CASE STUDIES

In this section, two case studies are discussed: the sustainable use of dairy effluent, and the use of solar energy and other technologies on dairy farms for improved energy and water efficiency. A cost-benefit assessment has been done for each, showing the bankability of these two regenerative agriculture practices.

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COST-BENEFIT ASSESMENT 1

EFFLUENT MANAGEMENT

This study investigated the potential financial benefits and risks of adopting improved manure management systems on pasture-based dairy farms through undertaking a cost-benefit assessment.

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

MANURE ON DAIRY FARMS – PROBLEM OR BENEFIT?

Livestock manure is the faeces and urine generated by animals. On a dairy farm, the manure that is washed down from the dairy parlour and holding yard contains organic material and is nutrient rich (Moreki and Chiripasi 2015). Manure is both a waste product with the potential to pollute, and a potential fertiliser. One challenge in dairy production is managing manure in a way that is advantageous for agricultural production, while minimising the potential negative impact on the environment and public health.

High greenhouse gas emissions are associated with manure management. The repeated application of effluent in the same areas might also cause nutrient build-up, potentially leading to pollution.

Systems for handling, storing and applying manure are known as manure management systems (MMS). The most common MMS in South Africa is the use of anaerobic lagoons or ponds where animal waste is mostly handled as a liquid. These ponds contain manure that is typically diluted with water, namely effluent. Apart from manure and water, the effluent also contains milk solids and all kinds of detergents that are washed from the dairy parlour.

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, while reducing nutrient losses (Sefeedpari et al. 2019). This may change how manure is perceived – from being considered as a problem to being seen as a valuable resource to improve the sustainability of dairy farming.

ACCESSING THE FULL REPORT

A complete description of the methodology and all the results are included in the full Trace & Save “Assessment of the potential financial benefits and risks of adopting improved effluent management” case study, available at: Financial Risks and Benefits of improved effluent management, FULL CASE STUDY-FINAL, 17.04.23.pdf.

MANURE MANAGEMENT SYSTEMS ON PARTICIPATING FARMS

Five willing farmers who work with Trace & Save, two from the Southern Cape and three from the Eastern Cape, were selected for this study to assess the potential financial benefits and risks of adopting improved MMSs. These farmers have either recently upgraded their MMS or are planning to do so. The current and/or previous system was then compared to the improved and updated system. Farms 1 and 3 have changed their MMS completely, whereas the upgrading of the other three farms comprises only extending the distribution of the effluent.

The five farms are a good representation of the 101 dairy farms with which Trace & Save has worked and represent a general highly productive dairy-pasture farm in South Africa.

A description of the previous/current, and/or upgraded/improved MMS is given in Table 5. The area of effluent distribution is given in hectares.

A typical effluent storage pond.

TABLE 5: SUMMARY OF MMSs ON THE PARTICIPATING FARMS AND THE AREA OF EFFLUENT DISTRIBUTION

Farm 1	
Previous system 6,7 ha	A multi-pond system with three ponds. The first pond allowed for the solids to settle. The liquid portion then moved to the second and then third pond before being fed into the irrigation system. Blockages from solid portions of the manure caused the farmer a lot of problems. Ease of management was the main reason for changing the MMS. The farmer emphasised that the problems associated with blockages had cost them a lot of money and time over the years.
Current system 21,6 ha	This farm has recently changed their MMS to a simple single-pond system. A trench was 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 as it is applied. The capital input of this system was R38 100 (cost of the trench and the new pipeline). The farmer stated that the operating cost is about a quarter of what it used to be. This MMS is much easier to manage and the farmer is thrilled with it.

Farm 2	
Current system 171,2 ha	This farm has two dairies, therefore two MMSs, which both function similarly: each with a multi-pond system and two anaerobic lagoons. A concrete trap separates most of the solids 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. Then it is fed into the irrigation system for distribution.
Upgraded system 320,8 ha	The improved system will function on the same principles (i.e. a multi-pond system) but the effluent will be distributed to new pivots to increase its distribution area. The upgraded MMS will only require the laying of a new pipeline. Management and running costs will be very similar to what they currently are.

Farm 3	
Previous system 180,8 ha	This farm had a multi-pond system and the effluent was distributed to the pastures through the irrigation system. The farmer, being very close to a town, experienced immense pressure from the public regarding environmental and social concerns, i.e. foul odours, greenhouse gas (GHG) emissions and pollution. These pressures were the main reason for upgrading the MMS. The farmer also had trouble with sediment build-up in the effluent pond, which had to be cleaned every four years, adding costs.
Current system 318,6 ha	The current MMS has a mechanical separator, which immediately separates the solid and liquid portions of the effluent 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 total cost to upgrade to the mechanical separator system was R1 014 000. The farmer stated that this system resulted in a higher quality solid and liquid manure product. He also said that the manure was 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 about R200 000. The total cost of the upgrading will therefore be R1 214 000.

Farm 4	
Current system 127,8 ha	This farm has a multi-pond system. The effluent is filtered into the second pond from a pre-trap and then distributed through the irrigation system to four of the seven pivots on the farm. The farmer stated that this system worked for them because it made it easy to spread a lot of effluent. However, the farmer has a lot of problems with sediment build-up in the pond.
Upgraded system 231,8 ha	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 ±20 m. The effluent will 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.

Farm 5	
Current system 189,5 ha	The current system makes use of a single pond. The effluent is directed through a trap before landing in the lagoon and is then pumped to certain points on the farm where an effluent irrigator/gun can be connected to irrigate the effluent onto drylands. This farm also makes use of a tanker to spread effluent to camps that are not covered by the irrigator and those further away from the dairy. The farmer said that this system was simple, but the effluent irrigator was only set up to work in a small area. The spreading of effluent with the tanker was more expensive and labour intensive.
Upgraded system 315,1 ha	The improved system will function on the same principle (i.e. a single-pond system) but the effluent will be distributed further to new dryland areas, thus increasing the distribution area of the effluent. The primary motivation for the upgraded system is 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 precious and stated that these costs could easily be justified and were worth it. The farmer also stated that the management and maintenance of an upgraded MMS would be the same as for the current system.

The effluent irrigator/gun used by Farm 5.

NUTRIENT CONCENTRATION AND REALISED VALUE OF EFFLUENT

The macronutrients, nitrogen (N), phosphorus (P) and potassium (K) that are available through the spreading of effluent were determined for each farm.

BOX 4: POTENTIAL VALUE AND REALISED VALUE

The potential value of effluent represents the total amount of nutrients in the effluent, using the values obtained from the Trace & Save database.

Realised value represents the quantities of nutrients that are deficient in the soil (i.e. what is required to satisfy the Trace & Save fertiliser recommendation).

In this case study, effluent value was only assumed on camps where the nutrients were needed. Trace & Save took soil samples in each camp of the participating farms every year. The Trace & Save fertiliser recommendation, per paddock for each farm, was used with the nutrient levels (that can be obtained through the spreading of effluent) to determine the realised value of the effluent.

The nutrients from the effluent that are actually required (realised value) across the entire area over which it is spread, was 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).

Nutrient concentrations of effluent samples

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

TABLE 6: SUMMARY OF THE N, P AND K CONCENTRATIONS FOR EACH MMS 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)

Table 6 shows a massive variation between the samples. This is because of the high standard deviation values. Standard deviation is a measure of variability in a dataset. Here, the high standard deviations mean that data points are spread out over a large range of values.

These variations are also observed in the literature. Nutrient concentrations in both liquid and solid manure differ significantly between dairies, within dairies and over time. This results from changes in animal diet, the age and breed of the cows, manure-handling and storage practices, and environmental conditions. Therefore, the averages from a larger dataset from similar MMSs were used to do all the case study calculations, taking samples in different months over several years to provide a more robust average. This was done instead of using the values from the single samples taken in January 2023 on each farm.

Variations in effluent nutrient content and quality make it important for farmers to analyse their effluent regularly, at least once a month, in order to have a proper insight into what is being applied to pastures.

Potential versus realised value of effluent for current and upgraded systems

The potential nutrient values and the realised values are shown in Tables 7 and 8, respectively, both for the previous/current and the upgraded/improved MMSs of each farm. The N is treated differently from the other two nutrients. All the N 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.

TABLE 7: POTENTIAL COMPARED TO REALISED VALUE OF EFFLUENT FOR PREVIOUS/CURRENT MMSs (kg/ha)

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: POTENTIAL COMPARED TO REALISED VALUE OF EFFLUENT FOR UPGRADED/IMPROVED MMSs (kg/ha)

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

The values for the potential and realised value of the effluent for the upgraded/improved MMSs (Table 8) is lower than for the previous/current MMSs (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 5).

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 P, on dairy farms. The differences between the potential and the realised values for both P and K above (Tables 7 and 8) will lead to the oversupply of those nutrients, causing nutrient imbalances in the soil. From a soil-health perspective, it is therefore helpful to increase the distribution area of the effluent, which results in a more uniform spread across the farm. Apart from the build-up of nutrients in the soil, the application of unnecessary and excessive nutrients increases the risk of leaching and pollution of freshwater sources by these nutrients.

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

TABLE 9: SOIL NUTRIENT STATUS OF PREVIOUS/CURRENT AND UPGRADED/IMPROVED MMSs (kg/ha)

	Previous/current system			Upgraded/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

*P Bray I analysis

BOX 5: A BIG-PICTURE NUTRIENT CHALLENGE FOR THE DAIRY INDUSTRY

Since Trace & Save takes soil samples on 101 pasture-based dairy farms across South Africa, it can point out the big-picture challenge of managing effluent. Of the 10 929 camps on the 101 farms, 23% require P fertiliser, 49% require K fertiliser and only 14% 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 solely blamed for this. They face a challenging situation, which reflects the reality of the greater challenge to the industry. This dilemma should not be thrown back at the farmers but would be better solved through a collaborative effort between farmers, milk buyers and the dairy industry structures.

The average P levels in the soils from these farms, across both the previous/current and upgraded/improved 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. 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 promotes optimising N fertiliser usage through good management practices.

REPAYMENT PERIOD

A repayment period for the cost of the MMS upgrade was calculated.

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 are required, from a soil-fertility perspective, are considered. The percentages in the graphs in Figure 14 show the realised value as a percentage of the potential value for previous/current and improved/upgraded MMSs of all the participating farms.

- **Highest realised value:** Farm 1 has the highest realised value compared to the potential value of all the farms (Figure 14). This is because of the high K requirements across both the current and the upgraded area. The farmer can use 100% of the effluent K across the old spreading area, and 97% across the improved spreading area. Tables 7 and 8 support this statement.
- **Worst realised value:** Farm 2, which has the worst realised value compared to the potential value of all the farms, has 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.
- **Highest increase in realised value:** Farm 3 has the highest percentage increase in realised value, with an increased effluent distribution area. Of all the farms, this farm therefore has the highest value to be gained from spreading effluent nutrients to new areas. Farm 4 also has quite a significant increase in realised value, 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 supports this statement.
- **Lowest increase from current to upgraded MMS:** Farm 5 has the lowest increase from the current to the upgraded system. This is because the soil nutrient levels for both P and K are very similar across both spreading areas (Table 9).

Upon inspection of all these graphs, for the majority of the farms, except Farm 1, an improved MMS will increase the realised value of the effluent.

Table 10 shows the rand value of the increase in realised values that is expected when the farms increase their effluent distribution area by upgrading their MMSs.

FINANCIAL INDICATIONS OF EFFLUENT VALUE AND THE REPAYMENT PERIOD FOR UPGRADING CURRENT SYSTEMS

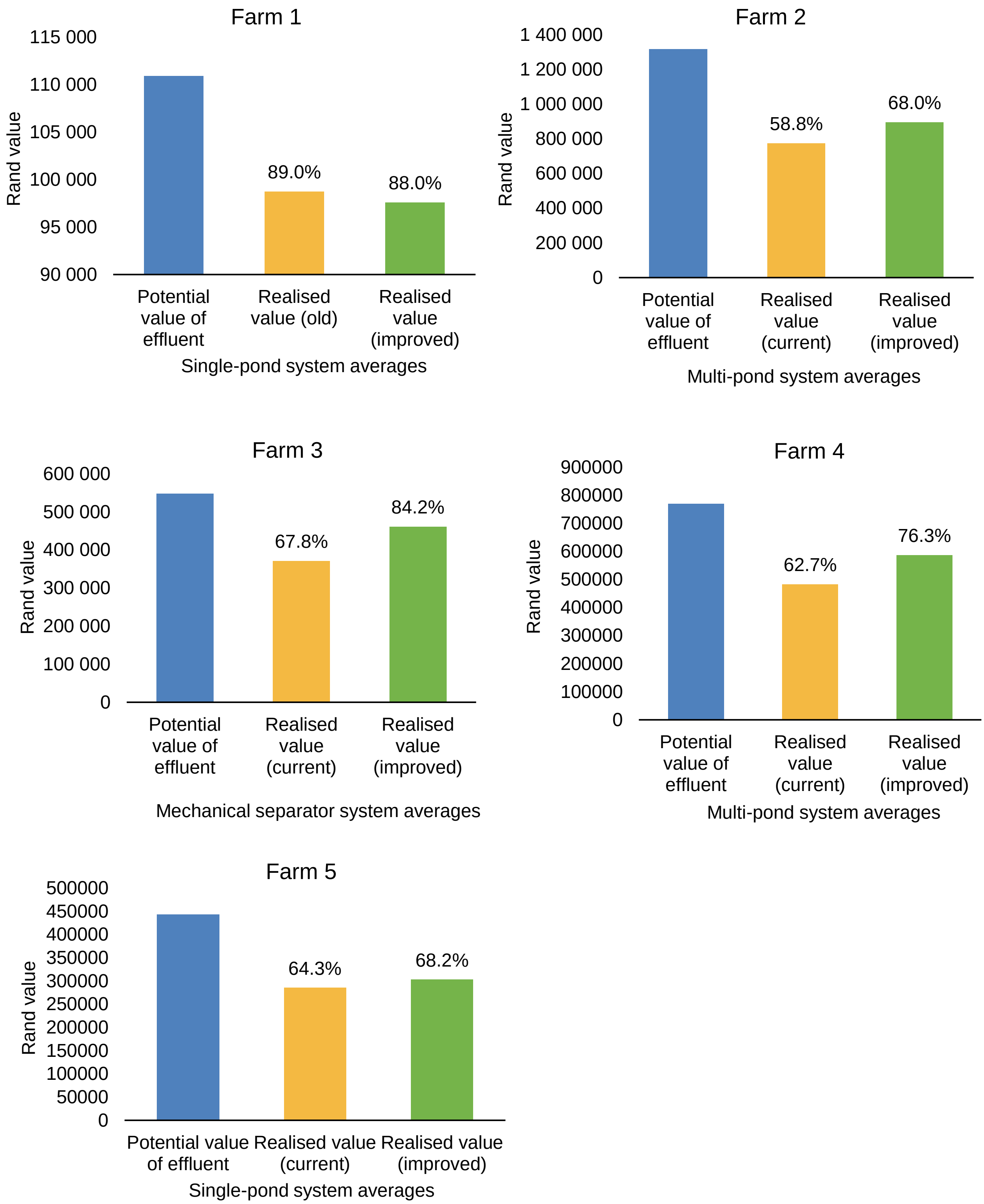

Figure 14: Financial value analysis of effluent, comparing the potential value of the effluent with the realised value, for the previous/current and upgraded/improved systems of all the participating farms. The percentage is the realised value as a percentage of the potential value.

TABLE 10: 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	-R1 164	R38 000	N/A
2	R121 298	R150 000	1 year, 3 months
3	R89 840	R1 214 000	13 years, 6 months
4	R104 729	R200 000	1 years, 11 months
5	R39 198	R150 000	5 years, 9 months

- **Reduced overall costs:** Although the realised value of the effluent decreased with the upgraded system for Farm 1, the overall costs for the system decreased. This is because of reduced pumping costs and reduced maintenance costs. The new system is also much easier to manage.
- **Shortest repayment period:** Farm 2 has the highest increase in realised value from extending effluent distribution. The size of the farming operation and the massive amounts of effluent generated allow for this, despite the farm having the worst realised values compared to potential values (Figure 14). Because the cost of upgrading is not excessively high, coupled with the high increase in realised value, the repayment period for the upgrading of the MMS on this farm is the shortest.

  Farm 4 has the second highest increase in realised rand value from upgrading the system to increase effluent distribution. This results in this farm also having a relatively short repayment period. Farms 2 and 4 have the shortest repayment periods of all the farms by far.
- **Huge capital input:** The cost of a mechanical separator is very high, as seen from the upgrading figures for Farm 3 (Table 10), which previously had a multi-pond MMS and upgraded to a mechanical separator system (Table 5). Using a mechanical separator system, there are no anaerobic storage conditions of effluent solids, which results in much lower GHG emissions. Although this system has lower GHG emissions, the huge capital input makes it unrealistic for most farmers.
- **Lowest value increase from upgrading:** Farm 5 has the lowest increase in realised rand value from upgrading the system. This is because of the low percentage of increased realised value (Figure 14).
- **Viable payback periods:** Farms 2, 3 and 5 all have viable payback periods without too much financial risk. It would therefore be worthwhile to upgrade and extend their MMSs. These upgrades are not capital intensive.

Better value from the effluent can be gained from proper effluent management by selecting the correct areas (from a soil-fertility perspective) that would most benefit from effluent application. Ensuring the regular spreading of effluent, rather than letting it sit in a pond for long periods of time, reduces the loss of nutrients from volatilisation and leaching. 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.

THE VALUE OF EFFLUENT IN REPLACING FERTILISER

One opportunity that is often discussed regarding the value of effluent is that its application of effluent could lead to a reduction in fertiliser use because of the nutrients present in effluent. 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 use. 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. The farmer stated that they used about 75% less fertiliser on the areas where they apply effluent compared to the rest of the farm.
- On Farm 5, they do not skip fertilisation events, but had reduced their fertiliser use from 30 kg N/ha to 23 kg N/ha per application in the previous year. However, the farmer did not attribute this reduction to the use of effluent alone.
- In contrast, Farm 2 does not skip any fertilisation events, and considers the nutrients added from the application of effluent as extra.
- On Farm 1, they spread the effluent on an area that they would not normally fertilise anyway, so they have seen immense value in the growth and health of the pastures where effluent is now spread.

BOX 6: THE BEST METHOD FOR DISPOSING OF OR SPREADING EFFLUENT

Farmers often debate why they should spread effluent using a spreader or a contractor if it is cheaper to spread fertiliser. But spreading effluent is not an optional practice. It is imperative to remove the effluent from the ponds and dispose of it responsibly.

Therefore, short of figuring out a way to get effluent off dairy farms and onto crop farms (which is where a large amount of the nutrients in effluent comes from in the first place, through the bought feed fed to cows), every dairy farmer needs to have an MMS and an effluent distribution system. With these systems, they can spread the effluent onto areas that most require it, and across as big an area of the farm as possible.

Using a contractor to spread effluent is gaining popularity among some dairy farmers. This system is especially advantageous because it is a non-permanent set-up and the farmers can spread effluent exactly where they want to.

However, choosing the cheapest option to spread effluent is not a sustainable practice for the dairy industry. This could cause excess nutrients in the soil, and the pollution of freshwater resources when excessive nutrients are applied and the nutrient requirements of the soil are not sampled or considered beforehand.

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

An effluent spreader is used for the effective use of dairy effluent on pastures and improved soil fertility.

COST-BENEFIT ASSESMENT 1: KEY FINDINGS

The value of effluent is often only calculated according to the nutrients present in the effluent. This, however, is not an accurate representation of the value. Because on 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. Adding more nutrients in this case can cause nutrient imbalances that adversely affect the functioning of healthy soils, or can cause pollution through the run-off of excess nutrients into water courses or can pollute groundwater sources.

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 was because of a lower K requirement of the soil in the new distribution area on Farm 1. The increases in realised value 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.

Realised value (and therefore the financial value of using effluent) is entirely determined by the nutrient requirements of the areas where effluent will be applied.

The repayment period for the upgrading of MMSs across the five farms 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 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. Upgrading to a mechanical separator system, for example, reduces GHG emissions significantly and improves ease of management, but for most farmers, this technology is unaffordable because of the hefty capital input. Optimal management is more important than the ideal system. A greater return on investment will be realised through good management, rather than by having the perfect system.

Using an effluent spreader presents a good option, allowing farmers to spread effluent on 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. Nutrient build-up is a major problem in pasture-based dairy farming and poses a great environmental risk of pollution. Farmers can therefore not simply choose the cheapest disposal option.

One cannot make broad generalisations that using effluent on pastures as a nutrient source will definitely create a cost saving, since the pasture may not require these nutrients. Rather, the financial value of effluent application and use depends on the following:

- Whether farmers have the equipment to spread the effluent themselves and can expand their effluent distribution area to reach areas furthest from the dairy that most require the nutrients.
- Whether there is an affordable option of using a contractor to do the effluent spreading if the farmer does not have the necessary equipment.
- What the nutrient requirements are of the camps where effluent will be applied (higher nutrient requirements = higher realised value of effluent = larger potential for financial saving).
- Whether the cost of upgrading the MMS system to distribute effluent to all parts of the farm that need it makes financial sense.

However, as this case study has shown, taking the above considerations into account, it is financially viable, and would be advantageous for most farms to expand their effluent distribution area, as it presents a bankable investment opportunity with relatively short repayment periods.