Overseer – Valuation of the Benefits

Prepared for:

Overseer

August 2018

Prepared by:

Andrew Barber[1], Henry Stenning[1],
James Allen[2], Phil Journeaux[2], Jeremy Hunt[2],
Dave Lucock[3],

AGRILINK

The AgriBusiness Group

AGFIRST

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Executive Summary

This Overseer Ltd commissioned report assesses the environmental impact that accelerated uptake of better management practices would have across NZ farming. The premise is that an enhanced Overseer program, with a centralised database and benchmarking and reporting capability, is a valuable tool (amongst a wide range of extension and research activities) that will help drive change. Having examined over 50 farm management practices, we modelled the impact at a farm level 14 of these. The results were then extrapolated nationally based on the premise of accelerated uptake.

The project aims were to:

1. Quantify efficiency gains from the new OverseerFM tool
2. Quantify the value to the industry from accelerated uptake of innovation
3. Quantify the greenhouse gas reporting (National GHG Inventory) benefits from Overseer enabling estimation of individual farm level GHG emissions

This report includes a table of all identified management practice options – with data on effectiveness against different contaminants, cost, and benefits where available in the literature. From this list of 52 practices, 14 were selected based on their practicality, likelihood to be implemented, and likely effectiveness. Not all of these practices are currently modelled in Overseer, e.g. strategic grazing management, but have been included to assess the potential impact of new measures if they were to be included in future developments. Similarly, sediment loss is not modelled in Overseer, but we have included its impact where appropriate. Stream fencing for example is modelled in Overseer as a reduction in nitrogen and phosphorous from direct deposition. However, although not modelled in Overseer, accelerated uptake of stream fencing will result in reduced bank erosion. The impact of this has been quantified separately.

The strength of Overseer is in its ability to model farm production systems at a farm scale. As every farm is unique, that can be reflected in the farm tailored Overseer model. This also makes the programme potentially extremely powerful as a learning tool, as both the baseline and scenario testing reflects what may happen on the specific farm.

OverseerFM has resulted in new budgets taking 50% to 75% of the time it would have previously taken in 6.3.0, or an average of 4.25 hours per nutrient budget. Based on 1,500 new budgets a year, that represents consultancy savings of approximately $1,200,000 a year.

The data sharing between the consultant/modeller and farmer will save considerable time as both will be able to view and discuss the farm model, rather than needing to prepare an explanatory report. Model accuracy will improve with improved engagement better reflecting the farm system. The new mapping feature is hugely beneficial in time savings and accuracy for setting up a farm model.

Benchmarking, harnessing and learning from the collective knowledge of others, is a powerful, well proven tool. Benchmarking and practice change has been well documented by the NZ Sustainability Dashboard Project. In the NZ wine industry members of Sustainable Winegrowing NZ (SWNZ) receive individualised benchmarking reports that link to learning resources. These reports are used to engage in meaningful conversations from a basis of better understanding. From this has come accelerated uptake of improved practices.

The underlining assumption in this project is that a centralised database on which individualised benchmarking reports are developed, will contribute to 25% of recipients implementing an improved practice. The number of farmers using Overseer varies by region and farm type, but we have assumed that Overseer covers 55% of farms. It is these farmers that will potentially have access to individualised benchmarking reports, scenario testing, and easily accessible links to learning resources. Accelerated uptake is based on 25% of these farmers, or 14% of all farms, making a practice-based change.

Models have then been constructed to demonstrate the regional and national effects these practice-based changes may have following accelerated uptake. The information used for modelling has come primarily from Overseer and research literature. This has then been scaled up to examine national scale contaminant reductions. While the aggregated regional and national results from such a bottom up approach is not intended to be the definitive answer, it demonstrates the scale of possible change.

Table 1 shows the potential impact of the practice change at an individual farm level and the impact of its accelerated uptake across NZ for 10 selected practices.

Table 1. Impact from the accelerated uptake of practice changes on discharges at a farm and national level*

	Farm Impact		Accelerated Uptake – National Impact		
	Nitrogen (%** & kgN/ha)	Phosphorous (%** & kgP/ha)	Nitrogen (%** & tN)	Phosphorous (%** & tP)	Value*** ($)
Stream fencing – direct deposition	0.9%, 0.1	2.6%, 0.0	<0.1%, 100	0.2%, 20	$192,000
Stream fencing – bank erosion			8,500	1,800	$16,530,000
Supplementary feeding with low nitrogen feeds	1.4 – 6.8%, 1.0 – 3.0		0.7% 2,200		$3,300,000
Diverse pasture	0 – 15%, 0.0 – 11.9		1.3% 4,100		$6,150,000
Dung Beetles – reduced overland flow	4.3 – 11.6% 1.2 – 5.4		1.6% 5,000		$7,500,000
Reduction in stocking rate, 5 – 15%	1.4 – 11.4%, 1 – 6	0.0 – 7.4% 0.0 – 0.1	0.6 – 1.7%, 1,900 – 5,400	0.1%, 14	$8,129,000
Restricted grazing and off-pasture animal confinement systems	15.8 – 25.6% 10	+5.4 – +11.7% +0.0 – +0.1	1.9%, 6,100	+ 0.3%, +40	$9,066,000
Strategic grazing management				810	$1,701,000
Optimum P concentration - soil tests		10 – 12%, 0.1		0.4%, 50	$105,000
Improved nitrogen use efficiency – less fertiliser	8.8 – 21.5%, 3 - 17	1.4 – 6.7%, 0.0	1.5%, 4,800	0.2%, 20	$7,242,000
Improved nitrogen use efficiency – increased effluent disposal area	1.5%, 0.6 – 1.2	0.0 – 1.8%, 0.0	0.1%, 450	0%	$675,000
Sub-total (excluding erosion)					**$44,060,000**
Total					**$60,590,000**

* All changes are reductions, unless otherwise shown with a + sign.
** Percentage of loss below the root zone.
*** Based on the saved annual nutrient cost to farmers of $1.50/kgN and $2.10/kgP

The total value of saved nutrients from accelerated uptake of the 10 selected practices is just over $60 million per annum. Erosion rates in NZ are very high by world standards, so it is no surprise that fencing, which reduces stream bank erosion, has the biggest impact. Excluding erosion mitigation, the impact of accelerated uptake from the 10 selected practices is just over $44 million per annum. The top five practices account for 86% of the value (excluding erosion mitigation), being in order of priority restricted grazing (21%), 15% reduction in stock (18%), dung beetle (17%), less nitrogen fertiliser (16%), and diverse pastures (14%).

The inclusion of low methane feeds such as brassicas and forest carbon sequestration, would add an additional $8,095,000 of national value from accelerated uptake, or a total value of $68,685,000.

Background

This Overseer Ltd commissioned report assesses the environmental impact that accelerated uptake of improved management practices may have across NZ farming. The premise is that an enhanced Overseer program, with a centralised database and benchmarking and reporting capability, is a valuable tool (amongst a range of extension and research activities) that will help drive change. We modelled, either using Overseer/Farmax or research literature, the impact at a farm level of 14 improved farm management practices. These results were then extrapolated nationally based on accelerated uptake across 14% of farms. This report supports the on-going development and value of Overseer.

The project aims were to:

1. Quantify efficiency gains from the new OverseerFM tool
2. Quantify the value to the industry from accelerated uptake of innovation
3. Quantify the greenhouse gas reporting (National GHG Inventory) benefits from Overseer enabling estimation of individual farm level GHG emissions

Accelerated Uptake of Management Practices

Benchmarking, harnessing and learning from the collective knowledge of others, is a powerful well proven tool for improving an organisations performance. Research conducted by the NZ Sustainability Dashboard Project, involved surveying wine growers on their use of individualised benchmarking reports. The survey results showed 94 percent said that the reporting was helpful to compare their performance to regional or catchment benchmarks. 41 percent said that they had discussed their report with others, such as supplier reps or neighbours, while 26 percent said they had made changes based on what they had learnt.

The premise for accelerated uptake of improved management practices is that if farmers have greater engagement in Overseer and the results are presented in a form where they can see their performance benchmarked against similar farms, then they are more likely act.

Our base assumption is that 55% of farms have an Overseer budget. Of this group, 25% may implement or improve on a specific management practices that was identified through Overseer benchmarking reports or scenario testing. Therefore nationally 14% of farms (55% x 25%) may make a practice-based change. We consider this to be a conservative estimate. All the accelerated uptake results can be proportionally scaled up or down based on alternative rates of uptake. If more farmers develop Farm Environment Plans,

Not all measures will be adopted equally across the agricultural sector. We have tried to account for this by lowering the rate of adoption based on the sector or other factors such as terrain. For example, the base line accelerated uptake (14%) was used for fencing properties that were less than 16 degrees, while we lowered this to 7% for those between 16 and 28 degrees and to 1% for those over 28 degrees. Similarly, optimising Olsen P levels was only applied to dairy, on the basis that sheep and beef farms generally have lower soil fertility levels so are less likely to have the opportunity to apply this measure.

Farmer Uptake

As outlined above, a central tenet of this analysis assumes a 14% adoption of the mitigation by farmers as a result of the benchmarking exercise and associated improved understanding and engagement. There are a wide range of factors which influence adoption of mitigation practices by farmers, including;

- The relative advantage the practice conveys, particularly the benefit relative to the cost
- The compatibility of the mitigation with the existing farming system
- The complexity of the mitigation
- The degree to which it can be trialled and/or observed
- The experience and expertise of the farmer

So, while the basic uptake figure of 14% is assumed, in reality the uptake of the various mitigations discussed in this report will vary depending on the factors noted above.

To illustrate how individualised benchmarking may look, we have mocked-up a potential stream fencing report. Information collected from Overseer's centralised database would be used to benchmark Farm A's performance against other Class 4 sheep and beef farms. In this example 50% of Class 4 farms have completed an OverseerFM budget. Farm A has fenced 20% of their streams, compared to a 60% of comparable farms in their region, or 50% nationally. Their current level of fencing has reduced nitrogen and phosphorous losses to water through direct deposition by 5% and 13% respectively. If they added a further 50% more fencing, they would reduce their nutrient losses compared to no fencing by 10% (N) and 21% (P). In the top righthand corner of their report is a short description about fencing and links to learning resources developed by DairyNZ and Beef + Lamb NZ. Note the figures used in this example are purely for illustrative purposes only.

OVERSEER Benchmarking Report

Stream Fencing

Farm Name	Farm A
Farm Type	Pastoral Livestock - Sheep + Beef
Farm Class	4 - North Island Hill Country
Region	Waikato

How does this affect me?

Preventing livestock access to streams, decreases stream bank damage (and sediment inputs via bank erosion) bed disturbance of sediments (and entrained E. coli, N and P) and stops the direct deposition of excreta into streams.

Links to Learning Resources

https://beeflambnz.com/compliance/environment/managing-stock-near-water
https://www.dairynz.co.nz/environment/waterways/fencing-waterways/

Farm Details

Total Area: 510 ha   Regional Average: 480 ha   New Zealand Average: 500 ha

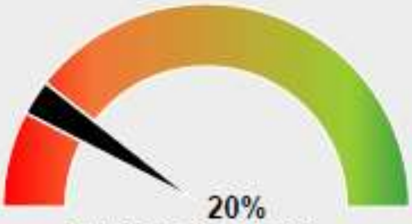
Number of Class 4 farms in Waikato with completed Overseer budgets: 600

Number of Class 4 farms in the Waikato: 1,200

Stream length on farm: (km)	<16°	16-28°	>28°	Total	Regional Average: (km)	<16°	16-28°	>28°	Total
Accord	3.4	2.1	0.8	6.3	*Accord*	4.1	1.0	0.9	6.0
Non-Accord	2.2	3.4	0.6	6.2	*Non-Accord*	3.2	4.1	0.7	8.0

For Class 4 Sheep and Beef farms:

Your Farm

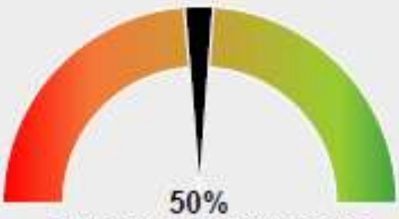


20%
Level of Accord Stream fencing

Waikato

60%
Average level of Accord Stream fencing

New Zealand



50%
Average level of Accord Stream fencing

Nutrient Losses

	Farm Baseline (no fencing)	With current levels of fencing	If fencing was increased by 50%	Waikato Average	New Zealand Average
Nitrogen (kgN/ha)	22	21	19	21	20
Phosphorous (kgP/ha)	1.6	1.4	1.1	1.5	1.4

Reduction from fencing

	Current level of fencing	Additional 50% fencing
Nitrogen	5%	10%
Phosphorous	13%	21%

Accord-type waterways are defined as deeper than a red-band gumboot (ankle deep), wider than a stride (1 metre) and permanently flowing.

Overseer

Methodology

Input and Time Savings

A total of 48 farm systems including dairy (North and South Islands), sheep/beef, horticulture, South Island High Country and mixed cropping have been modelled from a base of 13 farms. Seventeen models were trialling differing mitigations or other amendments. Importing existing .xml files into OverseerFM was also trialled.

Feedback was provided separately to Overseer on the benefits and issues of OverseerFM.

Accelerated Uptake of Improved Practices

We conducted a literature review, building on some of the authors preparation of MENUS (http://www.farmmenus.org.nz/home-2), of improved management practices. We relied heavily on the work conducted in 2013 by McDowell et al., *Assessment of strategies to mitigate the impact of loss of contaminants from agricultural land to fresh waters*. These practices were collated into an excel spreadsheet for later reference and interrogation. For each practice the excel based table described the practice, noted if the measure is already assumed to occur in Overseer (e.g. adequately trained staff), if it could be modelled currently in Overseer (low rate effluent irrigation), its effectiveness at reducing nitrogen, phosphorous, micro-organisms, greenhouse gases, and sediment. It will also summarised farm suitability characteristics (how widely the measure could be applied), and references.

From the 52 identified practices, 14 were selected based on their practicality, likelihood to be implemented, and likely effectiveness. We modelled, either using Overseer/Farmax or research literature, their environmental impact at a farm level in different regions and across different farm types. These results were then extrapolated nationally based on the premise of accelerated uptake may occur across 14% of farms. Not all practices can be applied across all land uses or terrain. For example, when extrapolating the on-farm fencing results up to a regional and national level, no additional fencing along Accord defined streams was assumed to occur on dairy farms. Similarly, while non-dairy pastoral land that was less than 16 degrees was assumed to have accelerated fencing uptake of 14%, that land greater than 28 degrees was modelled with an accelerated fencing uptake of just 1%.

The Price of Nitrogen and Phosphorous

Saved cost to farmers

The first approach considered was the "saved cost to farmers" in the sense of valuing the cost of nutrients applied as fertiliser and using this as a proxy as to the monetary value of the nutrients lost.

Information for this was gathered from several sources:

A. Dairy

(i) Dairy NZ. This did not differentiate between nitrogen, and the other nutrients applied (P, K, S)

Total nutrients applied in 2016/17 for the national average farm was:

Nutrient	kg/ha
N	160
P	25
K	30
S	40
Total	255

Total cost per hectare was $500, giving an average value per kilogram of nutrient of $1.96

(ii) AgFirst. This applies to the annual financial survey of the Waikato/BoP dairy model, where expenditure on nitrogen fertiliser is differentiated from P/K/S fertiliser.

The 5 years (2013/14 – 2017/18) showed the following costs, per kg nutrient:

Nutrients	2013/14	2014/15	2015/16	2016/17	2017/18	Average
N	$1.82	$1.48	$1.48	$1.30	$1.30	$1.47
P, K, S	$2.04	$2.04	$2.04	$1.98	$1.98	$2.02

B. Sheep & Beef

(i) AgFirst. Based on the annual financial survey of the central North Island Hill Country. This showed, per kg on nutrient;

	2016/17	2017/18	Average
P, S	$2.09	$2.12	$2.10

While the saved cost to farmers of not applying fertiliser can be calculated, it does not really provide a proxy as to the value of not discharging nutrients into water bodies, as the two factors are very different. There is not a direct correlation between nutrients applied and nutrients lost to water. However, if anything valuing the loss this way will be conservative. More than one unit of nutrient needs to be applied to balance a unit lost to water.

Opportunity cost to farmers

This relates to the cost to the farming enterprise in applying the mitigations, and then dividing this by the amount of "saved" nitrogen and phosphorus in order to gain a per kilogram nutrient cost.

There are a range of studies around the cost of mitigations relative to the amount of nitrogen and phosphorous saved (or not discharged) into receiving water bodies. A reasonably comprehensive one is The Southland

Economic Project: Agriculture and Forestry Technical Report[1]. In this project abatement curves were developed for a number of dairy and sheep and beef farms in Southland.

Examples include Figure 1 which shows the changes in nitrogen loss and profitability for each mitigation – the distance each data point is from '0' indicates how much a mitigation changes a farm's nitrogen losses and profitability from its baseline.

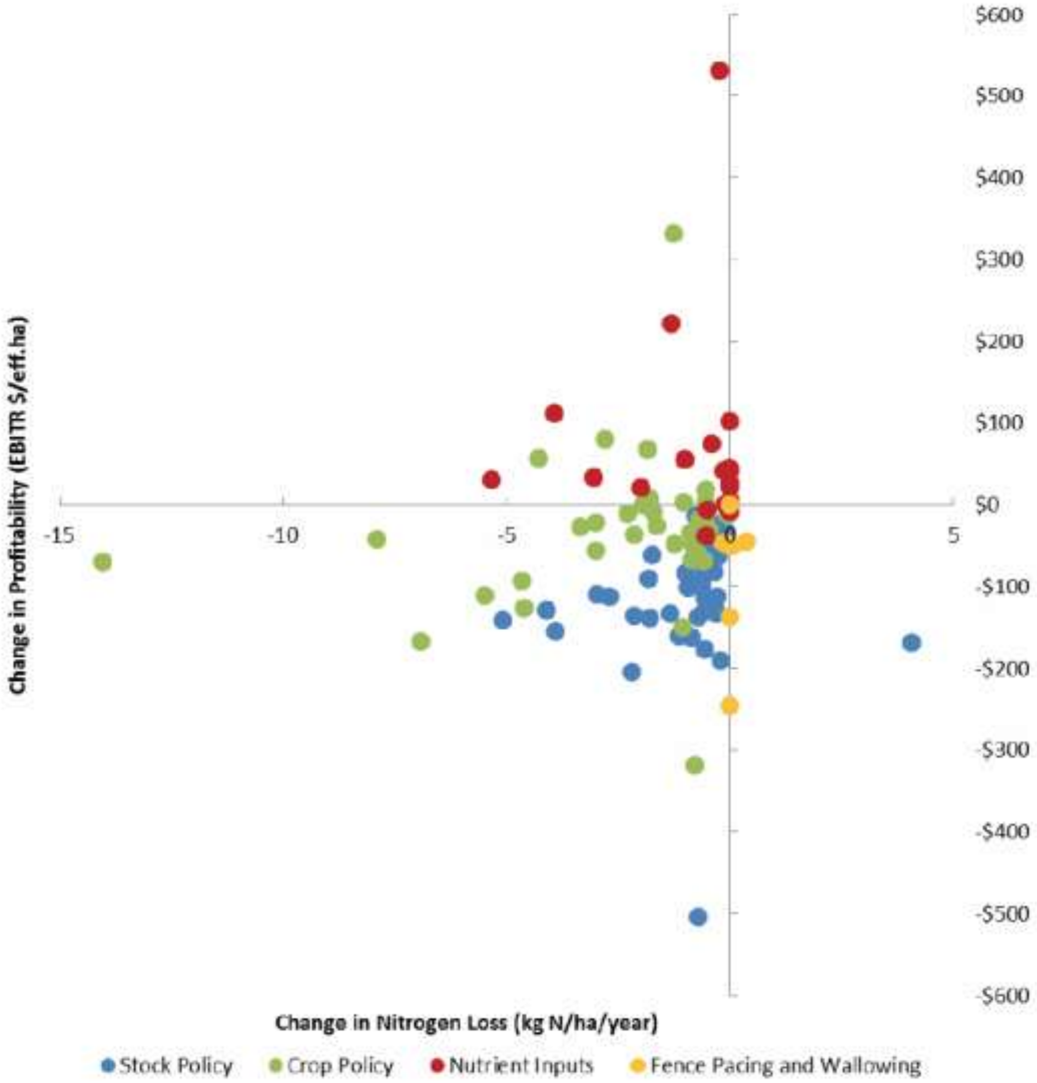


Figure 1 – Changes in nitrogen loss and profitability for 43 drystock farms.

Figure 2 shows the results of the phosphorus mitigation modelling for 13 dairy farms, with the relationship between the percentage reduction in phosphorus loss and operating profit. Each line represents a case study farm.

[1] April 2017, http://waterandland.es.govt.nz/setting-limits/research/southland-economic-project

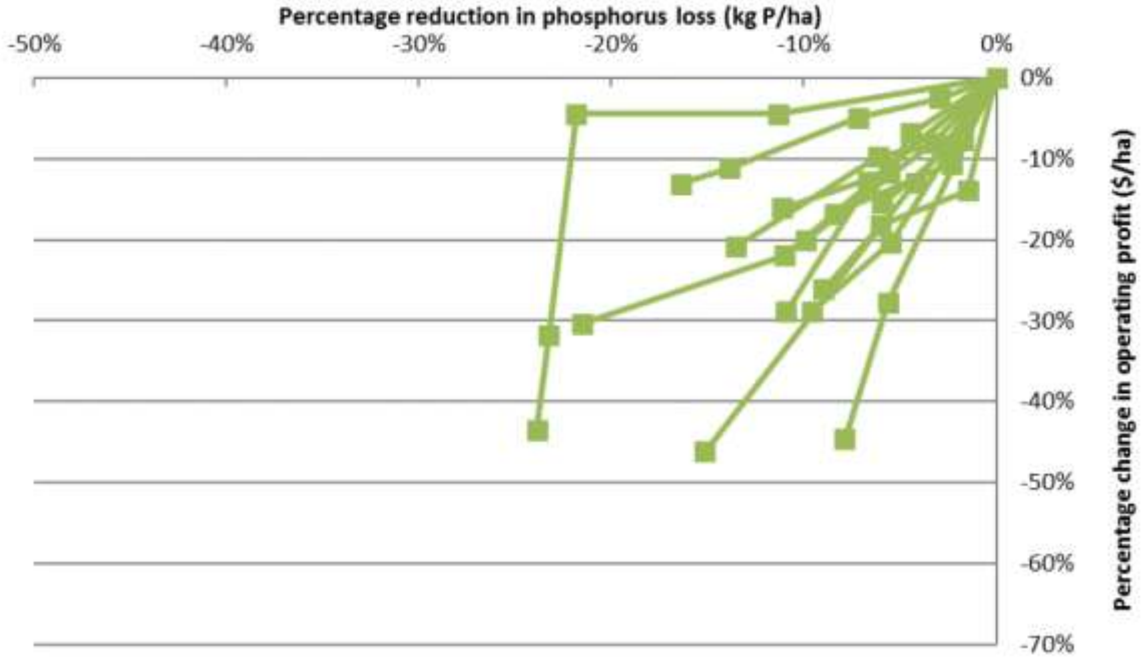


Figure 2 – Percentage reduction in phosphorus loss (13 dairy farms)

What these abatement curves show (Figures 1 and 2) is that there is significant variation between individual farms, and it is therefore very difficult to derive average per kilogram costs. In addition, the published material does not have sufficient detail to work down to a per kilogram cost level.

Again, such costs do not really provide a proxy as to the value of not discharging the nutrients, as again the two factors are very different.

Value to the environment of not discharging nutrients

Possibly the best way to value the reduction in nutrient discharge is to value the improvement in the affected water bodies.

The report, Economic valuation of Overseer impacts on freshwater quality in New Zealand: A review of selected studies, prepared by Tait and Saunders (2018) explores the public value from improved water quality.

A fundamental problem when considering the value of environmental outcomes is how to measure the value of impacts in a way that is comparable to the costs of mitigation options. Unlike commercial values such as irrigation, most environmental goods and services, such as clean water, healthy fish and wildlife populations, are not traded in markets. Their economic value - how much people would be willing to pay for them - is not revealed in market prices. The only option for assigning monetary values to them is to rely on economic non-market valuation (NMV) methods. In this way, NMV is a corrective tool for economics to capture values outside of markets. Economic valuation contributes to the demonstration of value, providing support for management actions that promote the capture of value. This view forms an important distinction in what defines economic valuation. Valuation does not advance the commodification of environmental goods and services, but rather is an avenue for assessing how changes in environmental outcomes affect individual's welfare.

Once a set of values have been identified, the challenge for the practitioner is to select an appropriate valuation method. Stated Preference (SP) methods – Choice Experiments (CE) and Contingent Valuation (CV) generate comparative datasets through survey-based hypothetical markets for the environmental goods of interest. The CV approach asks individuals about a single event or outcome, while a CE asks them to choose their preferred option from a 'choice set' made up of different configurations of multiple events or outcomes. Respondents to these surveys express their preferences for environmental outcomes and their associated willingness to pay (WTP) for them.

One study in 2009 found that Canterbury households were willing to pay $23 in rates for a 10% reduction in nitrogen ($25.70 in 2018 dollars) and $32 for a 30% reduction ($35.76 in 2018 $). In Canterbury there are approximately 204,800 households and at an average additional rate of $25.70 would generate $5.3m. A $35.76 rate would generate $7.3m.

On the basis of a Canterbury dairy farm leaching 70 kgN/ha, a 10% reduction is 7 kgN/ha. Across the 255,100 ha of Canterbury dairy land a 10% reduction equates to 1,786 tN. Therefore, the Canterbury community values a 10% reduction in nitrogen at approximately $2.95/kgN ($5.3m/1,786 tN). A 30% reduction is valued at $1.30 /kgN. This is prefaced on a one for one relationship between a change in the environment and the reduction on farm.

This willingness to pay for public good of up to $2.95/kgN, compares to the cost of nitrogen to the farmer that averaged $1.47. Based on the assessment above the split between the value of saved nutrients to the farmer and the NZ publics' willingness to pay for reduced nitrogen in streams is approximately 33/66 (private/public) ($1.47/($1.47+$2.95))x100. At the lower end of the publics' willingness to pay the split is 53/47 (private/public), or on average approximately 45/55.

This analysis needs to be treated with considerable caution, as Tait and Saunders concluded that there is insufficient literature to be able to draw robust conclusions on the value of Overseer (reflected in lower nitrogen losses) to the NZ public or consumers in market.

OverseerFM

One of the most significant enhancements in OverseerFM is the mapping function. Mapping is hugely beneficial in time and accuracy for setting up a model. As a new feature it is also needs further refinement.

Time savings

OverseerFM budgets took 50% to 75% of the time compared to nutrient budgets completed in Overseer 6.3.0. The time difference is approximate as it depended on the complexity of the farm being modelled.

A modeller working with OverseerFM, having collected the raw farm data (field exercise) would, in most cases, be able to input the block size incorporating variable such as irrigation and soil type using the mapping function with a sensibility check (farmer discussion). On this basis a simple farm system would take approximately 50% of the modelling time in FM compared with 6.3.0. This would increase to approximately 75% for more complex systems such as multiple cropping scenarios. Converting this to actual time, setting up a simple farm would take 4 to 5 hours, compared to 8 to 10 hours previously. At the other end of the scale a complex cropping (or equivalent) farm typically takes 12 to 16 hours to complete in 6.3.0, may now take 9 to 12 hours in OverseerFM to setup. The main reason for the time savings is down to the ability of the FM mapping function to handle a large number of blocks and the extra care required by the modeller to accurately model these farm system types.

On average time savings to setup a new farm using OverseerFM are estimated be 4.25 hours, ranging between 3 to 5 hours saved depending on the complexity of the farm being modelled. While it is difficult to predict the growth in new Overseer budgets, we have assumed a growth rate of 10% amongst the balance of farms that do not yet have an Overseer budget. This results in 1,500 new budgets a year. The annual consultancy time savings at $180/hour is approximately $1,200,000. This may be a conservative figure as Beef + Lamb New Zealand's Environmental Strategy has a goal that every sheep and beef farm having a tailored and active environment plan by the end of 2021. Given that an estimated 45% of farms do not currently use Overseer, and higher in the sheep and beef sector, there may be as many of 15,000 new budgets required to feed into FEPs by 2021.

Irrespective of the programme version, the accuracy of the output comes down to the ability of the modeller to fully understand the farm system they are modelling. The 'don't know what they don't know' aspect can lead to incorrect results and misinformation back to farmers, council and other stakeholders.

The greatest time saving in preparing a Farm Environment Plan (FEP) is through the use of a template that covers the attributes necessary and has the flexibility to allow for the uniqueness of the properties physical and managerial attributes. Efficiencies occur where existing FEPs inform first time Overseer data collection or vice versa.

The nutrient loss running tally at the top right-hand corner of the Overseer screen means that modellers can see the changes quickly when modelling ‘what if’ scenarios.

The reporting is laid out logically and can be copy and pasted into an excel spreadsheet easily for reporting or further analysis. Overall the look, feel and functionality is a huge improvement on 6.3.0.

Data sharing

Being able to use a central repository of farm data between different advisory services or future year-end analysis will be a significant time saver. Once the farm account data is set up, it can be used by multiple parties to do scenario or predictive analyses or future year-end analysis without having to create a new farm file (unless significant changes occur). This functionality was not available before OverseerFM.

A further advantage is that the adviser and farmer can remotely view the farm model at the same time. The advantage of this is that you can describe the model over the phone (for example) rather than revisiting the farm or writing a report. Reports can take from 30 minutes to 4 hours to write, once again depending on the complexity of the property and the requirements of the audience.

Also, we envisage that some farmers will be able to run ‘what if’ scenarios. This may take some time but is likely to become more ‘normal’ for farmers to run their own scenario testing.

All these new features will also significantly aid the final accuracy of the modelling.

Mapping

Irrigation can be mapped using a circle or multiple shape polygon drawing tool. Multiple irrigation shapes can be created on one block as long as they do not overlap and individually are larger than a minimal percentage in size of the total block. The multiple irrigation types can be mapped, or one can be mapped and then the rest of the block can be added as another irrigation type, along with irrigation management independent of the first irrigator drawn.

Management Practices

Stream Fencing

Preventing livestock access to streams, decreases stream bank damage (and sediment inputs via bank erosion) bed disturbance of sediments (and entrained *E. coli*, N and P) and stops the direct deposition of excreta into streams.

Estimated costs are $7/m of fencing for dairy and $16/m of fencing for sheep + beef, with the benefit to the farmer of a reduction in stock losses in waterways.

Stream fencing has already been completed on more than 95% of Fencing Accord defined streams flowing through dairy farms. Therefore, the national impact of accelerated fencing has been restricted to sheep and beef farms.

Elliot (2017) reports that stream fencing reduces sediment loss by 70% and 13% for nitrogen. While it is not clear what the baseline is for these reductions, clearly fencing has a proportionally larger impact on reducing sediment and its associated phosphorus compared to nitrogen.

Overseer modelling of stream fencing is based on preventing direct urine and dung deposition into the stream. On the modelled dairy farms this resulted in whole farm nitrogen reductions of between 3.8 - 4.9%, and a reduction in phosphorous entering waterways on a whole farm scale of between 34 - 38%. Overseer modelled stream fencing on sheep and beef farms reduced whole farm nitrogen losses by between 0.4 – 1.0%, an average of 0.1 kgN/ha. Phosphate losses were reduced by between 0.5 – 5.3%, an average of just 0.03 kgP/ha.

Figure 3 shows the impact of accelerated stream fencing across NZ sheep and beef farms, resulting in phosphorus reductions from direct deposition of 2.1% and a 0.8% reduction in direct nitrogen deposition.

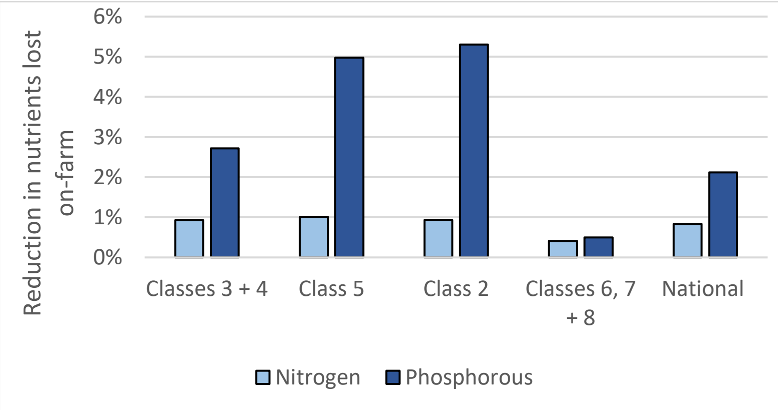


Figure 3 – National reduction in phosphorous and nitrogen loss from pastoral farms based on Overseer modelling

ACCELERATED UPTAKE

Currently it is estimated that around 50% of Accord Stream waterways on sheep + beef, and deer farms are fenced. With this figure being at around 95-99% for dairy.

With accelerated uptake in sheep + beef, and deer farms, an estimated 6.1% of additional fencing may occur, or 7,400 km.

This will result in a small reduction of pollutants entering waterways via direct deposition:

Nitrogen ↓ - Accelerated uptake of stream fencing across 14% of sheep and beef farms may reduce nitrogen losses by 0.03%, or 100 tN.

Phosphorous ↓ - Accelerated uptake of stream fencing across 14% of sheep and beef farms may reduce phosphorous losses by 0.2%, or 20 tP.

While Overseer does not model sediment losses, never-the-less accelerated uptake of fencing will have a positive environmental benefit beyond what is modelled in Overseer. To quantify this benefit, we estimated sediment loss based on the assumption that fencing reduces stream bank erosion by 50% on catchments that are greater than 16 degrees, with accelerated fencing uptake decreasing as the contour increases.

There are very few studies that quantify the effectiveness of fencing and riparian planting on sediment yields into streams. However, the few studies generally considered stock exclusion to be the main factor in reducing stream bank erosion. Current SedNetNZ modelling uses a sediment reduction factor of 80%, however a more conservative value of 50% was used in our model (Basher, pers. comm. 2018). International studies suggest that stream bank erosion accounts for up to 90% of a catchment's sediment yield (Hughes, 2016). However, this is very dependent upon where in the catchment the erosion is occurring. In the lower reaches of a catchment removal of livestock from riparian areas and/or the planting of small shrubs and trees are unlikely to have a significant effect on reducing the contribution of sediment from stream bank erosion these reaches (Hughes, 2016). We modelled stream bank erosion to contribute 10% of the sediment in streams of less than 16 degrees and 80% for those greater than 16 degrees. Erosion into streams of 191 mt per year is reduced by 2.8 mt from accelerated uptake of fencing.

The reduction in phosphorous loss attached to the sediment, at 650 mgP/kg, could be 1,800 tonnes of phosphorous. Based on nitrogen content of the eroded soil being 0.3%, the eroded soil may contain 8,500 tN.

ACCELERATED UPTAKE

With accelerated uptake in sheep + beef, and deer farms, an estimated 6.1%, or 7,400km of additional fencing may occur across all pastoral farms.

Sediment ↓ - the total volume of sediment entering waterways from reduced stream bank erosion may decrease by 1.5% from the accelerated uptake in stream fencing. This translates to a reduction of 2.8m tonnes of sediment entering waterways per year.

Phosphate loss attached to the sediment may be reduced by 1,800 tP. The nitrogen content of the eroded soil may be 8,500 tN.

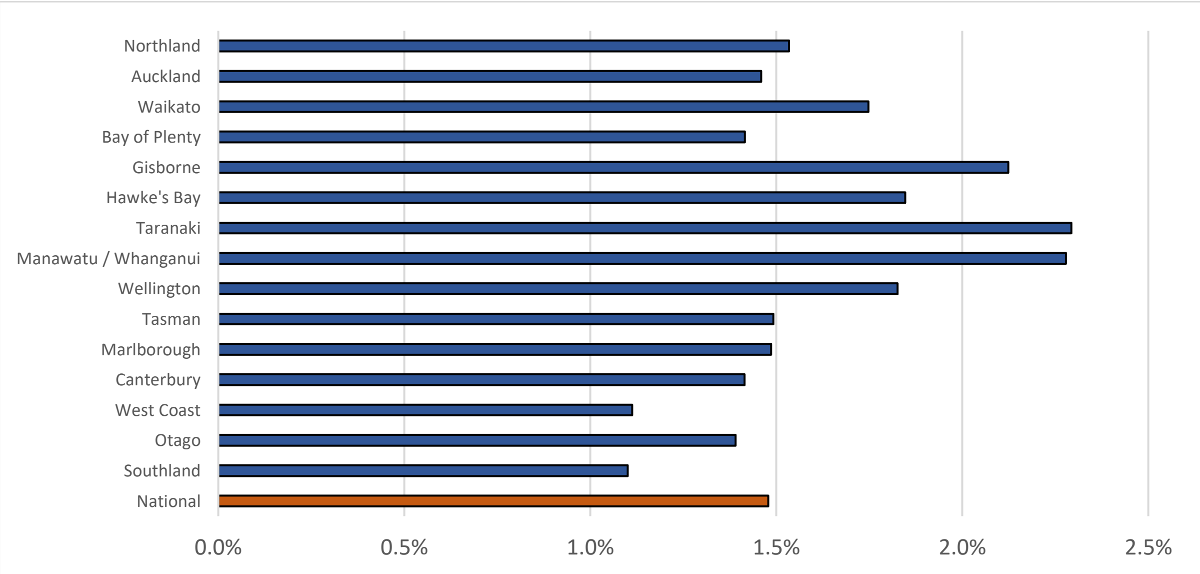


Figure 4 – Total reduction in sediment entering waterways as a result of accelerated stream fencing

Low Methane Feeds

Low methane feeds such as brassicas have the potential to reduce the amount of methane produced by ruminant livestock. Low methane feed could be used as forage for dairy, beef cattle and sheep, with an estimated cost of $1,300/ha/yr (De Ruiter, 2009).

Brassicas have been tested extensively in sheep in New Zealand and forage rape has consistently reduced methane emissions by 20-30% in sheep when fed as a full diet (PGgRC, 2016). This will decrease based on the proportion of brassicas in the diet.

Current practice on many farms is to grow a brassica crop either for winter or summer feed. Many sheep & beef farmers grow a brassica crop (e.g. rape) to finish lambs in the summer. In this situation, the brassica forms up to 100% of the diet for the duration of the crop; usually for 4-6 weeks.

ACCELERATED UPTAKE

With accelerated uptake of brassicas being fed to sheep as a full diet for 5 weeks:

Methane ↓ - emissions from sheep could be reduced by up to 0.3% nationally. This represents a GHG reduction of 24,900 tCO_2e. This is valued at $622,500 (@$25/tCO_2)

Supplementary Feeding with Low Nitrogen Feeds

Pastures contain more nitrogen than is required by grazing animals. Excess nitrogen is excreted, predominantly in urine, which is prone to nitrogen losses. Supplementary feeding with low-N feeds such as maize silage can increase animal productivity with little effect on the amount of nitrogen excreted in urine and lost by leaching.

The benefit of feeding lower N/higher energy feedstuffs is a greater degree of efficiency of nitrogen metabolism in the rumen, resulting in lower concentrations of nitrogen being excreted.

Overseer modelling of dairy farms results in a reduction of 6.8% (3 kgN/ha) in nitrate leaching when palm kernel is replaced with maize silage, and a 1.4% (1 kgN/ha) reduction when pasture silage is replaced with barley grain. With accelerated uptake this may result in nitrogen leaching being reduced by 2,200 tonnes, or 0.7% nationally.

ACCELERATED UPTAKE

With accelerated uptake of switching to low nitrogen feeds for dairy cows:

Nitrogen ↓ - reduced nitrogen losses of 0.7% nationally, 2,200 tonnes less nitrogen leached from dairy farms per year.

Forest Carbon Sequestration

Trees fix carbon dioxide from the atmosphere through photosynthesis and store it as biomass. Planting new forest will therefore help to offset greenhouse gas emissions from other sources. Additionally, trees and forest vegetation can take up excess nitrogen and phosphorous present in runoff, as well as help filter sediment when planted in buffer strips.

A typical radiata pine plantation will sequester around 28 tCO_2/ha/yr[2] (7.6 tC/ha/yr). Assuming a harvesting regime for the forestry, 80% of this is assumed to be released at harvesting. The remaining approximately 20% (stump, roots) is deemed "safe" carbon which does not need to be repaid at time of harvest. Farmers using forestry as a greenhouse gas offset, can therefore claim this approximate 6.0 tCO_2/ha against agricultural emissions.

Indigenous forests, where they will remain standing and are not harvested, sequester on average 6.4 tCO_2/ha/yr, ranging between 0.6 at year 1 to 8.7 tCO_2/ha/yr at year 27.

There is limited opportunity for forestry plantations on dairy land, so the assumptions are based on sheep and beef farms.

If 14% of sheep and beef farmers planted 5% of their farm in forestry, there would be the equivalent of 298,900 tonnes of CO_2 stored, offsetting 0.8% of total agricultural emissions. At $25/$tCO_2$ this is valued at $7,472,000 per annum.

ACCELERATED UPTAKE

If sheep and beef farms planted 5% of their land in new forestry, then following accelerated uptake:

Stored Carbon ↑ -

298,900 tCO_2e would be stored, offsetting approximately 0.8% of total agricultural emissions. This is valued at $7,472,000/year (@$25/tCO_2)

Diverse Pastures

The Foraging for Reduced Nitrate Leaching Program (FRNL) estimates that diverse pastures that include plantain fed to livestock could reduce nitrogen leaching by between 10% and 20% when the area of the farm sown in diverse pastures was 20% and 50%, respectively. This is achieved through both lower total urinary nitrogen excretion and lower urinary nitrogen concentration (Beukes et al. 2014; Romera et al. 2016).

While we have used the research results in the accelerated uptake modelling, they may be optimistic. While diverse pastures are no yet modelled in Overseer our analysis for 20% diverse pasture, achieved a 4% reduction in nitrogen leaching and a 7% reduction in greenhouse gas emissions on dairy farms. On sheep and beef farms there was no reduction in nitrogen and a 2 - 4% reduction in GHG emissions. All of which came at a cost to the farms. The main issue is that the "diverse pastures" generally grow less over winter/early spring – so there is often a need to reduce capital stock accordingly, which reduces total farm profitability.

Often the diverse pasture species do no persist as well as traditional ryegrass/white clover, which is a barrier to uptake. The introduction of a significant area of diverse pasture is also very likely to require some change in the farm system.

ACCELERATED UPTAKE

Following accelerated uptake from planting 20% to 50% of a farm in diverse pasture:

Nitrogen ↓ - leaching may be reduced by 15% on dairy farms, although our modelling is lower at 4%. Based on accelerated uptake of 20% diverse pastures, there could be a 2.1% reduction in nitrate leaching across NZ or 4,100 tN.

[2] MPI Look Up Tables https://www.mpi.govt.nz/dmsdocument/4762/loggedIn

Dung Beetles

Dung beetles have undergone co-evolution alongside livestock in much of the world, fulfilling an important role in pastoral farming systems.

Dung beetles were not introduced to New Zealand alongside livestock, and this introduction is only now occurring. Burial of faecal matter by dung beetles reduces nutrient runoff, increases pasture productivity and soil health, decreases incidence of parasitic disease and even reduces greenhouse gas emissions – with an estimated 40 kg of carbon sequestered per head of cattle per year from dung burial (Doube, 2008).

After seeding on a farm, dung beetles are expected to take 9 to 10 years to reach full farm carrying capacity. The benefits to reduced environmental discharges are based on full establishment, and 90% dung burial.

The creation of tunnels in the soil not only increases soil aeration, but also reduces runoff – and therefore reduces soil erosion. In a high rainfall event sediment runoff was found to be reduced by 97% (Forgie 2018), with a corresponding reduction of phosphorous loss.

Accelerated uptake of 14% across all Overseer modelled pastoral farms may reduce sediment loss by 3.8% or 7.3 mt. The quantity of nutrients attached to the eroded soil may be 4,700 tP and 21,800 tN.

ACCELERATED UPTAKE

Sediment ↓ - Up to a 3.8%, or 7.4mt, reduction in sediment loss from pastoral farms.

Phosphorous ↓ - As most phosphorous is lost bound to sediment, the reduction may be 4,700 tP.

Nitrogen ↓ - Nitrogen in the eroded soil may be 21,800 tN.

Nitrogen ↓ - Reduced runoff of nitrogen through improved soil infiltration and dung burial by dung beetles. Accelerated uptake across all pastoral land may prevent the loss of 5,000 tN.

Along with a reduction in sediment and the associated nutrients, less runoff will also reduce the risk posed by dung releasing into the overland flow *E. coli*, dissolved reactive phosphate, and nitrogen (McDowell, 2006).

Gillingham and Gray (2006) found runoff in low rainfall (< 1,000mm) Hawke's Bay of between 10-26%, and cited 27% in higher rainfall (1,660mm) Waikato. On the basis of 15% runoff and 1,200mm of rainfall, total overland flow equals 1,800 m^3.

McDowell (2006) found mean NO_3-N concentrations in overland flow of 2.7 mg/L, or 6.5kgN/ha based on the runoff scenario above. Gali et al (2012) found Total Nitrogen levels in runoff from grazing land of 1.5 mg/L and TKN of 1.3 mg/L. Edwards et al found TKN concentrations of 2.9 mg/L from rotational grazing. Nitrogen runoff was estimated at 3.6 kgN/ha (2.4ML x 1.5 mg/L), ranging between 1.5 kgN/ha (dry and 10% runoff) to 6.7 kgN/ha (wet and 27% runoff).

If dung beetles can reduce runoff by 81% (Forgie et al., 2018), there is the potential to reduce nitrogen loses due to overland flow from 2.7 kgN/ha to 0.5 kgN/ha, or a reduction of 2.2 kgN/ha (range 1.2 – 5.4 kgN/ha).

Nationally accelerated uptake may reduce nitrogen losses by 1.6% or 5,000 tN.

Reduction in Stocking Rate

Reducing stocking rate whilst maintaining production can lead to a reduction in waterway contaminants.

If stock numbers on a sheep and beef farm are reduced by between 5-15% then profit per hectare is reduced by 7-22%, or by about $38-114/ha (Doole, 2015), although this can be partially offset by more efficient farming practices.

A 5-15% sheep and beef reduction can lead to a 6-15% reduction in nitrogen loss, and a 0-1% reduction in phosphorous loss (Doole, 2015). There will also be reductions in greenhouse gas emissions and microbial pollution of waterways.

Overseer modelling of dairy farms shows a nitrogen reduction of between 1.4 - 4.5% with a 5% stock reduction, and between 8.3 – 11.4% following a 15% stock reduction. This is comparable to the results found by Doole (2015) for sheep and beef farms. Phosphorus reductions on dairy farms ranged between 1.2 – 2.1% reduction following a 5% reduction in stocking rate, and a 3.5 – 7.4% reduction with a 15% reduction in stocking rate.

Based on accelerated uptake of 5% or 15% reduction in stocking rates, there may between 0.6% to 1.7% reduction in nitrogen across NZ. This equates up to a 1,900 tN to 5,400 tN reduction in nitrogen losses.

Phosphorous reductions are not anticipated at the 5% reduction in stock and a modest 0.1% or 14 tonnes were predicted to occur across NZ farms with accelerated uptake.

The impact of a reduction in stocking rate can be variable and complex. A reduction in stock numbers, where total production is maintained, i.e. per animal production increases, can result in a relatively minor reduction in nutrient (and GHG) discharges. Similarly, depending on the farmer's grazing management skill, it can be possible to maintain or improve profitability in the face of a stocking rate reduction.

ACCELERATED UPTAKE

Combining results from Overseer modelling with data from literature, accelerated uptake of a 5-15% reduction of stocking rates would lead to the following reductions:

Nitrogen ↓ - A 5% reduction in stocking rates may lead to a 0.6% reduction in nitrogen loss from pastoral farms, or 1,900 tN.

A 15% reduction in stocking rates may result in a 1.7% reduction in nitrogen loss, or 5,400 tN (Figure 5).

Phosphorous = /↓ - A 5% reduction may lead to negligible change, whilst a 15% reduction may lead to a modest 0.1% or 14 tP reduction in phosphorous loss from accelerated uptake across NZ farms.

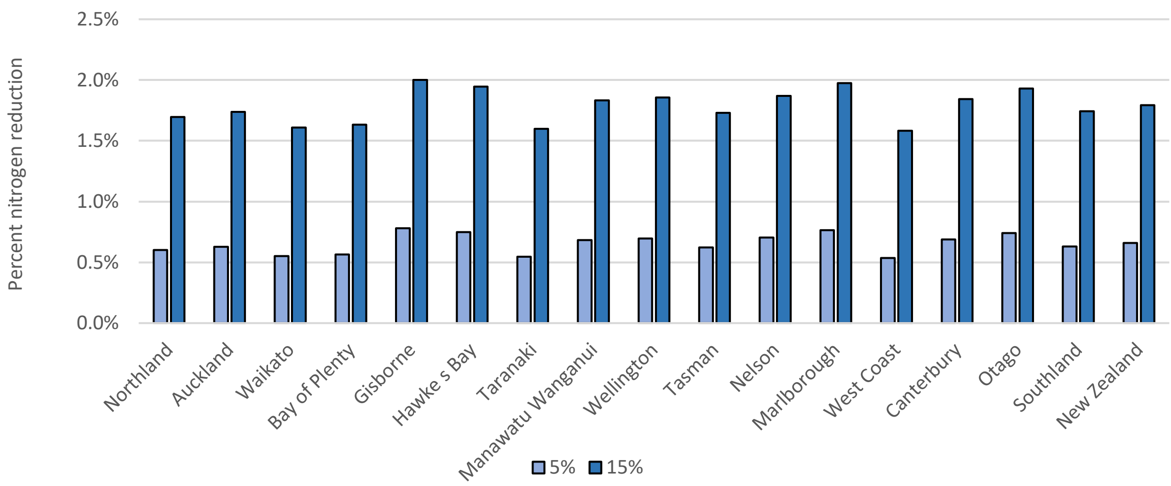
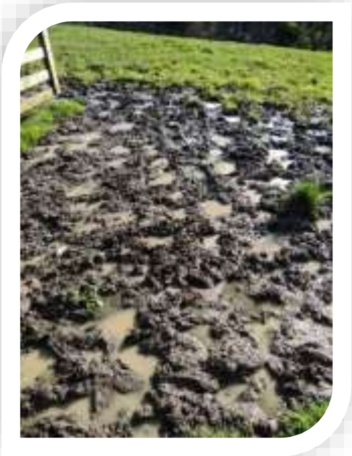


Figure 5 – Reduction in nitrogen loss from pastoral farms following accelerated uptake of a 5% and 15% reduction in stocking rates.

Restricted Grazing and Off Pasture Animal Confinement Systems

During high risk periods such as winter, where high rainfall leads to pugging and destruction of pasture by livestock, livestock are often removed from the pasture and housed in stand-off pads, wintering barns or other infrastructure.



Restricting livestock access to pasture during these high-risk periods has been shown to decrease nitrogen leaching losses, as well as runoff of sediment, phosphorous and *E. coli*. Nitrous oxide emissions will also be decreased due to a reduction in soil damage, although this may become offset by increasing emissions from collected livestock effluent.

It is important to consider the concept of pollution shifting or swapping. Reductions in one area can simply result in the pollutant being shifted to a different part of the production system (passive diffuse nitrogen leaching from animal grazing to concentrated nitrogen requiring active effluent disposal) or swapped such as from reduced soil damage and sediment losses for increased effluent pond greenhouse gas emissions.

There are significant costs to the farmer to establish and run restricted grazing systems, with estimates ranging from between $2-$30/head/week (Perrin and LCR, 2018).

ACCELERATED UPTAKE

Nitrogen ↓ - Overseer modelling shows wintering pads may decrease nitrogen losses by between 16 – 26%. Regionally accelerated uptake on 14% of farms may reduced nitrogen losses by 3.6% in the Waikato, and 2.2% in Canterbury. Nationally accelerated uptake across dairy farms may result in a 2.8% reduction in nitrogen losses or 6,100 tN.

Phosphorous ↑ - Overseer modelling shows wintering pads may increase phosphorous losses by between 5 – 12%. Nationally, accelerated uptake of wintering pads may result in a 1.1% increase in phosphorus losses, or an additional 39 tP discharged.

Depending on the region Overseer modelling of dairy farms has shown a reduction of between 15.8% - 25.6% in nitrogen losses when a wintering pad is installed. Accelerated uptake extrapolated across NZ would reduce nitrogen losses by 6,100 tN. However, Overseer also shows that this may result in an increase in phosphorous losses of between 5.4% - 11.7%, or a national average loss from accelerated uptake of 1.1%, or 39 tonnes phosphorous across NZ.

Figure 6 – Reduction in nitrogen loss from dairy farms following accelerated uptake of wintering pad installation.

Strategic Grazing Management

The management of critical source areas (CSA's) – such as swales and gullies – can help mitigate phosphorous, sediment and effluent loss to water from grazed winter forage.

The process of grazing management usually involves stock being grazed from the top of the paddock downhill, with CSA's being the last area to be grazed – or not being grazed at all.

Strategic grazing can reduce losses of sediment and phosphorous in these areas by 80-90% (Beef and Lamb NZ, AgResearch). For the purposes of estimating the impact from accelerated uptake we assumed that this practice affected 10% of a dairy farm, and 5% of the sheep and beef area.

ACCELERATED UPTAKE

Following accelerated uptake:

Sediment ↓ – Pastoral sediment loss may be reduced by approximately 853,000 tonnes.

Phosphorous ↓ – Pastoral phosphorous loss may be reduced by 810 tP.

Optimum Phosphorous Concentration Soil Tests

Having a soil concentration of phosphorous in excess of what is required for crop or pasture growth is an unnecessary source of phosphorous loss that can be corrected by better management through regular soil tests for Olsen phosphorous levels.

Olsen P tests show the level of phosphorous biologically available to plants. If it is in excess of what is required, then less phosphorous needs to be applied – and this can result in significant savings in fertiliser.

Overseer modelling of dairy farms in the Waikato and Canterbury shows that decreasing Olsen phosphorous from 40 to 30 points, results in a 10% and 12% reduction in phosphorous loss respectively, or approximately 0.1 kgP/ha.

Nationally accelerated uptake may result in a 0.4% reduction in phosphorous losses or 50 tP.

ACCELERATED UPTAKE

Levels of Olsen phosphorous differ between farm location and land use. If we make the assumption that accelerated uptake conditions for this measure involve a reduction in Olsen P by 10 points then:

Phosphorous ↓ - Total phosphorous loss on dairy farms may be reduced by up to 12%. Nationally accelerated uptake on dairy farms may result in a national reduction of 0.4% or 50 tP.

We did not model the impact across sheep and beef farms as generally their Olsen P levels are already low (i.e. <20), especially hill country farms, although this management practice could equally apply to intensive finishing farms with higher Olsen P levels.

Improved Nitrogen Use Efficiency – less fertiliser

Lowering the application of nitrogen fertiliser can significantly reduce nitrogen losses from pastoral farming. Dairy farmers generally apply a larger quantity of nitrogen fertiliser to pasture than other pastoral farming land uses, and so have the greatest potential reduction.

Eliminating the use of fertiliser will save money spent on fertiliser and fertiliser application systems, although this is more than offset by the reduction in pasture production and drop in animal production levels. While eliminating nitrogen fertiliser is a somewhat extreme measure, the scenario was tested to gauge the upper bound of its potential impact.

Depending on the region, Overseer predicts an 8.8 – 21.5% reduction in nitrogen loss from dairy farms if nitrogen fertiliser use is eliminated. This was a change of between 3 to 17 kgN/ha. Based on accelerated uptake across the dairy industry there may be a 2.4% reduction in nitrogen losses or 4,800 tN. This equates to a 1.5% reduction across all pastoral farm types.

In all the no nitrogen models, this required lower stocking rates and lower production, hence both nitrogen and phosphorous decreased. Phosphorous losses decreased by between 1.4 to 6.7%, although nationally the change was almost zero.

A key factor in elevated leaching due to nitrogen fertiliser usage is application timing. Many farmers do not now apply nitrogen fertiliser over the winter period

ACCELERATED UPTAKE

With the complete elimination of nitrogen fertilisers on dairy farms under accelerated uptake:

Nitrogen ↓ - Nitrogen lost from dairy farms may be reduced by 1.5% nationally, or 4,800 tN.

Phosphorous ↓ - Phosphorous lost may be reduced by 0.2% nationally, or 20 tP.

Improved Nitrogen Use Efficiency – increased effluent disposal area

Increasing the area that effluent is applied to the farm can reduce the need to apply synthetic nitrogen fertiliser to pasture – therefore reducing total nitrogen applied to and lost from the farm. It does however more active management and increases the risks.

Costs of increasing the effluent disposal area include the establishment of a greater irrigation system network to cover more farm area, and additional staff time.

Modelling in Overseer for a Waikato dairy farm with a 25% increase in the effluent disposal area reduced nitrogen leaching by 0.3%, whereas a 50% increase in the effluent area reduced nitrogen leaching by 1.4%. Similar figures where obtained for modelling a Canterbury dairy farm, where a 25% increase in effluent area reduced nitrogen leaching by 0.7%, and a 50% increase in area reduced nitrogen leaching by 1.6%. Reductions in phosphorus loss were negligible.

The modelling was based on the farm initially having the minimum accepted area (4ha per 100 cows), and it was this area that was increased in the different scenarios.

ACCELERATED UPTAKE

Increasing the minimum effluent disposal area by 50% on 14% of dairy farms may result in:

Nitrogen ↓ - Overseer modelling of a Waikato and Canterbury dairy farms showed a 1.4% and 1.6% reduction in nitrogen leaching respectively. Accelerated uptake may reduce nitrogen leaching nationally by 0.1% or 450 tN.

Earth Bunds and Sediment Retention Ponds

Earthen barriers constructed along the paddock edge in cropland to either prevent water flowing onto the paddock or to temporarily trap water before it leaves the paddock. Suitable for use on most cropping land, especially those with slopes greater than 3 degrees. During rain events the bunds create ponds of water at the bottom of paddock where sediment settles out. If properly constructed, positioned and maintained, they can be 80-99% efficient at reducing sediment loss. As the majority of phosphorous is lost bound to sediment, it is also a highly effective measure for reducing phosphorous loss.

Estimated costs for low tech earth bunds are around $130/ha, while sediment retention ponds can cost 10 times this (Barber, 2014). Both require on-going cleaning and redistributing the soil back onto the fields.

ACCELERATED UPTAKE

Sediment ↓ - Sediment lost from cropland may be reduced by 12%, or 0.35 mt.

Phosphorous ↓ - the reduction of phosphorous losses bound to the sediment may be 400 tP.

Sediment loss from cultivation various enormously, affected by slope, rainfall intensity, soil type, and management practices. On the basis that the erosion rate is 5 t/ha, sediment loss from cropping land (595,900 ha) may be 3.0 million tonnes. If bunds and sediment ponds are at least 85% effective, then accelerated uptake may result in 0.35 million tonnes less soil lost. The reduction in phosphorous loss, at 1,150 mg/kg, could be 400 tonnes.

Minimum Tillage

Minimum tillage encompasses a range of techniques from direct drilling of seed into stubble or pasture, through reduced number of cultivation passes, to more judicious use of conventional ploughs and harrows.

It can have a significant effect on erosion and soil health, reducing around 25% of sediment and phosphorous loss – dependent on the specific technique used (Barber, 2014). Using a base line cropping erosion rate of 5 t/ha and a 25% reduction in sediment loss, accelerated uptake may reduce sediment loss by 102,000 tonnes with an associated reduction of 120 tonnes of phosphorous.

Minimum tillage also reduces nitrogen loss by around 2-5%, as less nitrogen is disturbed and volatilised from the soil or allowed to runoff (Elliot, 2017).

Disruption of soil structure can lead to emissions of greenhouse gases. Reducing this disruption by minimum tillage techniques can reduced greenhouse gas emissions from cropping by around 4%. With zero tillage this reduction can rise to 20% (Elliot, 2017).

ACCELERATED UPTAKE

If tillage was reduced following enhanced uptake then:

Sediment/Phosphorous ↓ - Sediment and accompanying particulate phosphorous lost from cropland would be reduced by around 3.5% nationally. This amounts to 102,000 tonnes of sediment and 120tP.

Nitrogen ↓ - Nitrogen loss from cropland may be reduced by 0.5% nationally.

GHG ↓ – Greenhouse gas emissions from cropland soils would be reduced by around 0.6% nationally.

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Table of Management Practices

For other management practices and figure sources please refer to excel table of management practices

Management Strategy	Applications	Description	Modelled in Overseer	Effectiveness					Obstacles to uptake	Variability	Co-Benefits
				Sediment	Nitrogen	Phosphorous	Microorganisms (Specifically *E. coli*)	Greenhouse gas emissions			
Reduce Stocking Rate by 5-15%	All pastoral farming enterprises		Directly modelled	ND	6-15%	0-1%	ND	ND			
Stream fencing	S&B, already completed in dairy.	Preventing livestock access to stream, decreases stream bank damage and stops the direct deposition of excreta into streams.	Directly modelled	Dairy: 70% Sheep and Beef: 70% Deer: 70%	Dairy: 13% Sheep and Beef: 13% Deer: 13%	15-40%	Dairy: 60% Sheep and Beef: 60% Deer: 60%	-	Price of permanent fencing >> temporary fencing.	Gain is dependent on the area of the farm currently unfenced and stream density	Stream shading decreasing water temperature and light for periphyton and macrophyte growth.
Strategic Grazing Management	Pastoral	Research has shown that grazed winter forage crops contribute significantly to the risk of phosphorus (P), sediment and faecal losses to water. Critical source areas (CSAs) such as gullies and swales are a particularly important part of the landscape involved in the transport of these contaminants to water. Strategic grazing and careful management of CSAs can reduce losses of sediment and phosphorus (P) by 80-90%. The reduction is achieved by minimising stock movements and thus soil treading damage in the CSA. This means any rainfall and runoff that occurs is more likely to infiltrate the soil, minimising the amount of runoff and losses of sediment and P.	Not modelled	90% (Beef and Lamb NZ/ AgResearch)							

Management Strategy	Applications	Description	Modelled in Overseer	Effectiveness					Obstacles to uptake	Variability	Co-Benefits
				Sediment	Nitrogen	Phosphorous	Microorganisms (Specifically *E. coli*)	Greenhouse gas emissions			
Restricted grazing and off pasture animal confinement systems	Dairy	In fully or partially grazed systems, a strategy for minimising N, P, sediment and E. coli losses is to avoid deposition of urine and faeces or soil disturbance during periods of high loss risk, by either removing the animals from pasture at certain times or by extending the existing housing period.	Directly modelled	Low	High	Medium	ND	ND	High capital and operational costs and increased management complexity; immature design criteria and management systems that meet animal welfare and manure management requirements; and some risk of 'pollution swapping' by increasing NH3 or N2O emissions from the collected effluent and manures.	Costs vary widely due to variations in soil type and climate, and on the frequency of use of a restricted grazing strategy. For farms on heavy soil types and in wet locations where standing animal's off-paddock is desirable, a small or nil net cost might be assumed. For dairy farms on well-drained soil types with minimal risk of soil treading damage, significant cost might be incurred.	Decreased soil and pasture damage caused by animal treading will help increase pasture yields and decrease N2O emissions and denitrification rates.
Introduction of dung beetle colonies	All pastoral farming enterprises	Release of one or several colonies of dung beetles in order to bury faecal matter, reducing effluent and improving soil quality and usage.	Not modelled	97% reduction in normal to high rainfall events	ND	High (related to sediment reduction)	Reduced runoff leading to reduced *E. coli.*	Small reduction in CH_4 (dung). 40kg of Carbon sequestered in the soil per cow per year	Viewed as a new technology.	Dung beetle colonies do not always establish for a variety of reasons. Colonies may leave farm if initial placement is not in a central location.	Improved soil quality. Greater amount of usable grazing land. Results in increased production. Approximately $15,000+ extra production on an average dry stock farm, or $47,000+ on an average dairy farm.

Management Strategy	Applications	Description	Modelled in Overseer	Effectiveness					Obstacles to uptake	Variability	Co-Benefits
				Sediment	**Nitrogen**	**Phosphorous**	**Microorganisms (Specifically *E. coli*)**	**Greenhouse gas emissions**			
Improved N use efficiency	All pastoral farming enterprises	Greater N use efficiency can be achieved by: increasing per animal production with a commensurate decrease in animal stocking rate (replacement rates particularly) to maintain per hectare production and profitability; using less fertiliser N and some, if prices allow, low N feeds; and maximising the N value of farm dairy effluent by applying it to a greater proportion of the farm	Directly modelled	-	Medium	-	-	ND	Greater management expertise is required to maximise the amount of harvested feed under a low input farming system, while an increase in per cow production (to allow a decrease in stocking rate) will take time as improved genetics is introduced into herds	The ability to decrease N losses to water depends on (i) the existing level of farm intensity and N loss, and (ii) the management expertise to implement required changes in farm practices. As a comparative example, very low input/intensity farms have little scope for decreasing inputs and N losses still further, in contrast to high input farms where less N fertilization is technically quite possible. Farms that are already very expertly managed will also have little scope to further modify farming practices to decrease N losses	Decrease emissions of greenhouse gases and an improvement in energy use
Supplementary feeding with low-N feeds. Forages for Reduced Nitrate Leaching (FRNL) research programme	All pastoral farming enterprises	Supplementary feeding with low-N feeds such as maize silage can increase animal productivity with little effect on the amount of N excreted in urine and lost by leaching. For example, studies with dairy cows have shown maize silage supplementation to increase milk production by one-third had little effect on the amount of N leached per hectare.	Partially modelled	-	Plantain 20-50% reduced N leaching by 10 - 35%	-	-	ND	Lack of facilities for feeding out supplementary feed and costs of introducing them; increased workload; requirement for increased skills in feed utilisation; and increased risk, depending on milk payout and feed prices	Highly variable depending on source and price of feed and the efficiency with which it is fed to animals (with critical importance of the need to avoid substitution by the low-N feed for consumption of existing pasture). Thus, it is highly dependent on farmer management skills. On dairy farms in years of high milk payment, it can result in increased farm profitability.	May also lead to reduced nitrous oxide per unit of productivity but this can be more than countered by increased carbon dioxide production in the production and feeding of the low-N feed sources.

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				Sediment	Nitrogen	Phosphorous	Microorganisms (Specifically *E. coli*)	Greenhouse gas emissions			
Optimum soil test P concentration	All farming enterprises	Achieving an Optimal soil test P concentration (e.g. Olsen P) can be done with nutrient budgeting software such as Overseer. The magnitude for P loss mitigation is dependent on how excessive Olsen P is, but if in-excess will always represent a profitable strategy.	Directly modelled	-	-	5-20%	-	-	None	Gain is dependent on soils being enriched beyond their optimum	None
Bunds	All farming enterprises	Earthen barrier constructed along paddock edge to prevent water flowing onto or from field. Suitable for use on cropping land with slope greater than 3 degrees. Creates ponds of water at bottom of field where sediment settles out. Sediment in cropping may be collected and redistributed to the upper land slope areas. Bunds, in concert with riparian strips will further increase effectiveness.	Not modelled	80-90%	-	ND	-	-	Management expertise	Depends on infiltration capacity of soil	Increased sustainability of cropping. Decreased P input (unquantified) to waterways.
Minimum tillage	Cropping	Range of techniques from direct drilling of seed into stubble or pasture, through reduced number of cultivation passes, to more judicious use of conventional ploughs and harrows. Suitable for use on cropping land. Reduces the proportion of time that land is bare during the growing cycle.	Partially modelled	25%	Arable Cropping: 2% Horticulture: 5%	25%	-	4%	Management expertise	Depends on the amount of time land is bare	Increased sustainability of cropping. Decreased P input (unquantified) to waterways.

Management Strategy	Applications	Description	Modelled in Overseer	Effectiveness					Obstacles to uptake	Variability	Co-Benefits
				Sediment	Nitrogen	Phosphorous	Microorganisms (Specifically *E. coli*)	Greenhouse gas emissions			
Low Methane Feeds	All pastoral farming enterprises	Brassicas have been tested extensively in sheep in New Zealand and forage rape has consistently reduced methane emissions by 20-30% when fed as full diet.	Not modelled	-	-	-	-	20-30%		Possible increase in Nitrous Oxide emissions when grazed. In addition, there is strong evidence that high cereal diets can reduce methane emissions per unit of product; but cereal must make up at least 30-60% of the diet. This makes it unlikely to be cost-effective for New Zealand's pastoral grazing systems. It is also important to factor in the emissions generated to produce and transport the cereal feed. Several animal health problems can occur when livestock are switched to Brassicas.	
Forest Carbon Sequestration	All farming enterprises	Carbon sequestration is the process by which carbon dioxide is absorbed during photosynthesis, and is stored as carbon in biomass (trunks, branches, foliage, and roots). Gains in forest carbon stocks through growth and sequestration will reach a maximum level over time, and are eventually offset by carbon losses through harvesting, thinning, and natural decay.	Not modelled	-	ND	-	-	Radiata pine sequesters approx. 28 tCO_2/ha/yr (7.6 tC/ha/yr). The "safe" component is 6.0 tCO_2/ha/yr. Indigenous forests sequester an average of 6.4 tCO_2/ha/yr			