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USING CLEARTECH® TO REDUCE MODELLED NUTRIENT LOSSES AND ENVIRONMENTAL RISK

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Introduction

Improving farm dairy effluent (FDE) management through sufficient storage, targeted application of nutrients and increasing water use efficiency is one of the major solutions in reducing the environmental effects associated with losses of nutrients and pathogens, in particular nitrogen (N), phosphorus (P) and *E.Coli* into ground or surface water. There is increased concern in New Zealand in regards to water usage and shortage, combined with a concern for water quality. There is a need for new technologies and tools that mitigate nutrient losses and/or conserve water. For FDE, advances were made in water recycling in the form of 'Green-water', however this still poses a risk of exposure of micro-organisms to human health.

ClearTech® represents a new technology to treat FDE, by using a coagulant that flocculates colloidal particles in FDE into flocs that settle out of the liquid. It uses a polyferric sulphate coagulant, based on research by Cameron and Di, (2019) who determined it was the most effective option for use in treating FDE. In the same research, ClearTech® was tested extensively in laboratory studies, large tank trials, pilot plant trials & pasture field trials and proved successful in treating FDE to produce clarified water and generation of a reduced volume of 'treated FDE'. The results showed no adverse effects on plant growth or composition. Lysimeter studies also showed significant benefits in reducing leaching losses of E.coli, total P and dissolved reactive phosphorus (DRP) (Wang et al. 2019). ClearTech® has potential to allow flexibility of transfer of nutrients from 'high risk, low demand' periods to 'high demand, low risk' periods, where there is a sufficient soil moisture deficit. This means that nutrients can be applied to match plant growth and supply nutrients strategically to demands.

Overseer® Nutrient Budgets software is widely used in New Zealand to evaluate farmers nutrient use on farm, identifying and improving nutrient losses, and understanding farm system changes. It is also used frequently in a regional compliance framework which affects farmers directly in some areas. Therefore, with constant evolving research, mitigation tools will be essential that can be incorporated into Overseer® that may help farmers in their future goals and where required, reductions in nutrient leaching. Given that ClearTech® has the potential to reduce the risk of nutrient leaching, the aim of this research was to assess the nutrient loss effects of utilising ClearTech® on a farm scale using Overseer®.

Methods

Four existing farms from the Ravensdown database were used as a basis of the modelling. Farm location and names were omitted for privacy. Overseer® version 6.3.1 was used to model the farms, which was undertaken in accordance with the OVERSEER® 6.3.1 "best practice data input standards". The farms were all dairy operations, which were located in Southland, West Coast, Manawatu and Waikato, and comprised of a variety of soil types (Table 1).

Farm	Soil name	Texture	Drainage	PAW (0-60cm)
West Coast	Ahaura, Hokitika, Matiri	Silty & sandy loams	Well drained	30-97mm
Manawatu	Bushcroft, Ohakuni	Silty loam	Imperfectly drained	81-119mm
	Larbreck, Ashburton, Otorohanga	Sandy loam & loam	Well drained	51-114mm
Waikato	Airfield	Clay	Imperfectly drained	80mm
	MaiMai, Temuka	Silty loam & clay	Poorly drained	109-139mm
	Utuhina,	Peat	V. poorly drained	264mm
	Kakupuku	Silty loam	Well drained	100mm
Southland	Lumsden	Silty loam	Poorly drained	107mm
	Morven, Riversdale, Balmoral	Silty & sandy loams	Well drained	60-64mm

Table 1. Soil summary of the modelled farms. Source of data S-maps (Manaaki Whenua, 2019)

In order to avoid bias in results driven by differences in farm management, small changes were made to align the farms as far as reasonable. All farms were modelled with pasture only, in order to avoid the influence of nutrient losses driven by crop blocks. In addition, the farms were modelled with no imported supplements, a default lactation length, a cow weight between 480-500kgLW. Only the Southland farm was partially irrigated by pivot and the rest were dryland. Cow numbers and production remained as the original data. Key information for each of the farms is summarised below in Table 2.

Farm	Rainfall mm/yr	PET mm	Peak Cows (1 Dec)	Peak cows/ ha grazed	Milk solids/ cow (kg)	Fertiliser N (kg/ha/yr)	Effluent area (ha)
West Coast	2033	694	689	1.9	274	53	30
Manawatu	1138	869	250	1.8	384	122	24
Waikato	1400	790	212	2.3	439	98	24
Southland	1004	745	1204	2.5	487	99	234

Table 2. Characteristics of the four farms modelled in Overseer®. Climate data from Overseer® climate station tool using latitude and longitude.

In regards to FDE management, all farms before the inclusion of ClearTech® were modelled with a holding pond, with liquid FDE sprayed regularly over the effluent area at an application depth of 12-24mm. Solids were not modelled as separated before entry to the holding pond and pond solids were modelled as spread over the effluent area in March annually.

For the ClearTech® scenario models, all base information was the same, except all FDE was modelled as exported. The ClearTech® treated FDE portion was then represented by first calculating the estimated FDE generated from the milking shed per cow per day (105.2L/cow) used from LUDF (Cameron & Di, 2019), and calculating this over the milking season 1st August to 31st May. To mimic the action of the coagulant, this total volume was reduced by two thirds to represent one third remaining as 'treated FDE' and two thirds remaining as clarified water. The clarified water portion was not modelled as this was assumed to be recycled. The nutrient concentrations of the treated FDE used were tested and reported in a previous study (Cameron and Di, 2019); Total-N content averaged 447g m^{-3}, Total-P was 111.8g m^{-3}, potassium (K) was 195g m^{-3} and Sulphur (S) was 320.97g m^{-3}. Other nutrients were not used due to the focus of the modelling on NPKS.

The concentration of nutrients were calculated for the treated FDE volume (volume FDE produced/month x concentration of nutrient (g/kg)). The total NPKS (kg/month) for the treated FDE produced from August to May was averaged over the period of October to March and applied in the form of organic fertiliser. The type of organic material selected was imported dairy effluent, in a slurry/liquid form. The total kg/month applied over the effluent area from October to March for each nutrient NPKS is summarised below in Table 3.

Farm	N (kg/month)	P (kg/month)	K (kg/month)	S (kg/month)
West Coast	495	124	216	355
Manawatu	189	42	73	120
Waikato	168	42	73	121
Southland	835	209	364	599

Table 3. NPKS applied (kg/month) over the effluent area from October to March.

An analysis of the nutrient losses, with a focus on N and P was conducted by comparing the results from the Overseer® models with the original farm and the farm with inclusion of ClearTech®.

Results

As reported in the previous trials conducted by Cameron & Di (2019), there was an increase in the total N, total P and S in the treated FDE portion compared to untreated farm FDE, due to the coagulation process and the increased solids content of the treated FDE. As concentrations of nutrients and their differences have been discussed extensively in previous work, these have not been repeated here, and only the Overseer® modelling results outlined. With the inclusion of ClearTech®, whole farm N, P and K losses, as predicted by Overseer®, decreased across the four farms (Table 4(a) and b).

(a)

	Farm modelled without ClearTech®					
Farm	Total N lost (kgN/yr)	N lost to water (kgN/ha/yr)	Total P lost (kgP/yr)	P lost to water (kgP/ha/yr)	K lost to water (kg/ha/yr)	S lost to water (kg/ha/yr)
West Coast	24947	63	2486	6.2	25	41
Manawatu	5585	34	99	0.6	14	32
Waikato	2854	30	228	2.4	41	145
Southland	26965	54	486	1	11	42

Note: Losses a result of Leaching and/or run-off

(b)

Farm	Farm modelled with ClearTech® Total N lost (kgN/yr)	N lost to water (kgN/ha/yr)	Total P lost (kgP/yr)	P lost to water (kgP/ha/yr)	K lost to water (kg/ha/yr)	S lost to water (kg/ha/yr)
West Coast	24165	61	2473	6.2	25	45
Manawatu	5492	34	98	0.6	14	35
Waikato	2755	29	223	2.3	40	150
Southland	26127	52	478	1	11	47

Note: Losses a result of Leaching and/or run-off

Table 4(a) and (b). Overseer® 6.3.1. Output summary of N, P, K and S losses for the whole farm system in the original farm model (control) and model including ClearTech®.

Whole farm total N losses (kg/yr) decreased by 1.7 to 3.5% across the farms, with the Waikato farm having the highest reduction (Figure 1). The reductions in whole farm total P losses (kg/yr) were lower than N, ranging from 0.5 to 2.2%, with the Waikato farm having the highest reductions (Figure 1). There were minimal changes in the K losses, with only the Waikato farm having a noticeable reduction (2.4 %). In contrast, S losses increased by 3.4 to 11.9% across the farms.

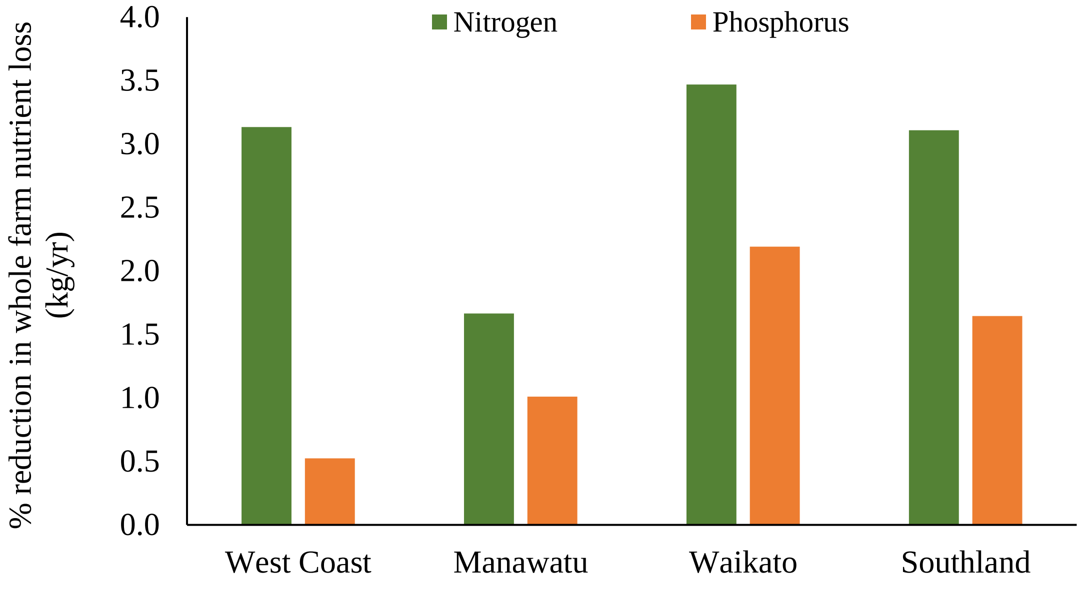

Figure 1: Percentage reduction in whole farm N lost (kgN/year) and whole farm P loss (kgP/yr) to water as modelled by Overseer® (version 6.3.1) using Clear Tech.

The whole farm losses in N, P and K, and increases in S can be attributed to the higher decreases/increases in these nutrients on the effluent blocks, which affected the total farm average. On the effluent blocks only, average N loss (kg/yr) reduced by 5.3 to 20.1% and average P loss reduced from <0.1 to 19.4% (Figure 2) using ClearTech®.

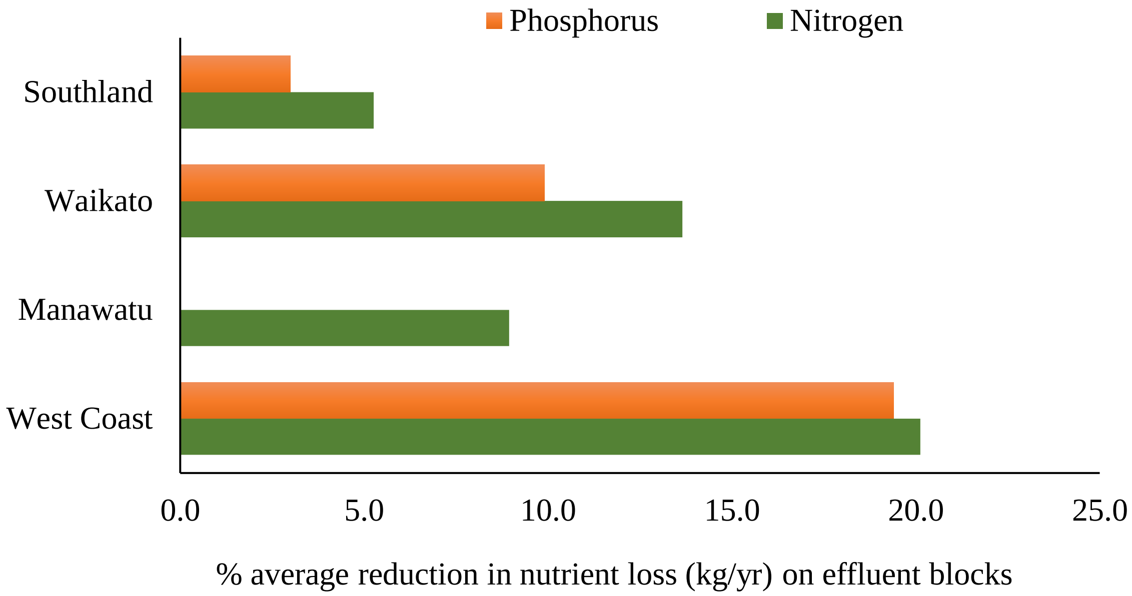

Figure 2. Percent average reduction in total N lost (kgN/year) and total P lost (kg/year) to water as modelled by Overseer® (version 6.3.1) on effluent blocks only using ClearTech®

Discussion

Treatment of FDE in previous trials (Cameron & Di, 2019) showed ClearTech® significantly reduced *E.coli* levels, total N concentration, total P concentration and DRP concentration in the clarified water portion. These reductions indicate that land application of the clarified water would be less likely to cause adverse environmental impacts on water quality than the current practice of untreated FDE. In the 'treated' FDE portion, there was a significant reduction in *E.coli* concentration and DRP concentration, indicating there would be less risk of E.coli and P run off through overland flow and into water bodies. With the storage potential of using ClearTech® (up to two thirds more storage ability), there is increased ability to defer effluent applications when conditions are not suitable or there is an insufficient soil moisture deficit. It should be noted that sufficient storage will still be required for deferring effluent, even with ClearTech®.

There were significant increases in the treated FDE in a range of nutrients including total-N, total-P and S concentrations due to the coagulation process and increased solids content (Cameron & Di, 2019). However, due to the change in effluent management from a holding pond with effluent sprayed as required, to being targeted to lower risk months, whole farm N and P losses decreased across the four farms. As there were no changes to the non-effluent area management, the reductions were solely a result of the changes in nutrient losses on the effluent blocks, from changing effluent management. As ClearTech® was modelled as applying effluent from October to March, this avoided application during the high risk periods of April to September, particularly May to August when temperatures (and therefore PET) is lower, and rainfall is typically higher. During this time there is lower plant growth and uptake of nutrients, resulting in a higher leaching risk. If effluent applications are avoided during this time, it is clear there would be a positive effect on nutrient leaching losses.

Farms were standardised as far as possible in the models, but there were still several unavoidable farm management and production differences that likely affect overall nutrient loss. For example, the effluent area ranged from 24ha (Manawatu & Waikato) to 234ha (Southland). For farms with smaller effluent areas, nutrients are applied to a more concentrated area, and therefore the risk of nutrient loss is higher. In contrast, the Southland farm has a higher dilution of nutrients over its effluent area, and therefore the N loss reduction on the effluent blocks was lower (Figure 2). However, as these reductions are over a wide area on farm, the whole farm average loss was higher. The differences in climatic conditions would also have a significant effect on nutrient losses in both scenarios. The high rainfall and low PET (Table 2) of the West coast farm supports this with the highest reduction in N and P loss on the effluent blocks with the inclusion of ClearTech®.

The limitations of Overseer® for modelling effluent systems may also have resulted in a smaller reduction than anticipated. The litres per cow per day generated as effluent in the milking shed is likely to be lower in Overseer®, compared to the 105.2L measured at the LUDF farm and subsequently used in the ClearTech® modelling. If ClearTech® was modelled using the average of 70L/day/cow (DairyNZ, 2014), there would be a further reduction in 33% of the treated effluent applied, and potentially lower nutrient losses. In addition, Overseer® assumes best practices in regards to effluent applications, with no 'poor management' that would result in 'large' discharges (Wheeler, 2016). Unfortunately, this may not always be the case, and therefore losses from some of the farms may be higher in the original model.

The soils across the four farms are mixed in their drainage and water holding capacities. The well drained soils and those with lower PAW had higher N and P losses when effluent was applied both prior to and with the inclusion of ClearTech®, when compared to the poorly drained soils. It should be noted that outside of modelling artificial drainage in Overseer®, the model cannot be accurately sensitive to the effect of preferential flow of nutrients that may occur on farm. Due to a mixture of soils and PAW on each farm, and effects of other management differences, it is difficult to correlate the reductions in nutrient losses with the inclusion of ClearTech® to the soil type alone.

ClearTech® would be most beneficial from a management perspective on farms that have soils with low infiltration rates or impeded drainage, high rainfall and low evapotranspiration. These soils are categorised as 'high risk' in regards to effluent management. In these cases the ability to defer effluent irrigation would greatly reduce the risk of overland flow of P other contaminants, particularly E-coli. Generally, these types of soil suit low rate application systems, which further increases the storage requirements for effluent. In contrast, the N leaching risk for these soils is lower, when compared with 'low risk' soils for effluent management (well drained, flat land). Therefore, when modelling poorly or imperfectly drained soils in Overseer® there is little change in N loss to water when changing parameters. As a result, using Overseer® may not currently be that suited to highlight the true benefits of ClearTech®. Modelling a multitude of farms across multiple locations, climates and soils would be required to determine whether there would be value in using ClearTech® in Overseer® as a mitigation tool. Despite this, the management benefits alone are significant. With further research, there may be potential in the future to incorporate ClearTech® into Overseer® to demonstrate the nutrient loss reduction potentials, should the science allow.

Conclusion

The reduction of several nutrients in trials to date, combined with initial reduction findings from Overseer®, indicates that ClearTech® has the potential to significantly reduce nutrients applied and lost to the environment. However, comparing the treated FDE portion to the untreated FDE control is difficult within the limitations of Overseer® modelling. Clear Tech would be most beneficial on farms that have soils with low infiltration rates and have high rainfall to avoid the risk of overland flow of P and contaminants. It would therefore not be expected to see significant reductions in N and P lost to water as these soils are less prone to leaching. However results still show a reduction in N & P leaching on farms with mixed soils due to avoiding high risk winter periods. Further investigation with farms covering a variety of soils would be useful to establish if there would be benefits in incorporating Clear Tech into Overseer® as a mitigation tool to highlight nutrient loss reductions.

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