effluent onto areas that most require nutrients. However, these systems come at a cost, resulting in chemical fertilisers being cheaper than the value of the nutrients in the effluent. Nevertheless, spreading effluent on dairy farms is not an optional practise and it is essential to collect the effluent from the storage ponds and dispose of it responsibly. Nutrient build-up is a major problem in pasture-based dairy farming and poses a great environmental risk of pollution. Farmers can therefore not just choose the cheapest disposal option.

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# Appendix I

Interview questionnaire

Already upgraded system:

- What were the benefits of the old system?
- What were the shortcomings of the old system?
- What was your motivation for wanting to upgrade your old system?
- What did it take to improve your old system?
- What was the cost of upgrading your old system?
- What are the benefits of a new, or updated, system?
- What are the shortcomings of a new, or updated, system?
- What is the cost of maintenance and management (ex. pumping) of the new system? Has it cost you more, over and above the upfront costs to change it?
- Where does your effluent spreading system currently reach?
- Where do you spread effluent? (if it is different to above)

Looking to upgrade system:

- What are the benefits of the current system?
- What are the shortcomings of the current system?
- What is your motivation for wanting to upgrade your current system?
- What will it take to improve your current system?
- What is the cost of upgrading your current system?
- What are the foreseeable benefits of a new, or updated, system?
- What are the foreseeable shortcomings of a new, or updated, system?
- What is the estimated cost of maintenance and management (ex. pumping) of the new system? Will it cost you more, over and above the upfront costs to change it?

# Appendix II

## Effluent sample analysis

**Table A** The full effluent sample analyses that was taken for each of the five participating farms.

| | Unit | Farm 1 | Farm 2 | Farm 3 | Farm 4 | Farm 5 |
|---|---|---|---|---|---|---|
| **Physical and Aesthetic Determinands** | | | | | | |
| Sodium Adsorption Ratio (SAR) | | 1.1 | 2.4 | 5.7 | 3.0 | 3.8 |
| **Macro Chemical Determinands** | | | | | | |
| Total Ammoniacal Nitrogen (TAN) as N | mg/L | 255 | 238 | 143 | 78.6 | 175 |
| Nitrate (NO3) as N | mg/L | <0.18 | <0.18 | <0.18 | <0.18 | <0.18 |
| Sodium (Na) Dissolved | mg/L | 62.8 | 153 | 420 | 147 | 250 |
| Calcium (Ca) Dissolved | mg/L | 109 | 146 | 226 | 101 | 165 |
| Magnesium (Mg) Dissolved | mg/L | 76.0 | 97.2 | 113 | 50.5 | 104 |
| Potassium (K) Dissolved | mg/L | 584 | 627 | 499 | 333 | 550 |
| Phosphorus (P) Total | mg/L | 90.3 | 66.4 | 133 | 28.9 | 53.1 |
| Total Nitrogen (N) | mg/L | 480 | 300 | 210 | 101 | 270 |
| **Micro Chemical Determinands** | | | | | | |
| Boron (B) Total | mg/L | 0.27 | 0.35 | 0.66 | 0.23 | 0.29 |
| Copper (Cu) Total | mg/L | 0.51 | 0.12 | 0.35 | <0.05 | <0.05 |
| Iron (Fe) Dissolved | mg/L | 0.89 | 1.30 | 7.00 | 1.10 | 1.10 |
| Iron (Fe) Total | mg/L | 33.7 | 5.70 | 11.6 | 1.40 | 3.10 |
| Manganese (Mn) Dissolved | mg/L | 0.58 | 0.29 | 1.30 | 0.61 | 0.34 |
| Manganese (Mn) Total | mg/L | 5.4 | 0.91 | 2.0 | 0.68 | 1.00 |
| Zinc (Zn) Total | mg/L | 3.6 | 0.92 | 2.0 | 0.23 | 1.40 |
| **General Chemistry** | | | | | | |
| Orthophosphate (PO4) as P | mg/L | | 34.5 | 71.5 | 13.9 | 23.8 |

# Appendix III

Assumptions

According to Chastain and Camberato (2004), where effluent is generated only at the milking parlour, which is true for all five farms included in this case study, the total solids content of effluent ranges between 0.6 and 1.7%. This is a very small percentage, and the effluent generated are therefore completely dependent on the amount of water used to wash the dairy parlour and holding yard. Trace & Save collects this data from farmers, and therefore we have assumed that the total effluent generated per farm is the litres of water used to wash the dairy per day multiplied by 365 days (Equation 1). This gives a more realistic, farm specific figure. The figures from literature often have very different contexts than South African dairy farms. Obviously, there will be loss from evaporation from the effluent ponds, but the rate/amount of evaporation is completely unknowable with the data currently available. Therefore, rather than making large assumptions, we have chosen to exclude evaporation from these calculations. pg 6

Only the macronutrients (nitrogen [N], phosphorous [P] and potassium [K]), were used in the calculations of this case study. Farmers rarely use effluent as a source of other nutrients. Although, it is acknowledged that there is much greater value to effluent than purely the N, P and K nutrients, for the sake of the case study, we thought it best to calculate effluent value based on these three, most abundantly fertilised nutrients. pg7

The N is treated a bit different than the other two nutrients. All of the nitrogen in the effluent has value and is treated as such. However, an 8% loss has been accounted for, which includes volatilisation and nitrous oxide emissions that occur when the effluent is spread on the pastures (IPCC, 2006). pg 10

Trace & Save views N fertiliser as a management tool, and there are no specific recommendations for N application rates. Trace & Save rather promotes optimising N fertiliser usage through good management practices. Hence, for this case study we have treated all the N as valuable, because it would be too complicated to treat it any other way. And farmers generally perceive effluent as a form of N fertilisation. pg 11