A review of wetlands and other methods of reducing P and N loss into New Zealand waterways.

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Executive Summary

It's not often when a group a farmers meet, and the conversation does not turn towards increased compliance and regulation. Water quality standards are usually brought up and no matter whether you are rural or urban most would agree rivers and lakes in New Zealand need to be clean and swimmable, after all, brand "New Zealand" is all about plush countryside and beautiful lakes rivers and mountains.

In the last 30 years New Zealand agriculture has increased nitrogen use by over 600% from 62,000t to 452,000tonnes and cracks are starting to appear. Anthropogenic inputs from intensive agriculture and poor practices can be harmful to the health of our waterways, precious wetlands rich in biodiversity and known for their many environmental benefits including filtering nutrients and carbon sequestration have been degraded or drained over time.

New Zealand has positioned itself well to feed a growing population, but land use change and intensificationis adding pressure to ecosystems and in many cases degrading water quality. Because agriculture is so important to the NZ economy and the very social wellbeing of our people, how do we mitigate the impacts of intensive agriculture on the waterways so that future generations can enjoy the same privileges many of us had growing up.

In this report, I review research on wetlands and other methods which have been proven to mitigate agriculture nutrient loss to waterways. In hope of finding a silver bullet to many water quality issues the answer really is not that simple, the dynamics of agriculture in NZ is diverse. Finding a solution is difficult due to different production systems, geographic, climatic and soil property differences.

I came to understand that many mitigation techniques are on farm management practices such as keeping your Olsen P within economic optimum range, avoid soil damaging activities, better effluent storage etc. I also discovered that land use capability should be at the crux of decision making when it comes to consenting what production system is suitable for that piece of land from an environmental perspective as its much cheaper to allocate the correct land use than back pedal damages to the water quality.

Wetlands are significant for many other reasons other than filtering nutrients and understanding their importance for biodiversity I discovered that they can be a useful tool in the toolbox and are recognised in nutrient budgeting models such as overseer, rejuvenating existing wetlands is a great place to start and constructed wetlands whilst costly can serve many purposes.

My main recommendations are as follows:

1) **Exposing some hard truths on NZ's water quality**

    - I encourage everyone to visit the LAWA website and see what the status of their local river(s) is.

2) **Understand what mitigation methods would be effective for your catchment**

    - Some of the most cost-effective methods are on-farm management practices.

3) **Protect and Promote Wetlands and other sensitive areas.**
   - Increase public knowledge and appreciation of wetland functions and processes.
   - Ensure landowners and government agencies commit to wetland protection, enhancement, and restoration.

4) **Support Integrated catchment management**

   - Gives farmers a sense of ownership and responsibility to influence their local catchment.

5) **Deep understanding of Land use capability models**

   - Regional councils and MfE need to have a deep understanding of land use capabilities, linking land use to an appropriate production system; one which it can handle environmentally.

   - This method includes protecting highly productive "elite soils" from urban sprawl.

6) **Subsidise and Incentivise**

   - Wintering of dairy cattle in wet areas is a huge contributor to N & P losses. A potential solution could be to subsidise feed pads or feed barns, this way, effluent could be stored and applied during dryer months.

7) **Compliance and regulation**

   - Support for the farm planning approach and freshwater farm plans.

     i) Clear water objectives from councils in line with the NPS-FM from skilled staff.
     ii) Provide a practical way for farmers to meet both regionally set and nationally prescribed rules & responds to the characteristics of each farm.

   - All NZ farms should meet NZ Farm Assurance Programme Plus (NZFAP +) within a certain period.

8) **Embrace Regenerative Agriculture (RA)**
   - Embrace RA: healthy soils store more carbon, more nutrients, and more water, relying less on synthetic inputs.

Purpose

Fresh water is such a contentious subject. With growing tension between farmers who feel burdened by the weight of increased compliance and regulation, and Government Ministers who are determined to make swift changes whilst also acknowledging NZ's reliance on agriculture as our main export earner, even more so in a pandemic world with no inbound tourism.

Currently one third of NZ's rivers are unsafe to swim in and contributing industries and catchment stakeholders will have to work impossibly hard to reach the government's ambitious target of 90% of New Zealand's large rivers and lakes being swimmable by 2040, change needs to happen swiftly, and a collective effort needs to be made. Brent Paterson of MyEnviro said "the environment does not work to a timeline, so the sooner we start, the sooner we get it done".

World population is projected to increase in the next 30 years from 7.8 billion (2020) to 9.9 billion by 2050 (United Nations, 2017).

The NZ agriculture industry will need to be smarter with the way they produce food, and that action must be taken now, to ensure we are balancing the use of natural resources to support our society's health, well-being, and economy, while taking care of our natural environment.

Land use is intensifying (Land, MFE 2021) farmers are increasingly reliant on short crop rotations, land development, and synthetic fertilisers to finish lambs faster, produce more milk, and grow higher yielding crops. Speeding up the nutrient cycle is part and parcel of intensification, and with that comes increased nutrient losses. Despite the inception of the Resource Management Act 1991 (RMA), waterways continue to be degraded, thousands of hectares of wetland are lost, and the urban areas are sprawling into highly productive food producing land (Gray, 2017).

Just think, some of the poor decisions our forefathers made (introducing pests and weeds into NZ), saw the extinction of several native birds, and degradation of fragile alpine areas. The future of NZ water, hinges on what we do now.

Introduction

New Zealand's economy is heavily reliant on Agriculture production. It is estimated one in four people are either directly or indirectly employed by the agriculture industry. Our ancestors 'broke in' land in the 1800's and our nation became reliant on exporting meat and wool. Today we can be very proud of our world-leading pasture-based farming systems, however, the world is changing, and climate change is real. Our population is growing, but our available land isn't, and a reliance on food systems fit for feeding a growing population is under threat.

Managing farm productivity based on increased gross output alone sees farmers increase the use of synthetic fertilisers, crop more frequently, develop irrigation, and drain wetlands. Defying nature to make a farm more productive is undoubtedly going to diminish water quality. Excess nutrients lead to more nutrient loss into waterways causing eutrophication, and increased nitrates in drinking water; sparking councils to issue unsafe swimming signs or treating drinking water with additional chemicals. It appears we are doing something, but we're just not doing enough. Richard McDowell is one of the most prevalent researchers in this space quoting "my worry is that our ability to optimise systems to decrease losses may not keep pace with the rate of intensification and P loss" (McDowell 2012).

Mitigating the nutrient loss to our waterways is a complex issue: according to literature referenced in this report a huge amount of work has gone into methods to reduce the impacts. The challenge is to understand what land uses practices are causing harm, what mitigation method(s) should be used, how should it be used, and who should be using that method.

Certain methods may only suit certain climatic or geographic situations, and others may only be cost effective in certain parts of the country, or under a certain farm system. For example, a multi-year performance measurement on constructed wetlands in three parts of the country draining dairy land showed that the Northland wetland had greater denitrification ability than the Southland one due to climatic differences with the warmer Northland climate favouring de-nitrification conditions. (Tanner, C. & Sukias, J. P. 2011). Some catchments will have to use one or two methods, others will have to use several. There is no doubt that some catchments will need more attention. Notably, some methods offer intangible benefits which are hard to quantify, such as increased biodiversity.

The government recognises there is a need for clear central government policy to set a national direction, although it's important they understand where time, energy, and resources are best spent, so we can make swift changes while minimising the burden on farmers, and harm to production (NPS-FM 2021) Central to farmer uptake of new regulations, is cost effectiveness. The key will be to educate farmers on where to begin, and follow with the ongoing options and implications, if nutrients are not responsibly managed. Regional councils, communities, rural professionals, and farmers will likely have to work together to identify what methods should be used, in order of priority, and where the critical sources are.

In the following review I take a holistic all-encompassing approach, not only looking at current mitigation methods, but also what the future for managing nutrients may look like. For simplicity reasons, I have chosen just two nutrients harmful to waterways in high concentrations; Phosphorus and Nitrogen. Both are considered main instigators for stimulating eutrophication (Keeney, 1973). It is important not to focus too much on either nutrient because both have greatly different characteristics, therefore require different management practices to mitigate. This highlights the need to treat each nutrient individually and have plans in place for mitigating both. The focus of this study is to understand what techniques are the most cost effective to mitigate agricultural induced Nitrogen (N) and Phosphorus (P) losses entering waterways, while still maintaining productive pasture-based agriculture systems.

Aim

Review Constructed Wetlands and other methods of reducing nutrient loss to waterways. I will focus on cost effectiveness as a measure, and the practical implications of each method. So, with farm profitability in mind, I will look at what cost effective methods could be focused on now, to have the greatest impact on the future.

New Zealand maintains a largely subsidy-free farming industry (research excluded), the cost-effectiveness of any mitigation strategy is central to their voluntary uptake (McDowell & Nash 2012). My aim is for the whole industry (farmers, Co-ops, field reps, catchment groups, consultants, and regional councils) to better understand the different mitigation strategies & techniques to promote and protect water quality in their communities for the betterment of New Zealand.

Vangelis Vitalis, New Zealand's Chief Trade Export Negotiator, recently acknowledged that while environmental regulations came at a cost to farmers, they would have a pay-off in improved access to international markets, if they helped quell opposition in those markets and encourage free trade deals with NZ (Vitalis 2021)

If, by the end of this report, it is still not clear whether to use a constructed wetland, or other methods to mitigate nutrient losses, my aim will be to at least increase awareness, so that enhancing, protecting water quality and our natural biodiversity is considered when it comes to on-farm and community decision making.

Methodology

The methodologies used for this report was an extensive literature review, along with primary interviews.

The literature review was a major component of my research and included resources from mainly domestic & international publications, and industry reports. Much of the literature I studied was from the work of Professor Richard McDowell & Dr Chris Tanner. Both have completed a lot of work in the space of mitigating agricultural nutrient loss to waterways (McDowell, 2009, 2011, 2012, 2013 & Tanner, 1995, 2011) other sources of information were Ministry for the Environment (MFE), non-government departments such as Beef and Lamb, Dairy NZ, Forest and Bird, fertiliser companies, Land and Water Aotearoa and trusts such as Wetland Trust.

The interviews were carried out with three farmers, three scientists, three industry representatives, one person from MFE and one person working in the environmental space, with the aim of achieving a wide variety of views and perceptions, from a diverse range of people, with varying levels of experience.

The Nutrient cycle

Phosphorus

To understand the problem, we must understand the phosphorus and nitrogen cycle. Phosphorus (P) and Nitrogen (N) are chemical elements essential for plants and animals to grow.

P is typically imported into a farm system via fertiliser and purchased feed. Approximately 30% of the P ingested by grazing stock, will leave the farm in products such as milk, and meat. The remainder will be excreted as dung.

Because P is relatively insoluble (it binds strongly to soil particles), the main losses into waterways occur via surface run-off and, to a lesser extent, leaching through the soil. Therefore, activities which disturb soil structure e.g., cultivating, pugging, and high rainfall; contribute to the loss of phosphate via erosion and surface runoff. P also enters waterways through direct deposition, or runoff of dung and fertiliser, particularly after high rainfall.

Very high phosphorus concentrations in a stream, river, or lake, cause rapid weed growth and algal blooms which can choke aquatic life and cause long-term damage to the health of a waterbody. Where groundwater supports surface water flows, the dissolved reactive phosphate (DRP) in the groundwater can also contribute to the growth of algae in surface water.

Nitrogen

Nitrogen is also imported into the farm through feed and fertiliser and is fixed through legumes from the atmosphere. Nitrogen is exported from the cycle via products (milk, meat and feed), and lost from the cycle via gas (volatilisation) and drainage (N leaching). Through a process called hydrolysis, nitrogen converts into nitrate nitrogen, which, if not absorbed by the plants, it can be easily leached due to its high solubility.

Nitrogen is an effective fertiliser and essential plant nutrient, but increased concentrations in water can cause negative environmental effects. Excess nitrogen can contribute to rapid growth of aquatic weeds and algae in rivers, streams, lakes, estuaries and the ocean, commonly resulting in plant or algal blooms. As the plants die, and the excess organic material decomposes, oxygen in the surrounding water is used up. This reduction of oxygen threatens the life of fish and macroinvertebrates, not to mention the risk of exceeding acceptable drinking standards.

New Zealand's Wicked Problem - Nutrient Use

New Zealand agriculture relies on nutrient inputs to achieve the current level of production. Many farmers opt for applying fertiliser, as often it's the cheapest way to grow extra dry matter to eliminate a pasture feed deficit. For example, based on current Urea pricing, and a conservative 1:10 Nitrogen response, you can expect to pay around 16c/Kg/DM. Compare this to buying Maize Bailage at around 60-70c/kg/DM. Fertiliser, while an expensive aspect of on-farm costs, application of synthetic N is more affordable than having to buy supplementary feed during a feed deficit.

1990 – 2019

Between 1991 and 2019, estimates of nitrogen applied to land in fertiliser increased from 62,000 to 452,000 tonnes (just over a sixfold increase, or 629%). (Stats NZ 2021) The total amount of nitrate-nitrogen leached from livestock, increased from 189,000 tonnes nationwide in 1990, to 199,000 tonnes in 2017. In 1990, nitrogen leaching from sheep contributed 34% of national nitrogen leaching, which decreased to 15% in 2017. In contrast, dairy cattle contributed 39% in 1990, which rose to 65% in 2017. Livestock nitrogen leaching in Canterbury has increased 117% since 1990 (from 15,000 tonnes to 33,000 tonnes in 2017) (Stats NZ 2021)

The Financial Impact of Banning Nitrogen Application

A report by AgFirst, commissioned by the NZ Fert Association, estimated that if nitrogen use was to stop in New Zealand, the impact on the economy would be a $19.8b drop in gross output, a drop in GDP of $6.7b, and a reduction in employment by 73,760 (Journeaux et. al, 2019).

National Policy Statement: Fresh Water

In 2017 the Government set a national target of making 90% of New Zealand's large rivers and lakes swimmable by 2040. It set an interim target of 80% swimmable by 2030.

The National Freshwater Policy 2020, aims to right some of the wrongs, in respect of freshwater degradation. The policy includes the involvement of Tangata Whenua, avoiding further loss of wetlands, aquatic life, meeting objectives, and overall prioritising the health and wellbeing of water bodies. The policy directs regional councils to work towards these targets and report on progress. Recently national regulation limiting Nitrogen use was implemented, limiting application to no more than 190kg N/ha/yr.

Current state of NZ Waterways

To understand the current state of our national waterways, I used Statistics New Zealand (Stats NZ) and Land Air Water Aotearoa (LAWA), which pulls together water quality data from regional councils, NIWA and Unitary councils.

The National Objectives Framework (NOF) are the requirements set by the National Policy Statement for Fresh Water (NPS-FW) for the councils to set their water related policies for their regions. In terms of Nutrient levels for Nitrogen and Phosphorus, the NOF can be broken down into five bands, ranging from very likely improving to very likely degrading.

Below are snapshots of trends in Total P and Total N for various regions over the last 10 years.

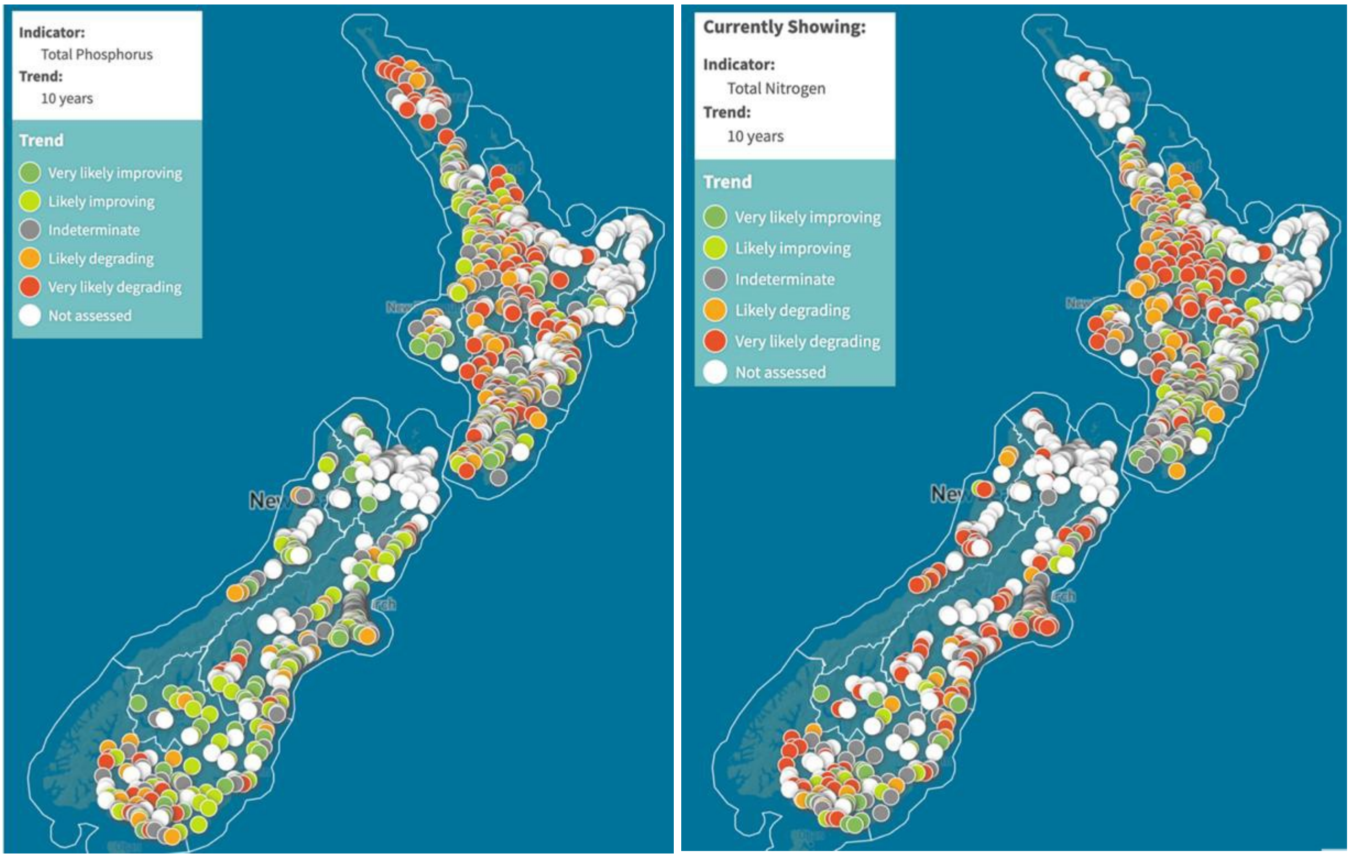

Figure 1: Ten-year trend in water degradation for Total Phosphorus and Total Nitrogen (Source: LAWA, 2021)

The red and orange dots indicate there are some areas for concern. This data can be used to help stakeholders set objectives. Stats NZ said that modelled data showed that 70% of all of New Zealand's River length had at least one form of nitrogen exceeding the Australia New Zealand Water Quality Guideline (ANZG) 2018 default guideline values for the period 2013–17. This indicated median concentrations were above the expectation for natural conditions, and therefore posed a risk to aquatic species.

Catchments and Waterways

In a survey of 37 catchment-scale studies in New Zealand Larned et al., (2004) found that among land uses, water quality had deteriorated the most in rivers and streams draining grazed pasture. Pastoral land use area makes up 40% of NZ's total land area, and 45% of NZ's River and stream length. Compared to the native land cover median, total nitrogen (TN) concentrations were six times higher in the pastoral class and ten times higher in the urban class. However, urban area makes up only 1% of the total land area in New Zealand, and 1% of NZ's River and stream length (Recreational Water Quality, n.d).

So, while urban streams generally have the worst instream health, they only make up a very small portion of our waterways. This highlights that, pastoral farmers can have the greatest impact on national water quality.

Land Cover Class	Area	
	ha	%
Forest	**9,140,048**	**34%**
Indigenous forest	7,003,135	26%
Exotic forest	2,136,913	8%
Scrub / shrubland	**2,049,776**	**8%**
Indigenous scrub / shrubland	1,809,959	7%
Exotic scrub / shrubland	239,817	1%
Grassland / other herbaceous vegetation	**13,097,302**	**49%**
Tussock grassland	2,335,411	9%
Exotic grassland	10,607,939	40%
Other herbaceous vegetation	153,952	1%
Cropland	**473,847**	**2%**
Cropping / horticulture	473,847	2%
Urban / bare / lightly-vegetated surfaces	**1,536,915**	**6%**
Natural bare / lightly-vegetated surfaces	1,279,370	5%
Artificial bare surfaces	20,502	<1%
Urban area	237,043	1%
Water bodies	**543,103**	**2%**
Water bodies	543,103	2%

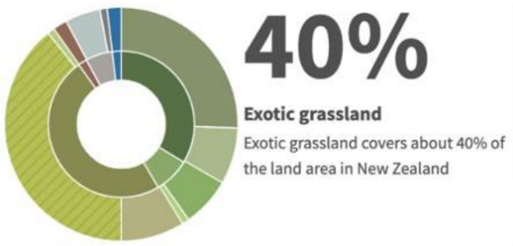

Figure 2: Land Cover Class by hectare (Source: LAWA, 2018)

Wetlands

What is a wetland and why are they important?

Wetlands are permanently or temporarily wet areas that provide habitats for plants and animals that are specially adapted to wet conditions (Hawke's Bay Regional Council 2021). In a future where nutrient management will be critical, wetlands are considered as being one of many tools to improve nutrient losses. They have significant cultural value for Maori for sourcing Tuna (Eels) and other fresh water fish. Wetlands act as sponges, catching farm sediment runoff (high in P) and absorbing nutrients through plant uptake, and offer denitrification conditions (the reduction of nitrate (NO3) to nitrogen gas (N2) limits nitrates from runoff entering downstream waterways). They also provide habitat for native bird and aquatic species. An unusually high proportion of New Zealand's native birds are wetland species; 30%, compared with less than 7% worldwide (Troup, 2007). Wetlands also have ability to store carbon, mitigate flooding, hold recreational significance, and protect biodiversity.

History of New Zealand's wetlands

Since the arrival of Europeans in the 1800's, clearing and draining of wetlands to be converted into pasture, was common practice. For the latter half of the 19th century, the government offered Land Development Loans (1978) These incentives made it economical to develop marginal land areas, encouraging the burning of bush and draining of wetlands. Today over 90% of New Zealand's wetlands have been drained or filled (Wetland Trust, n.d).

Despite national priority for protection in the 1991 RMA, wetland loss and depletion continue to occur. Almost 5,400ha of freshwater wetland were lost to non-natural causes between 1996 and 2018. Concern over this attrition and its impacts on water quality and biodiversity decline has prompted the Ministry for the Environment (MfE) to make the drainage of natural wetlands a prohibited activity in the National Environmental Standards for Freshwater 2020 (NPS-FM).

Will Wetland loss continue?

The NPS-FM provides an exception to the definition of a natural wetland which excludes areas that are more than 50% "improved pasture" and are subject to temporary, rain-derived water pooling. Ecologist Sarah Grant believes this exemption sidesteps the policy, and believes that wetland loss will continue to occur. Part of the problem is that areas covered in grasses, rushes and carracks can be classed as pasture and their importance overlooked. Figure 3 shows a seepage wetland which could be damaged easily by cattle in winter wet conditions. Note the change of slope and non-pasture plant species. This image highlights the critical source for protection and suggested fence location (white line). Under current policy it is likely that this wouldn't meet the wetland criteria.

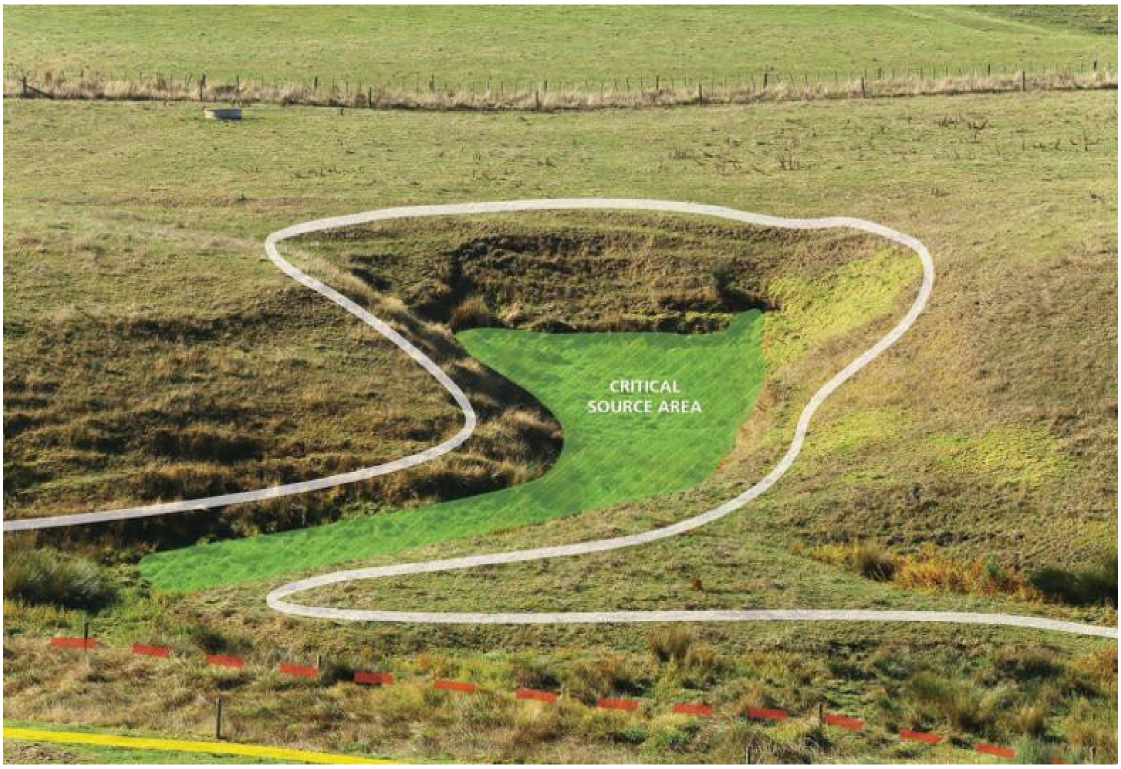

Figure 3: Idealised fencing of a seepage wetland (Source: Diary NZ, 2018)

Constructed Wetlands

Constructed wetlands (CW) are man-made wetlands, and their benefits are becoming increasingly recognised for much the same reasons as standard wetlands, although they can be purpose built to suit certain objectives. Dr Tanner says a well-designed farm wetland, which is appropriately sized for its catchment (1% of catchment area) can remove 25 - 50% of nitrate N in warm areas of New Zealand, and 20 – 40% in cool areas (Tanner & Sukias, 2011). While constructed wetlands are effective in removing N through microbial de-nitrification, their capacity to remove P tends to be lower and more variable.

Costs

One of the barriers to CW is cost. Fonterra and HBRC have sponsored a 1.6ha CW in Central Hawke's Bay, costing $350,000 ($218,000/ha). This wetland treats water from the 160ha Tukipo catchment. The layout is expensive due to the large size and various settling ponds, however, it is expected it will reduce P, N and E. coli concentrations, as well as increasing biodiversity.

Cheaper options

Two wetlands constructed in Southland, showed costs/ha including fencing and planting was $18,000/ha and $31,000/ha respectively, both draining a much smaller area than Tukipo.
NIWA estimated a 40% and 30% reduction in N & P loss to waterway (Environment Southland, 2020). This proves that even small CW can be beneficial at limiting nutrient runoff.

Ongoing maintenance is needed for wetlands, particularly if they are used to catch sediment and remove P. Every 5-10 years, a digger will need to clean the wetland. Plants will likely also need replacing as their growing life comes to an end, as they will stop absorbing nutrients as effectively (Hoogendoorn et al., 2017).

Can Constructed Wetlands really reduce Phosphorus…? It Depends…

(Kadlec & Knight, 1996) and (Cui et, al. 2008) concluded that the overall P-removal capacity of a constructed wetland is strongly dependent on the sorption characteristics of the substrate. If high P topsoil is removed before construction takes place, P removal is greatly increased, however this reduces the ability for the wetland to denitrify the water due to a reduced carbon and organic matter (OM) source, which denitrification bacteria rely on. However, If the wetland is planted, it should only take a couple of years before OM and carbon are built up again.

Long term, the efficacy of wetlands to remove phosphorus decreases as wetlands fill with sediment. As long as this sediment is removed every 5-10yrs, P removal is continued, and there is the potential to recycle this material back onto farmland as a form of fertiliser. Alternatively, P sorption substrate and filter materials can be added. Practicality and cost effectiveness of this method depends on accessibility to some of these materials such as distance to an aluminium smelter (Ballantine & Tanner, 2010)

5-year study of constructed Wetlands.

A study of three constructed wetlands (Toenepi, Titoki and Bog Burn) treating tile drainage from grazed pastures, carried out in three different areas in New Zealand, had various levels of success. It was notable that the removal of nitrogen was particularly successful, where it was discovered the most Northern Titoki wetland was most effective at removing nitrate nitrogen due to a warmer climate favouring denitrification bacterium. It was also noted that during high rainfall events, wetlands effectiveness is reduced if capacity is reached, and overflow drains are in use.

Total Nitrogen (TN) Removal

Annually, the tile drains exported 14-109 kg/ha of TN (58 to 90% was nitrate-N). The wetlands intercepting these flows removed 7-63% of TN loadings annually.

Total Phosphorus (TP) Removal

Wetland P removal was poor in all wetlands, with 12-115% more total P exported annually overall than received. P loads measured at the outlets of the wetlands of Toenepi and Bog Burn remained higher than at the inflow over periods of 3–5 years. It must be noted that tile drains with intercepting mole drains have a high ability to lose phosphorus to waterways which likely influenced the result.

Plants in constructed Wetlands slow down retention times

In a study where the effect of dairy farm wastewater loading and the effectiveness of plants in removing Nitrogen and Phosphorus in a CW were studied, it was found: If water retention periods increased from 2 to 7 days, mean reduction of TN increased from 12% to 41% in an unplanted wetland and 48% to 75% in a planted wetland. Total Phosphorus (TP) removal increased from 12% to 36% and 37% to 74%, respectively.

Planted wetlands showed greater removal of N and P from dairy farm wastewaters than unplanted wetlands, with differences most apparent in the higher loaded wetlands (Tanner et, al. 1995). This shows that slowing down the path of water collectively through planting seepage zones, and a tiered pond system (as seen at Tukipo Hawke's Bay) can greatly add to the effectiveness to remove N & P.

Are CW a practical cost-effective method?

It depends on which nutrient is being mitigated, it depends on how big the CW is and the layout, i.e., is there a sedimentation dam, what is the speed of flow, is the wetland planted, will it be well maintained, or are there any P absorbing materials added (such as wood chip). Of course, we know wetlands offer other benefits such as biodiversity, decrease in E-coli, aesthetic value, cultural significance, flood protection and carbon offsetting.

Often regenerating an existing depleted wetland is a great place to start and depending on the water quality objectives wetlands can be an effective method which meets multiple objectives. Waterbodies tasked with meeting water quality goals are more likely to be achieved with community backing and funding from Non-Profit Organisations (NPO's), Councils, and co-operatives. 30% of NZ's native birds are Wetland species, so creating increased habitat for rare wildlife and front-footing global markets, who are already valuing regenerative farming practices, adds to this movement. Farmer Willie White says of his CW "It's great to be part of a wider project assessing the benefits of wetlands for farmers, and the wetland is aesthetically pleasing and will attract birdlife."

Fundamentally CW's offer many benefits and should be considered when catchments are tasked with improving or maintaining water quality.

Wetlands improve ecosystem services

While it's easy enough to measure nitrate and phosphorus reduction as water enters and then exits a wetland it is much harder to measure eco system health. Ecosystems are notoriously difficult to measure because they represent the dynamic flow of benefits from ecosystems to people (Haines-Young & Potschin, 2010) of course much like the saying 'beauty is in the eye of the beholder', this measurement comes down to an individual's perception, or how they value increased biodiversity and overall ecosystem health.

Furthermore, ecosystem services may be highly variable across space and time. i.e., birds migrating North during a NZ Winter.

When land use intensified throughout the 1990's – 2000's in the UK, paddocks became bigger to accommodate larger machinery thus reducing wooded hedge rows. Many farmers, but not all, noticed a decrease in biodiversity such as number of birds nesting in hedge rows and a reduction in bees. They specifically noticed a reduction in biological control of pests and diseases, thus impacting crop health and increasing reliance on sprays. Biological control is a service provided by species of farmland birds and predatory invertebrates, such as spiders and birds as these groups feed on, and therefore limit the populations of pest species (Stiles, 2021)

In a recent NZ research paper, multiple methods were used to measure the success of restored wetlands on NZ farms including first person surveys, geospatial modelling, and field measurements. Comparing field measurements with surveyed perceived services enabled a more comprehensive and a somewhat accurate picture to the benefits of wetland restoration.

The results from the surveys on wetland ecosystems services

Of the 22 possible ecosystem services of wetlands, land holders perceived a median of 6.5 services. The most common cited service was increased wildlife or biodiversity. The second most cited service was aesthetics or beauty. 10 out of 18 landholders noted perceived mitigating fertiliser runoff. Only 2 out of 18 perceived increased farm profitability.

It was concluded that wetlands should be acknowledged for their multiple benefits for the greater good. Robertson et al (2019) stated that "elevating the role of wetlands in policy is especially urgent, as the current scale of wetland restoration does not match the magnitude of their continued loss in NZ". Wetlands are not recognized under the emissions trading scheme (currently only afforestation has been recognized). The recognition of all planting would incentivise even more farmers to restore wetlands and riparian plant streams.

Alternative Methods to reduce nutrient loss

It's not a one size fits all

There is no silver bullet when it comes to mitigating methods. The more I have researched, the more I discovered that geography, farm type, soil type, climate, nutrient type, current state of the waterway, cost, effectiveness, and speed of effectiveness, all influence which method(s) should be applied to a catchment scenario. McDowell summarises well by saying that strategies should be chosen based on the objective, how quickly the objective needs to be met, and pick the strategies that best suit the property. (McDowell 2013)

Stream Exclusion of Cattle

Stream exclusion of cattle is one of the most cost-effective ways to reduce N, P sediment and E-Coli from entering waterways. McDowell and Wilcock (2007) observed enriched concentrations of total P in stream flow associated with factors including trampling and destabilization of the stream bank by stock. Thus, stream exclusions for pastured cattle provide cost-effective reductions in P loadings. One study concluded that farms with the highest stocking rate and largest paddocks with access to a watercourse should be prioritised (Kilgarriff et al., 2020).

Olsen P within target range

Maintaining Olsen P levels within a target range is probably the most cost-effective ways to reduce unnecessary P losses, and should be one of the first steps taken in nutrient management balancing P inputs with outputs. Figure 4. shows that the most P losses occur at a high Olsen P (above agronomic optimum) and when the application of Single Super Phosphate (SSP) is highest. P losses can be high if Olsen P concentrations are enriched and above plant requirements (Woolsey et al., 2007). Results from a survey of over 240,000 soil test results for Olsen P, showed 50% of dairy farms were above the biological and economic optimum values (Monaghan et al. 2006).

Unfortunately, the graph does not show non-water-soluble forms of phosphate fertiliser, A low soluble P fertiliser like reactive phosphate rock (RPR) has been shown to decrease P loss at a catchment scale by about a third compared to highly water-soluble superphosphate (McDowell et al., 2013). Despite the environmental benefits of RPR fertiliser, reps are often encouraged to promote single super phosphate even in areas which would suit non-water-soluble P. We can only assume this is because large investment has been made in superphosphate factories, specifically in NZ.

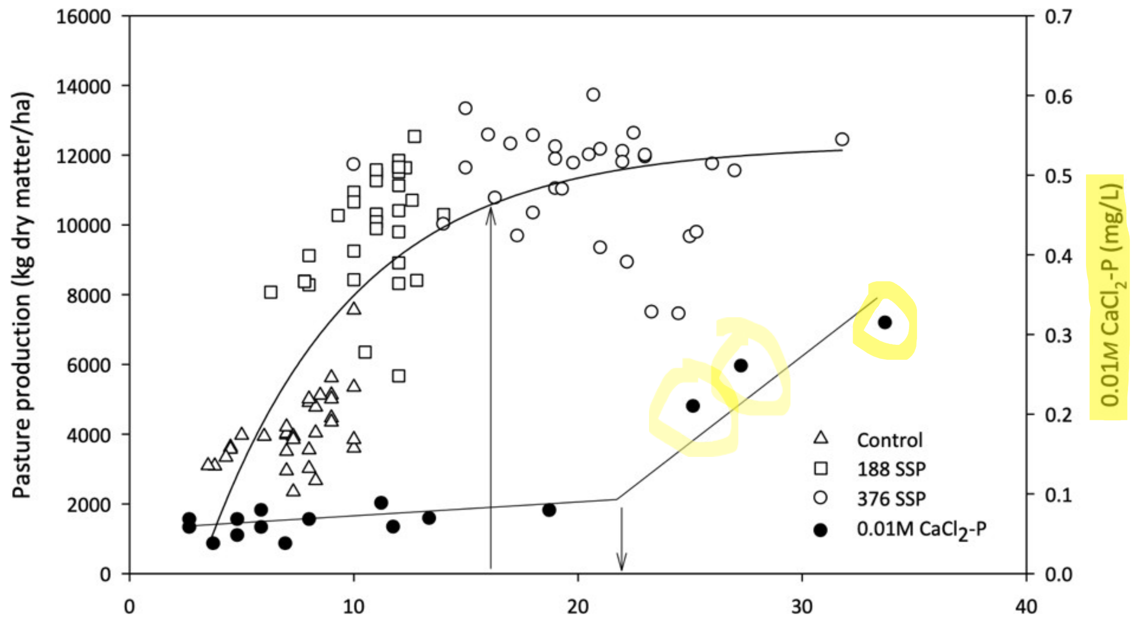

Figure 4: The agronomic optimum in Olsen P for annual pasture production (up arrow) and a potential threshold (down arrow) in Olsen P for P loss in subsurface drainage (as estimated by 0.01M CaCl2-P) (Source: McDowell et al., 2012)

Surface Runoff

One of the most common ways for P to enter waterways is surface runoff. Usually derived from high intensity storms, contributing the vast majority of total P lost annually (80%). Despite surface runoff only accounting for 32% of total annual flow, careful consideration should be given to the location of areas where animals congregate i.e., troughs/gateways, raceways, and lanes. The application of steel smelter slag, rich in Al- and Fe- oxides, to the sides of laneways was shown to decrease P losses in runoff by about 95% and losses to a small catchment by about 66% (McDowell, 2007). Transporting slag would a make it impractical for use outside a 100 km radius of the steel mill at Waiuku i.e., Northern Waikato and Southern Auckland regions (Ballantine & Tanner, 2009).

Low-Rate Dairy Effluent Application & Larger Effluent Storage

Low-rate effluent application require soil moisture concentrations to be monitored so that effluent can be applied when soil moisture is low. Houlbrooke et al. (2006) showed that a low-rate strategy decreased P losses by 67%. While considered highly effective, it is costly to increase effluent storage and in areas with high rainfall, such as Southland, the method is even more expensive, despite this the method is considered a “low hanging fruit” when it comes to better managing nutrient loss. McDowell et al. (2011) showed that focusing on better methods to apply dairy shed effluent could significantly decrease P losses and eutrophication in the Pomahaka River, Otago, New Zealand. McDowell has summed up three different P mitigation strategies in the figure 4., showing that the biggest decrease came from improved effluent management.

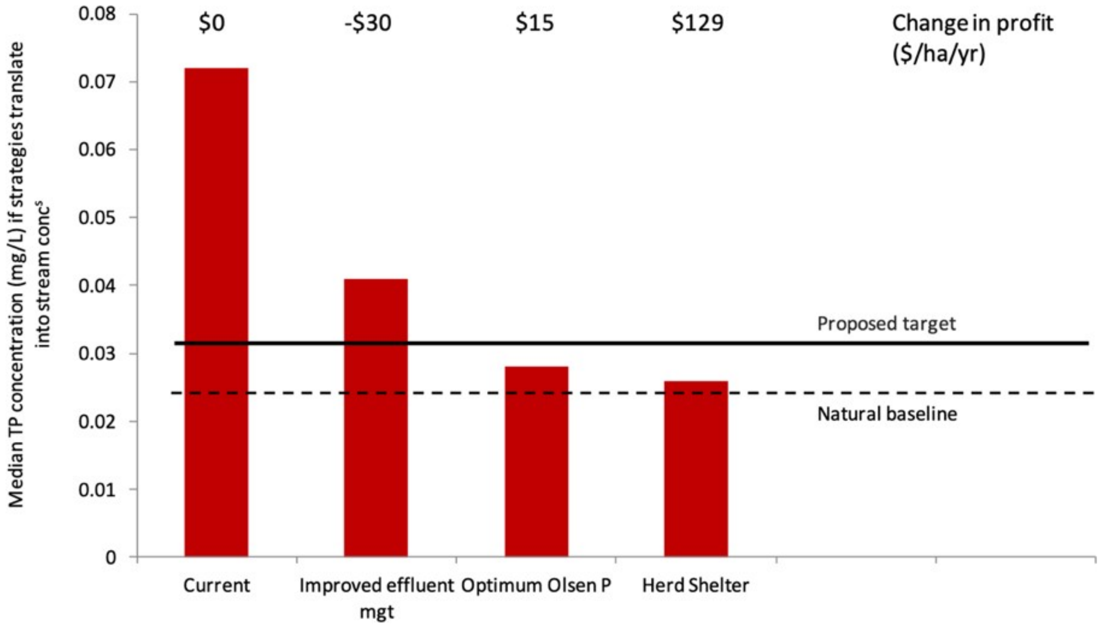

Figure 5: Estimated median total P concentration lost in runoff from an average dairy farm in the Pomahaka catchment and with mitigation strategies implemented one on top of another (source: McDowell et al., 2011)

Stocking rate

Reducing the stocking rate can have a profound impact on nutrient cycling, however its usually not considered an option because of the economics of it, although, gains have been made through genetics to increase production per head, enabling some farmers to reduce their stocking rate. Ecologist Mike Joy weighs in by saying that "we could reduce the number of cows we have in the country - say, a 20% reduction - and we would get in most places a 40% reduction in the amount of nitrate pollution that comes from that" (Joy, 2018). He also states that " farmers in most cases would make as much if not more money by reducing, but of course the ones that wouldn't make more money under that model are the big industry players: the fertiliser companies and the Fonterra's, and so they go to a lot of trouble not to have 'reality' come out" (Joy, 2018).

Restricted Grazing/Off pasture confinement systems:

Restricted grazing is often used on dairy farms to temporarily house or feed stock off pasture when it is wet, to avoid causing soil damage through pugging and nutrient losses from run off and leaching. The benefits of a feed pad, or a standoff pad, enables the effluent to be captured and spread at a more appropriate time, when soil conditions are more suitable. The disadvantages include large capital outlay and increased management factors. The cost effectiveness varies due to variations in soil type, cost of supplements and climate.

Change animal type

Sheep have a lighter environmental footprint than cattle, and beef cattle have a lighter footprint than dairy. The N loading rate under a urine patch for sheep is typically half of that of a dairy cow. A dairy cow is within the range 400-1200 kg N ha-1 (Jarvis & Pain, 1990) compared to about 300-500 kg N ha-1 for a sheep (Haynes & Williams, 1993; Silva et al., 1999). Effectiveness of this method depends largely on farm contour; many sheep farms use cattle to clean up rank some feed and the profitability of land use obviously ensures some land types are economically suited to dairy rather than sheep.

Improved N use efficiency

Just as the most cost-effective way to reduce P losses is by maintaining an agronomic optimum Olsen P, improving N use efficiency is the most cost-effective way to mitigate N losses. An aspirational goal for a 20% improvement in N use efficiency by 2020 was proposed potentially producing an annual saving of ~20 million tonnes of N (Sutton et al. 2013).

Dairy NZ have been working hard in this space setting up the P21 future farm project where two trials in Waikato and Canterbury were conducted with the aim of increasing N use efficiency by reducing N inputs by 50% compared to control farms. The project applied strict principles to reduce nutrient loss; lower stocking rate, strict seasonal grazing management, decreased reliance of imported supplements, higher reliance on legumes and the use of a standoff pad to capture urine. The results concluded that N leaching was reduced by around 20-40% (in the Waikato trial 50% of this was attributed to stand off pad) and per cow production was lifted by 33kg/MS/cow, however, farm profit took a hit. The Canterbury trial farm system had; - $140/ha less profit ($6.30/kg MS), 596kg MS less per ha and grew 1.4t DM/ha/yr less pasture. The trial concluded by stating that these strategies can effectively reduce nitrate leaching losses while retaining high levels of physical and financial performance when optimally managed

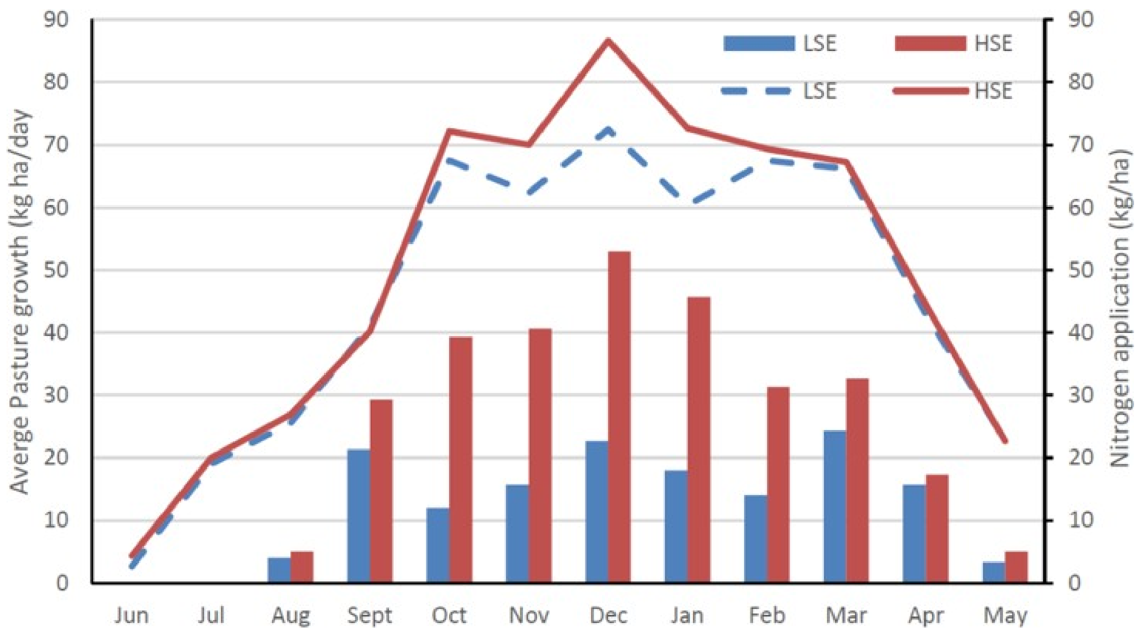

Figure 6: Pasture growth curve and N application for the LSE (low stock equivalent/trial farm) vs the current status quo for a Canterbury dairy farm (Source: Dairy NZ, 2021) N.B. LSE – Low stocking equivalent. HSE – High Stocking equivalent

Riparian/Buffer Strips

Riparian strips act as a buffer strip, decreasing contaminant loss in surface runoff by a combination of filtration and deposition nutrients. Benefits include mitigating both N, P, E-Coli and sediment loss to waterways. The effectiveness can be improved by planting certain species which absorb more P and N. Studies show that the width of the buffer should be at least 5m and perform even better at 10m. Strips have increased biodiversity and aesthetic benefits, however they're costly to implement, with additional fencing and possible stock bridge costs. Ultimately, slowing down the movement of water reduces erosion and sediment losses.

A study in 2016, applying economic land use, modelled the benefits of riparian strips and relevant costs (fencing etc) of restoring riparian margins on all streams in NZ, flowing through primary sector land. It concluded a net benefit of $5m (NZD) per year at a width of 10m based on medium costings (Daigneault et al., 2017).

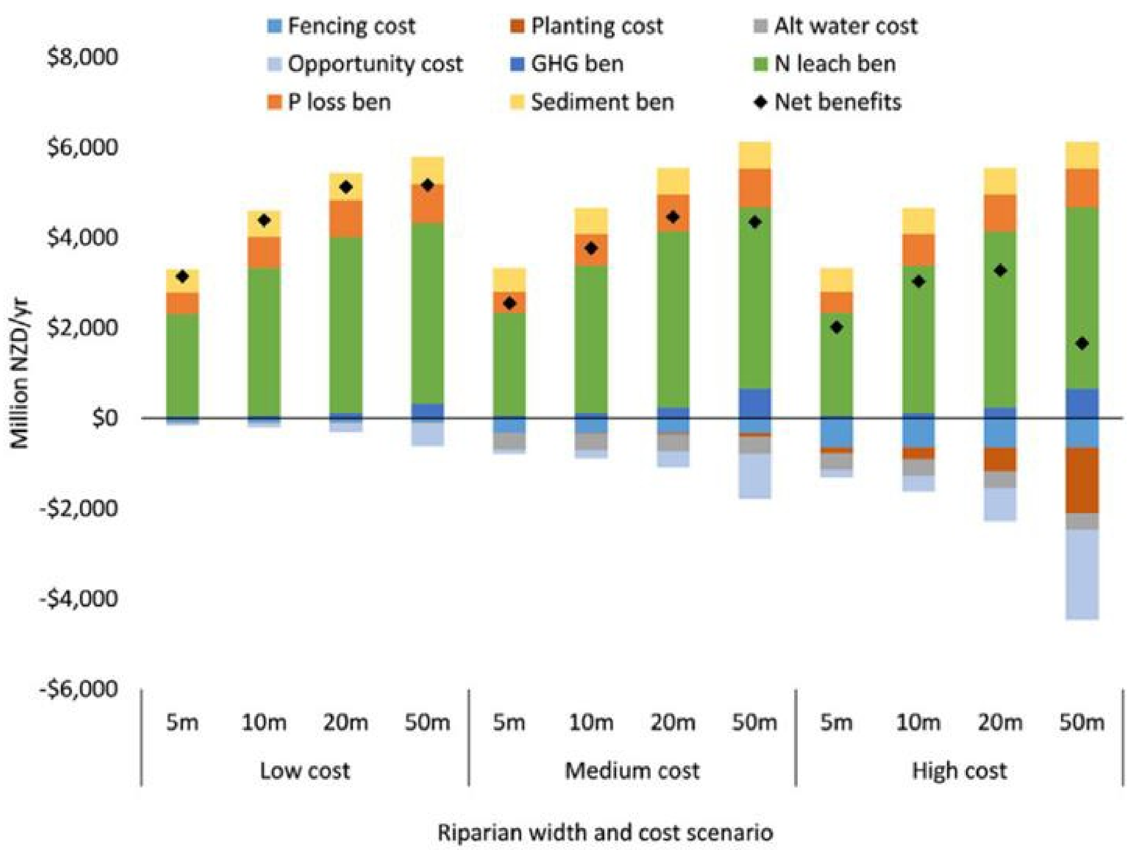

Figure 7: Estimated net benefits (million NZD/yr) for national riparian restoration. (Source: Daigneault, Eppink, Lee, 2017)

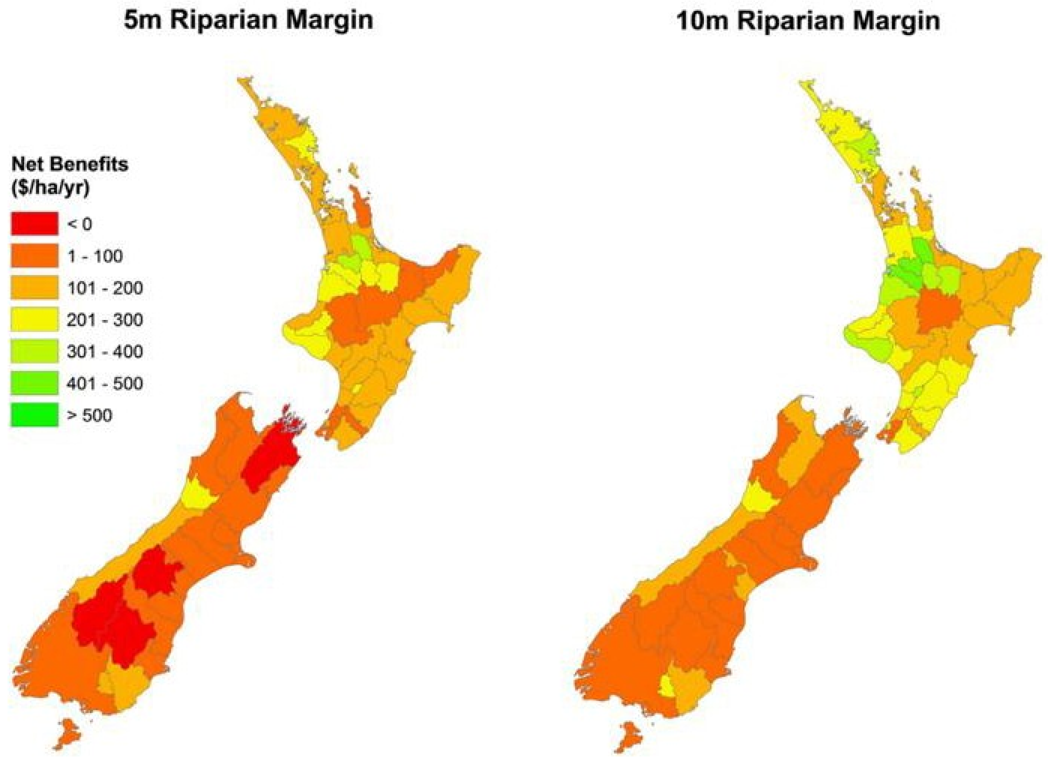

Figure 8: Net benefits of riparian planting based on a 5m margin compared to a 10m. (Source: Daigneault, Eppink, Lee, 2017)

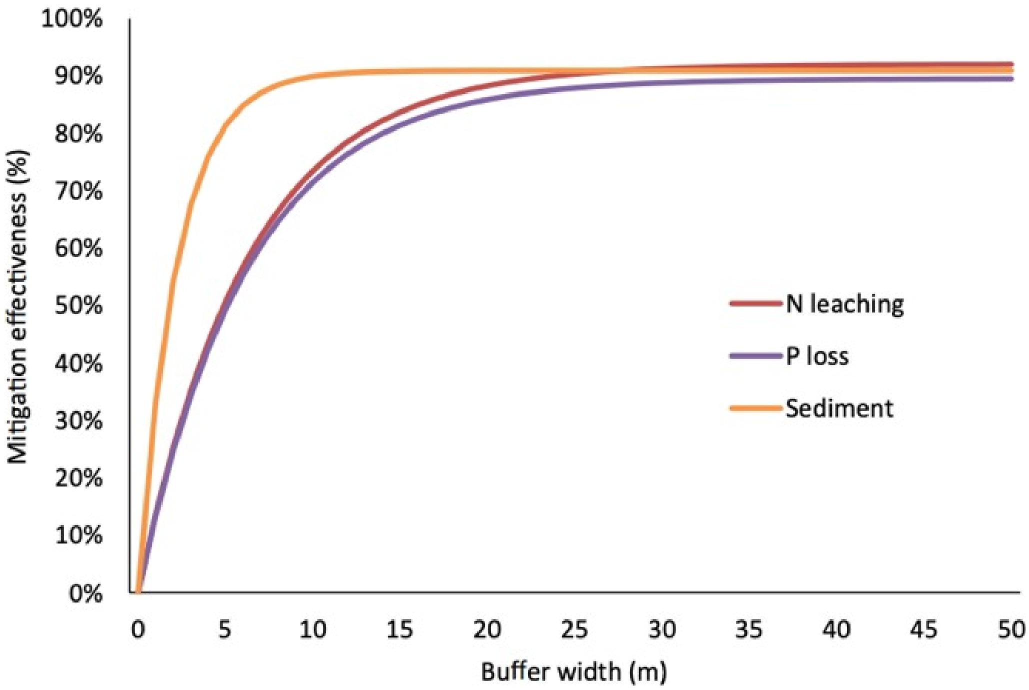

Figure 9: Nutrient mitigation effectiveness based on buffer width. (Source: Daigneault, Eppink, Lee, 2017)

Tile Drain and Mole drain amendments

Tile drains and mole drains are a problem because they transport large amounts of dissolved phosphorus and leached N, particularly damaging if dairy cows are wintered on these areas. Tanner and Sukias (2011) discovered that the wintering part of the current dairy system makes a disproportionately large contribution to N losses, contributing 60% of the total dairy system N leaching emission. Historically tile drains were used to drain wetlands to convert to pasture. Ironically one of the best amendments to reducing N losses from these drains is by intercepting these them with wetlands. A multiyear study, measuring the performance of 3 constructed wetlands for nutrient removal from subsurface drains from intensive dairy farms showed that annual nitrate-N loads were reduced by 48% - 61%, 9% - 52% and 32% - 60% respectively (Tanner & Sukias, 2011). To mitigate P losses from these drains CW's need to include sediment traps or a series of settling dams or by use of steel smelter slag or allophane (McDowell et al., 2008)

Restricted Grazing of Winter Forage Crops

Winter Grazing on forage crops has the potential to cause considerable amounts of surface runoff and threaten water quality from concentrated deposits of nutrients. Farmers in the High Country or in Winter cold areas, such as Otago and Southland, rely heavily on Winter forage crops to feed their animals over the Winter.

A study was undertaken in the Bog Burn catchment in rural southland which has seen a tremendous rise in dairy cow numbers in the last 20 years. Monthly stream monitoring showed that median nutrient (N and P), sediment and faecal bacteria concentrations exceeded guidelines recommended for surface waters (Monaghan et. al, 2006). Autumn feeding of cattle to Winter feeding crops to cattle, achieved a 14% less nutrient loss and added to the cattle grazing system by getting better weight gains. Figure 10 shows the predicted N and P emissions from farm systems within the intensively farmed Bog Burn catchment in Southland.

Attribute	Milking platform	Dairy wintering	Dry stock	Forestry
N + P loss to water (kg/ha/yr)				
N	16	55	6	1.3
P	1.3	0.1	0.6	0.2

Figure 10: Bog Burn Catchment, Southland: Predicted N and P emissions from farm systems. (Source: Monaghan et al., 2006)

In this particular catchment it is clear that dairy wintering in wet areas is a huge contributor of N loss to waterways.

(Monaghan et al. 2006) suggests that a significant improvement in catchment water quality could be achieved through the implementation of targeted best management practices (BMPs) including restricted grazing of winter crops as well as the use of covered feed pad or stand-off areas to use when wet conditions promote nutrient loss.

The 4 R's of fertiliser: Right source, Right Rate, Right time, Right place

The 4R's promote responsible fertiliser use minimising nutrient losses. Fertiliser if used responsibly losses can be minimised. The 4R's must be used in conjunction with other BMP's to mitigate nutrient losses. (Nutrient Stewardship. (n.d.)

Right Source

This R requires the farmer to match the fertiliser type to the plant's needs, and refers to soluble or non-soluble fertilisers or slow-release coated N.

Right Rate

Finding the right rate involves matching the amount of fertiliser to the agronomic optimum for plant needs and no more. Rates can be determined through soil testing and understanding the plants requirements.

Right Time

Applying fertiliser at the right time makes nutrients available when crops need them and avoids unnecessary losses. Higher losses occur in Winter/Autumn when higher rainfall occurs, conversely applications of N in summer dry conditions contributes losses through volatilisation.

Right Place

Ensuring application is made in the right place keeps nutrients where plants can use them. Advances in technology have enabled less or zero fertiliser to be applied to those areas where there are deemed minimal economic returns or where critical source areas (CSA) should be avoided due to environmental impacts. Comparatively these areas traditionally may have just received blanket application of say 300kg/h.

Soluble vs Non-Soluble P Fertilisers

Non-water-soluble forms of P, such as RPR, have been shown to decrease P loss at a catchment scale by about 33% compared to highly water-soluble superphosphate (McDowell et al., 2010). Despite this, single superphosphate remains the most widely used soluble P fertiliser in NZ with some scientists arguing the two main co-operative fertiliser companies are to blame. Both Dr Burt Quinn (Quinnfert) and Dr Jaqueline Rowarth (Ravensdown Elected Director) weigh in on the argument. With water soluble fertilisers such as superphosphate studies show P loss is greatest within 60 days of application therefore industry practice recommends not applying large amounts of soluble P before major weather events. "If you apply superphosphate where no significant rainfall events occur within 50 days, minimal losses will occur" (Rowarth et al., 2019).

Data shows that at a catchment scale, RPR can potentially decrease phosphorus in streams by up to 58% compared with superphosphate (Monaghan R. et al. 2006). Quinn & Rajendram (2019) take aim at the industry by saying "ways must be found to create a soil fertility research environment that is far more open to discussion and scrutiny, the publishing of trial data, and the availability of environmentally-protective products are under the almost total control of the management staff of the two superphosphate manufacturing cooperatives. Mike Joy (2018) shares a similar view "this overarching power that is held by industry, and they dominate the research, and they have a lot of lobbying power with government". In 2019, the co-op fertiliser companies received $10 million each from the Ministry for Primary Industries' Sustainable Food & Fibre Futures (SFF Futures) fund for research and development purposes. From this nutrient management software "Mitigator" (more on later in report).

Land use capabilities and variable rate application

Variable rate application cuts down on total fertiliser usage and nutrient losses by applying the economic optimum rate for each land use class or nil application over critical source areas. This is achieved through identifying the productivity potential of different areas of a farm, undertaking soil sampling to assess soil characteristics/fertility across the different land management units, and then referencing the land use classes which indicate the general capability of the land for productive use. Eight Roman numeral classes are used, with LUC Class I representing the best land with elite soils, through to LUC Class VIII which is generally unsuitable for production.

For cropping farms, technology is being developed where Geographical Information Systems (GIS) use hyperspectral remote sensing to measure soil fertility so that wiser applications of sprays and fertilisers can be made influencing the time to apply, the rate, and where to apply. A study in Wales, using variable rate, showed a reduction of greenhouse gases of 5-10% and an increase in net income by up to 7%. The below image is an example of a farm map showing different land use capabilities. Figure 11 shows a guide that Beef and Lamb shared, detailing the land use capability approach, for their farmers to achieve optimal results.

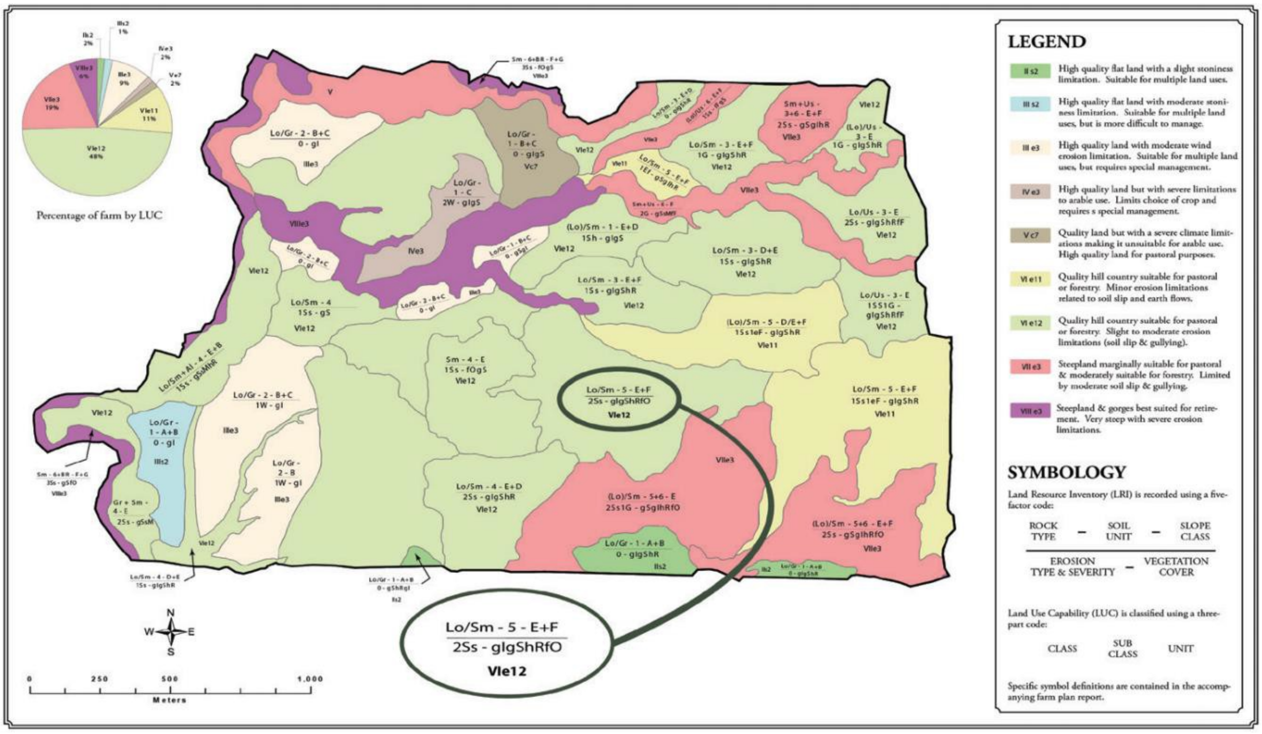

Figure 11: Land use class guide. (Source: Beef and Lamb, n.d.)

Summary of cost effectiveness of P strategies

Strategy		Main targeted P form(s)	Effectiveness (% total P decrease)	Cost - Range (USD $/kg P conserved)[1]	Cost - Waikakahi (USD $/kg P conserved)[1]
Optimum soil test P	Management	Dissolved and Particulate	5-20	(highly cost-effective)[2]	(15)
Low solubility P fertilizer	Management	Dissolved and Particulate	0-20	0-20	0
Stream fencing	Management	Dissolved and Particulate	10-30	2 - 45	14
Restricted grazing of cropland	Management	Particulate	30-50	30 - 200	n.a.
Greater effluent pond storage / application area	Management	Dissolved and Particulate	10-30	2 - 30	13
Flood irrigation management[3]	Management	Dissolved and Particulate	40-60	2 - 200	4
Low rate effluent application to land	Management	Dissolved and Particulate	10-30	5 - 35	27
Tile drain amendments	Amendment	Dissolved and Particulate	50	20 - 75	n.a.
Red mud (bauxite residue)	Amendment	Dissolved	20-98	75 - 150	n.a.
Alum to pasture	Amendment	Dissolved	5-30	110 - >400	n.a.
Alum to grazed cropland	Amendment	Dissolved	30	120 - 220	n.a.
Grass buffer strips	Edge of field	Dissolved	0-20	20 - >200	30
Sorbents in and near streams	Edge of field	Dissolved and Particulate	20	275	n.a.
Sediment traps	Edge of field	Particulate	10-20	>400	>400
Dams and water recycling	Edge of field	Dissolved and Particulate	50-95	(200) - 400[4]	200
Constructed wetlands	Edge of field	Particulate	-426-77	100 - >400[5]	300
Natural seepage wetlands	Edge of field	Particulate	<10%	100 - >400[5]	n.a.

[1] numbers in parentheses represent net benefit, not cost. Data taken as mid-point for average farm in Monaghan et al. (2009).
[2] depends on existing soil test P concentration.
[3] includes adjusting clock timings to decrease outwash < 10% of inflow, installation of bunds to prevent outwash, and re-levelling of old borders.
[4] upper bound only applicable to retention dams combined with water recycling.
[5] potential for wetlands to act as a source of P renders upper estimates for cost infinite.

Figure 12: Summary of efficacy and cost of P mitigation strategies for low, average and high producing dairy farms vs an average farm in the Waihikahi, Canterbury catchment. (Source: McDowell and Nash, 2012).

The highlighted data in figure 12 shows which techniques are the most cost effective for reducing P loss in Canterbury. Clearly, on farm management methods are the most cost effective as well as amending tile drains. Although constructed wetlands don't appear to be cost effective, their ability to reduce nitrogen, sediment and e-coli make this an unfair example.

Cost effectiveness of methods mitigating N losses

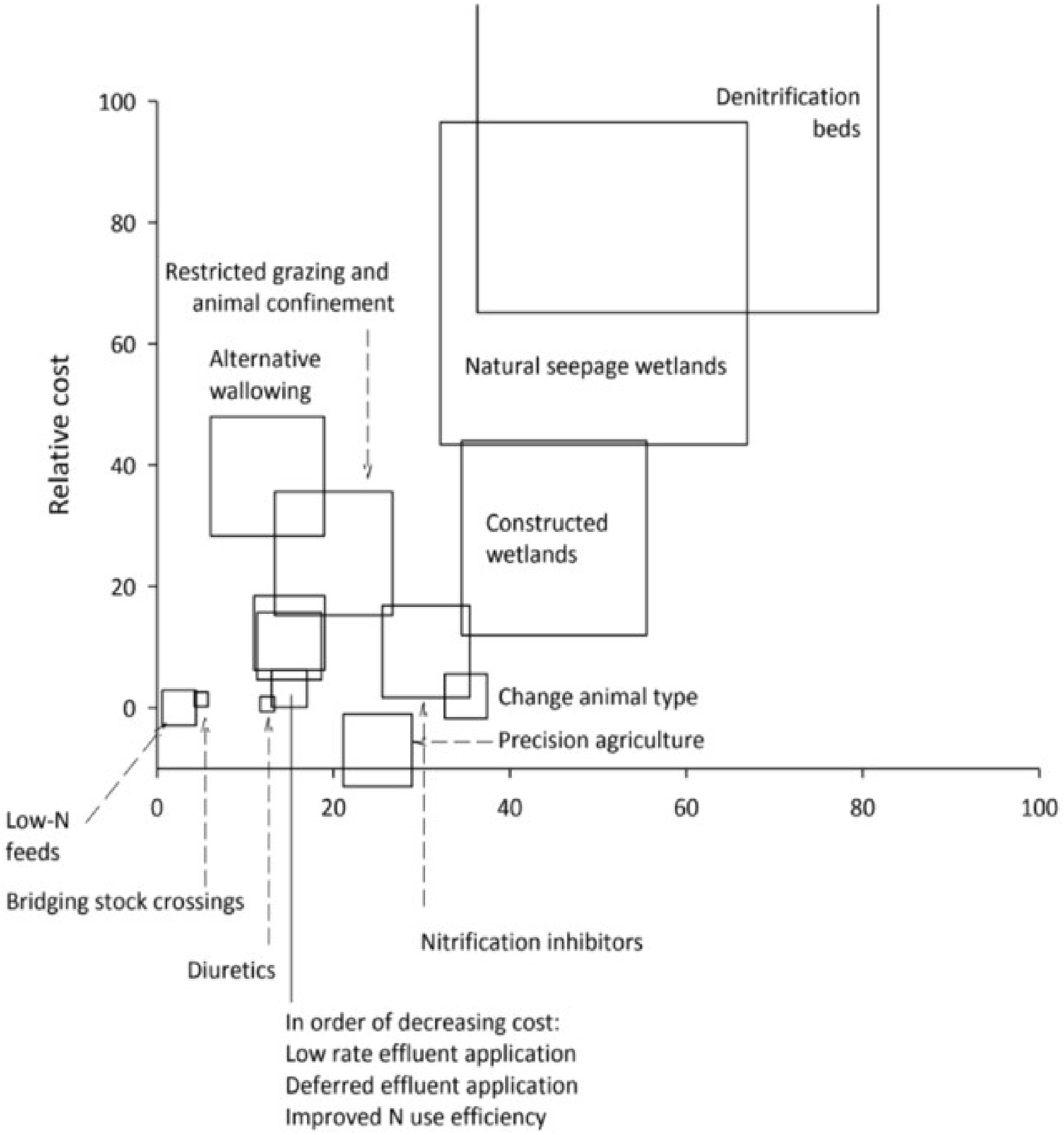

Figure 13: Diagram of the relative cost and effectiveness percentage of strategies to mitigate nitrogen losses to water at the farm-scale. (Source: McDowell, Wilcock, Hamilton, 2013)

The cost is shown as the cost per kg of N mitigated relative to the most expensive strategy – denitrification beds at $393 per kg N retained/ha/yr. The centre of the squares in figure 13 represent the mid-point in the range for each strategy, while the size represents the relative variability of each strategy as the square root of the product of the range in percent cost by effectiveness.

Diagram of Cost effectiveness of methods mitigating P losses

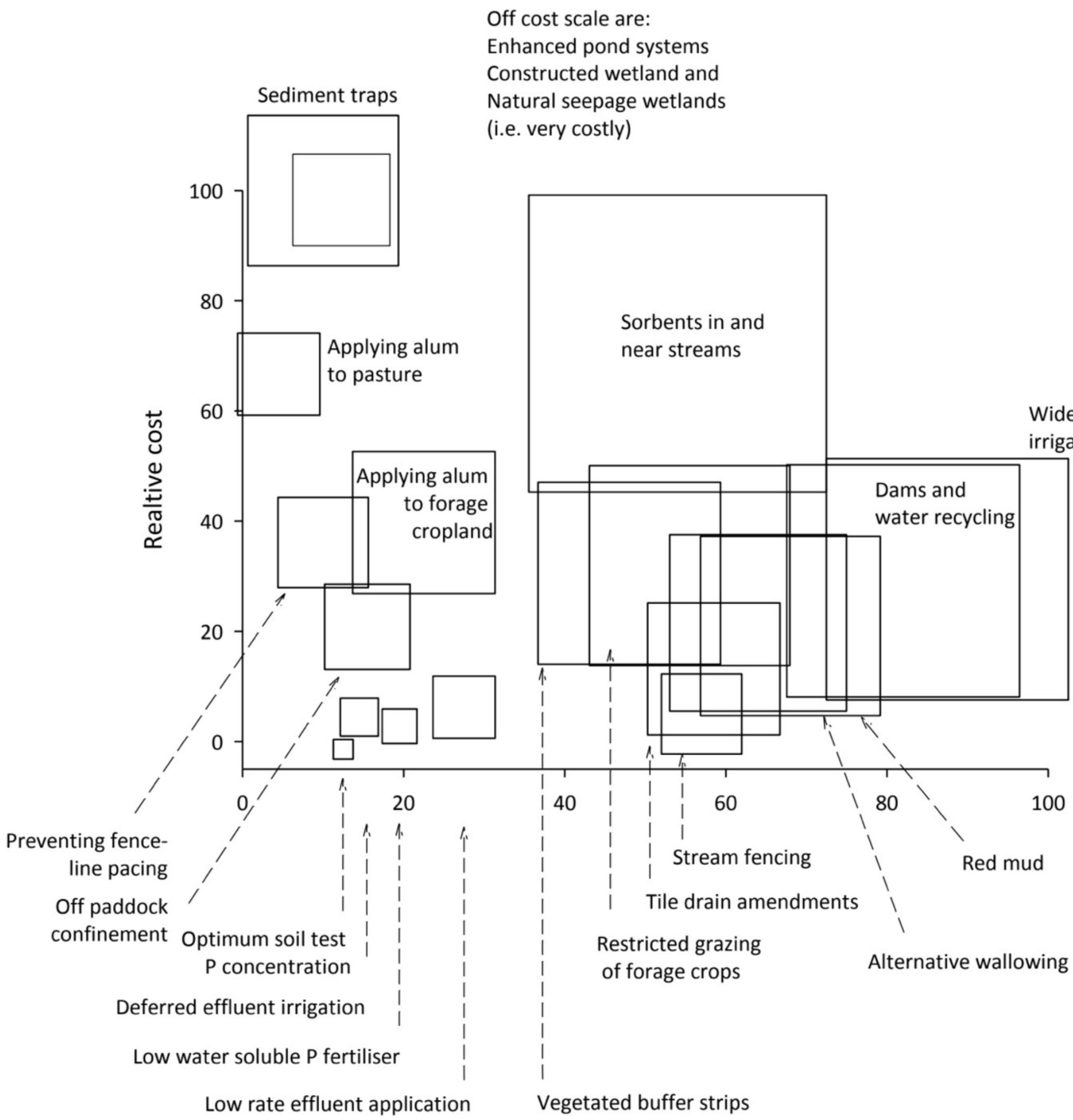

Figure 14: Diagram of the cost and effectiveness percentage of strategies to mitigate phosphorus losses to water at the farm-scale. (Source: McDowell, Wilcock, Hamilton, 2013)

The cost is shown as the cost per kg of P mitigated relative to the most expensive strategy - sediment traps at $360 per kg P retained/ha/yr. The centre of the squares in figure 14 represent the mid-point in the range for each strategy, while the size represents the relative variability of cost-effectiveness for each strategy as the product of the range in percent effectiveness by the range in cost. Enhanced pond systems and the two-wetland type were considerably more expensive (1400 – 4000% > sediment traps).

Identify critical source areas

Using the 80:20 rule, 80% of contaminants from 20% of area. Often poorly understood, areas of high source and transport potential are termed critical source areas (CSA) more important for P loss rather than N these areas can often contribute the most nutrient losses despite only making up a small portion of a farm or catchment. It is more cost-effective to mitigate the loss of contaminants at the source than at the catchment (Turner et al., 1999).

Examples of CSA's are winter forage cropping paddocks, stream banks, erosion prone gullies, steep hills, areas where effluent is spread etc. In two catchments in Otago, it was discovered application of strategies to mitigate P losses when applied to critical source areas was 6-7 times more cost-effective than applying the strategies across entire farms or entire catchments (McDowell et al., 2012). Management of these CSAs, in McDowell's words, are the "low hanging fruit" in mitigating P losses. Managing a CSA could be as simple as putting up a hot wire around a boggy section of a paddock before grazing. The challenge for example would be training a junior farm hand to think about these sorts of things while out doing stock shifts.

With land use intensifying the concern is that even mitigating P loss from CSA may not enable a farm to reach water quality targets in a sensitive catchment. A proactive approach is therefore needed that identifies streams that are resilient to P inputs and areas unlikely to lose much P (McDowell, 2012), this challenges leaders to consider other options, as the blanket approach is not always optimal. A potential alternative is to re-consider regional council's responsibilities to implement policy based on critical source areas and resilient vs non resilient areas in accordance with guidelines from the NP-FWS.

Education and extension to farmers and rural professionals around best management practice for CSA, should be encouraged and supported so that ongoing BMP occurs long after the farm environmental plan boxes are ticked. Furthermore, for New Zealand dairy farms, which receive no financial subsidies or incentives to decrease P losses, optimal placement and timing of mitigation strategies within CSAs will likely minimise any impact on profitability.

When evaluating policy decisions, detailed spatial models can be used to test land use scenarios (Wheeler et al., 2013). High resolution digital evolution models (DEM) are an approach which can identify critical areas where targeting of buffer strips and other mitigating techniques are most cost-effective (Thomas et al., 2016). This has helped ensure policy such as the low slope requirement for winter cropping and exemptions, where, for example, it's unrealistic to fence off small waterways on steep hill country.

Integrated Catchment Management

The MFE has acknowledged its support for catchment groups for the benefits of sharing best practice and the ability for farmers to collectively lead their catchments water quality objectives enabling a sense of ownership. The "Mangaone catchment group" in the Puketitiri district in Hawke's Bay has taken this a step further by funding an Eco detection unit which can take hourly water samples and display the data for all members, this enables land practices to be constantly monitored and linked to spikes or dips, for (example: nitrate levels.

Technology

Mitigator

The government funded a primary growth partnership project titled "Clearview". From this, Mitigator was designed and developed to understand specifically where P & N losses are occurring (hotspots) and how can they be mitigated. Mitigator uses GIS for capturing, storing, checking, and displaying data related to positions on Earth's surface providing greater insight into the spatial variability of nutrient (sediment and microbial) loss within a farm landscape (Stafford & Peyroux, 2013). Not only will this allow smarter decisions around variable fertiliser rate, it will also create a visual aid for farmers and professionals to identify critical source areas and use BMP's. Scenarios can be played out to show the effect of various mitigation strategies. The intended initial use for this tool is to assist strategic variable rate fertiliser plans, i.e., formulating how best to apply a budgeted total annual amount of N-fertiliser. (Stafford & Peyroux, 2013).

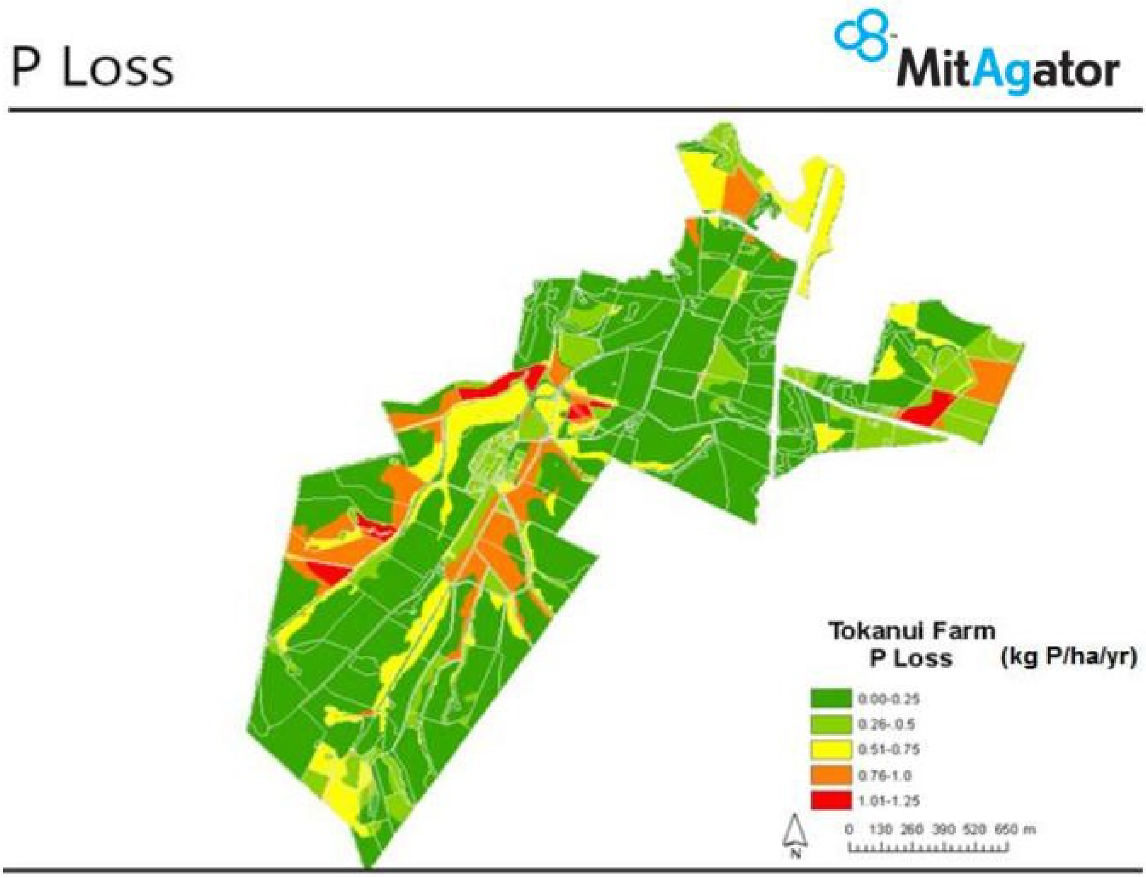

Figure 15: Risk map for P loss and sediment loss generated by MitAgator for AgResearch Tokanui. This map was produced using a 2m resolution DEM and a soil map data developed at a scale of 1:5000 (Source: Peyroux, 2013)

MyEnviro

My Enviro is a cloud-based software which measures changes in the environment by digitising farm environment plans and integrating real-time, verifiable data and analytics on the things like soil health, water quality, emissions, pasture growth and fertiliser history (Paterson, 2021). It's greatest benefit when it comes to water quality is that it has the ability to ingest live water quality data which can be matched with farm operations. Therefore, a link can be made between on-farm practices and spikes in nitrate levels in a waterway.

Director of MyEnviro, Brent Paterson says that "understanding the water quality through real time data, then attaching farm plan outcomes to the water quality (i.e., Riparian planting etc, BMP's etc), will create tangible benefits."

Regenerative Agriculture

Regenerative agriculture (RA) is a farm systems approach based on principles that mimic nature's natural processes. Focus on collaboration instead of competition. It's a low cost, low input system that is climate friendly and has better positive outcomes for the three pillars: social fairness, soil health, and animal welfare. At its core, RA is about looking after soil health, which means increasing soil carbon not depleting it (Hill, 2021).

What has this got to do with water quality? If the soil has more carbon content, it acts as a sponge enabling increased water retention, and the cycling of nutrients. This system, therefore, reduces losses, along with other practices, such as extended grazing patterns. Plants can extend their roots deeper, cycling nutrients further below soil surface. These systems are noted as being more resilient in the long term to droughts, floods, and financial stresses.

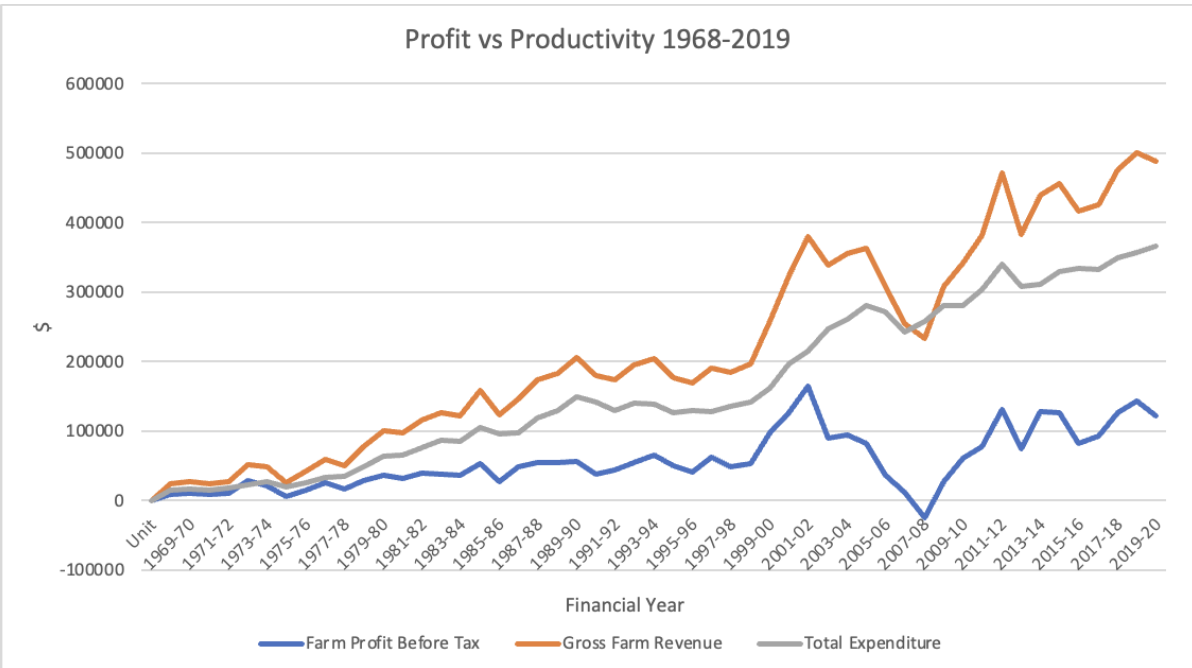

Figure 16: Farm Production vs Profit from 1968-2020 for Eastern North Island Class 5 (Source: Beef and Lamb NZ, 2021)

Figure 16 shows that while gross farm revenue has gone up farm profit has not increased at the same level. The graph also highlights the vulnerability (greater range in peaks and troughs) from the turn of the century, as New Zealand was exposed to globalisation, and Nitrogen use increased.

Regenerative farmers from various discussion groups, agree that this is because we are relying on high-input systems which are depleting soil health. The parties that do well from the high-input model, are the same parties who are typically against RA as they know that under an RA system (less inputs), there is less business for corporate agribusiness companies such as fuel, bank, seed, farm supplier stores, fertiliser, and consultants, among many other support services. Under the RA model, farm revenue is lower, but profit is higher (Hill, 2021).

Conclusions

Early into my research, I discovered constructed wetlands are not necessarily the most cost-effective mitigation method for reducing N & P loss alone, in fact they could be considered the ambulance at the bottom of the cliff technique. I discovered on-farm management practices and reducing inputs are the best place to start, and by far the most cost effective. However, given intensive agriculture is hard to reverse because of prior capital investment and land value based on a certain level of production it is a 'horses for courses' issue, as constructed wetlands should absolutely be considered in many cases, given the multiple benefits they offer. Potentially, they could grant catchments a licence to continue current land use practices, thus future-proofing farm practices without regulations forcing land use change, and potentially dropping land value.

The other mitigation strategies are already available for use, and they are supported by research, but they need to be implemented. I believe through research, extension, education, collaboration, skilled people, and swift execution, we will get proven techniques into practice to see tangible results.

The unconscious bias at the beginning of my report highlights where the agricultural education and overall attitude of the ag industry was 10-12 years ago, which is when I first began tertiary study and working on farms, when it used to be all about maximising farm production. Now, having reflected on how things have changed, I can see that while big ships are slow to turn, regenerative farming groups are growing. Wetlands are being restored, riparian planting is increasing, soil testing and fertiliser application are being more carefully considered, and stock management techniques are being discussed. I must admit that since embarking on this research, my own attitude has changed after being hit between the eyes with some stark facts and figures. I now see that further changes need to be made so future generations can enjoy the same water quality privileges that I had growing up, and future farmers can continue the social licence to farm.

So, what do my findings show, and how do we make tangible changes? Someone once said that NZ first 'cashed in' its seals & whales, then its Kauri, then its gold, and now we are 'cashing in' our water. Whilst understanding the economic benefits of intensive farming, I discovered that not all land is cut out for it, therefore, I see a huge benefit in having highly skilled people implementing the Land Use Capability Index and understanding the problems we face if we get it wrong. Trying to back pedal consequences from past decisions is much harder and more costly than imposing regulations as part of a resource consent, or simply declining applications.

We also need the highly skilled people to have deep farm systems knowledge, environmental knowledge, and market knowledge. Collaboration will be needed across all parties, from top to bottom, with channels of information flowing freely. It takes many components to implement change, starting with strong leadership and big-picture thinking. Slowly, we are shifting from production-focused systems to triple-bottom-line analysis (people, profit, planet) this has the added benefit of future-proofing sustainable land use, but also meets an ever-increasing demand for information from discerning customers. Hopefully, this solidifies a seat at the global trade negotiating tables, let alone demanding price premiums.

International Trade negotiator Vangelis Vitalis said that geopolitical tension, rising protectionisms, and environmentally conscious consumers are a real threat to the NZ export industry, and if we give countries any excuse to not import our products, we will be left behind. It can be frightening to think how connected the world is today, and we may be one Netflix Documentary away from uncovering the truth about NZ water quality.

Most farms in NZ are owner-operators, which is fantastic for local communities, enabling people to put their roots down and increase responsibility of land guardianship. The downside is that increased compliance is hard for an owner-operator to stay on top of. "We have to be part of the community, and we've got to be profitable, so we can carry out our environmental responsibilities" (Galloway, 2018), and so that we don't lose this uniqueness. It becomes a balancing act between ensuring compliance, and best practice is being followed; keeping farms profitable to ensure the owner-operator model is still viable.

Although some farmers feel like speed of policy change is too fast, with 'Groundswell' protesting unworkable regulations, the government has since taken a step back and the Ministry for the Environment (MfE) is currently consulting on changes to intensive winter grazing, stock exclusion, wetland, and freshwater farm planning regulations. Inviting farmers, growers, and other stakeholders to provide their on-the-ground knowledge and practical ideas to ensure the regulations are workable. Farmers and industry representatives should see this as an opportunity to influence the changes that need to be made so the government is not forced to commit to a "blanket" nation-wide approach, farmers and communities will benefit if regulations are site specific.

Considerable investment has been allocated in the water quality space, with MfE investing $700m through Jobs for Nature, and in budget 2021 $37million has been allocated over 4 years to accelerate the delivery of the farm planning framework. Despite the earlier discontent regarding lack of consultation and speed of timeframes, I hope the sector can now move forward in the right direction in a collaborative effort with all stakeholders.

Recommendations

There is no silver bullet. The best we can do is expose the crisis, champion environmental success, incentivise and disincentivise, educate our youth, and lay the foundation for thriving rural communities.

My recommendations are as follows:

9) Exposing some hard truths on NZ's water quality

- I encourage everyone to visit the LAWA website and see what the status of their local river(s) is.

10) Understand what mitigation methods would be effective for your catchment

- Some of the most cost-effective methods are on-farm management practices.

11) Protect and Promote Wetlands and other sensitive areas.

- Increase public knowledge and appreciation of wetland functions and processes.
- Ensure landowners and government agencies commit to wetland protection, enhancement, and restoration.

12) Support Integrated catchment management

- Gives farmers a sense of ownership and responsibility to influence their local catchment.

13) Deep understanding of Land use capability models

- Regional councils and MfE need to have a deep understanding of land use capabilities, linking land use to an appropriate production system; one which it can handle environmentally.
- This method includes protecting highly productive "elite soils" from urban sprawl.

14) Subsidise and Incentivise

- Wintering of dairy cattle in wet areas is a huge contributor to N & P losses. A potential solution could be to subsidise feed pads or feed barns, this way, effluent could be stored and applied during dryer months.

15) Compliance and regulation

- Support for the farm planning approach and **f**resh water farm plans.

  i) Clear water objectives from councils in line with the NPS-FM from skilled staff.
  ii) Provide a practical way for farmers to meet both regionally set and nationally prescribed rules & responds to the characteristics of each farm.

- All NZ farms should meet NZ Farm Assurance Programme Plus (NZFAP +) within a certain period.

16) Embrace Regenerative Agriculture (RA)

- Embrace RA: healthy soils store more carbon, more nutrients, and more water, relying less on synthetic inputs.

References

Ashton, A. (2018, September 1). Q and A: Federated Farmers Hawke's Bay president Jim Galloway. *Q and A: Federated Farmers Hawke's Bay President Jim Galloway*. Retrieved from https://www.nzherald.co.nz/hawkes-bay-today/news/q-and-a-federated-farmers-hawkes-bay-president-jim-galloway/H3GLYQPKXSTG6DEMDKUCM3NC3E/

Ballantine, D. J., & Tanner, C. C. (2010). Substrate and filter materials to enhance phosphorus removal in constructed wetlands treating diffuse farm runoff: A review. *New Zealand Journal of Agricultural Research, 53*(1), 71-95. doi:10.1080/00288231003685843

Cui, J., Sackton, K. L., Horner, V. L., Kumar, K. E., & Wolfner, M. F. (2008). Wispy, the Drosophila Homolog of GLD-2, Is Required During Oogenesis and Egg Activation. *Genetics, 178*(4), 2017-2029. doi:10.1534/genetics.107.084558

Cutress, D. (2020). *Can Precision Farming Help Mitigate Climate Change?* (Farming Connect, Tech.). Wales: IBERS, Aberystwyth University.

Daigneault, A. J., Eppink, F. V., & Lee, W. G. (2017). A national riparian restoration programme in New Zealand: Is it value for money? *Journal of Environmental Management, 187*, 166-177. doi:10.1016/j.jenvman.2016.11.013

Environment Southland. (2020). *A Guide to Constructed Wetlands* [Brochure]. Author. Retrieved from https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/community/farming/good-management-practice/documents/Land sustainability guides and factsheets/A guide to constructed wetlands.pdf

Flynn, S. (2021, May 17). Opinion: The (wetland) elephant in the room. *Boffa Miskell: News & Insights*. Retrieved from https://www.boffamiskell.co.nz/news-and-insights/article.php?v=the-wetland-elephant-in-the-room

Grant, J. (2018). *Mitigating Nitrogen Loss The Financial Impact* (Vol. 38, Rep.). Kelloggs Rural Leadership Programme.

Gray, J. (2017, December 30). Urban sprawl and the land that keeps on giving. *Herald*. Retrieved from https://www.nzherald.co.nz/business/urban-sprawl-and-the-land-that-keeps-on-giving/CON62QQXSJ6UXGKB44QFSS7UW4/

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. *Ecosystem Ecology,* 110-139. doi:10.1017/cbo9780511750458.007

Harte, A. (2021, September 9). Perspective of a past fertiliser rep [E-mail interview].

Hawke's Bay Regional Council, Water Management. (2021, April 13). *Large wetland being constructed in Tukipo, Central Hawke's Bay* [Press release]. Retrieved from https://www.hbrc.govt.nz/home/article/1054/-large-wetland-being-constructed-in-tukipo-central-hawkes-bay?t=featured&s=1

Hill, R. (2021, September 21). Holistic Ag; Regenerative Agriculture [E-mail interview].

Hoogendoorn, C., Lambert, M., Davantier, B., Theobald, P., & Park, Z. (2017). *Nitrogen Fertiliser Application Rates and Nitrogen Leaching in Intensively Managed Sheep Grazed Hill Country Pastures in New Zealand* (2nd ed., Vol. 60, New Zealand Journal of Agricultural Research, Rep.). doi:doi:10.1080/00288233.2017.1287100

Houlbrooke, D., Morton, J., Paton, R., & Littlejohn, R. (2006). The impact of land-use intensification on soil physical quality and plant yield response in the North Otago Rolling Downlands. *Proceedings of the New Zealand Grassland Association,* 165-172. doi:10.33584/jnzg.2006.68.2652

Jarman, A., & DairyNZ. (2020, July 3). *New Wetland Guidance to Help Improve Water Quality* (Publication). Retrieved https://www.dairynz.co.nz/news/new-wetland-guidance-to-help-improve-water-quality/

Journeaux, P., Wilton, J., Archer, L., Ford, S., & McDonald, G. (2019). *The Value of Nitrogen Fertiliser to the New Zealand Economy* (Rep.). AgFirst.

Joy, M. (2018, November 12). Mike Joy - Solving NZ's freshwater crisis [Interview by J. Mulligan, Transcript]. In *Mike Joy - Solving NZ's freshwater crisis*. Radio New Zealand.

Joy, M. (2021, August 25). Ecology [E-mail interview].

Kadlec, R.H. and Knight, R.L. (1996) Treatment Wetlands. Lewis Publishers, Boca Raton, 893 p.

Keeney, D. R. (1973). The Nitrogen Cycle in Sediment-Water Systems. *Journal of Environmental Quality, 2*(1), 15-29. doi:10.2134/jeq1973.00472425000200010002x

Kilgarriff, P., Ryan, M., O'Donoghue, C., Green, S., & Huallacháin, D. Ó. (2020). Livestock exclusion from watercourses: Policy effectiveness and implications. *Environmental Science & Policy, 106*, 58-67. doi:10.1016/j.envsci.2020.01.013

Land. (2021, March 30). Retrieved from https://environment.govt.nz/publications/environment-new-zealand-2007-summary/section-three-state-of-the-environment/land/

Larned, S. T., Scarsbrook, M. R., Snelder, T. H., Norton, N. J., & Biggs, B. J. (2004). Water quality in low-elevation streams and rivers of New Zealand: Recent state and trends in contrasting land-cover classes. *New Zealand Journal of Marine and Freshwater Research, 38*(2), 347-366. doi:10.1080/00288330.2004.9517243

MacGibbon, R., & Tipa, G. (2001). *Managing Waterways of Farms: A Guide to Sustainable Water and Riparian Management in Rural New Zealand* (Rep.) (M. Cresswell, Ed.).

Map out a sustainable future with MitAgator. (n.d.). Retrieved from https://ballance.co.nz/mitagator

Marumaru, R. (2021, September 6). Perspective of a past fertiliser rep [E-mail interview].

McDowell, R. W. (2007). Water Quality in Headwater Catchments with Deer Wallows. *Journal of Environmental Quality, 36*(5), 1377-1382. doi:10.2134/jeq2007.0015

McDowell, R. W., Snelder, T., Littlejohn, R., Hickey, M., Cox, N., & Booker, D. J. (2011). State and potential management to improve water quality in an agricultural catchment relative to a natural baseline. *Agriculture, Ecosystems & Environment, 144*(1), 188-200. doi:10.1016/j.agee.2011.07.009

McDowell, R. W., & Nash, D. (2012). A Review of the Cost-Effectiveness and Suitability of Mitigation Strategies to Prevent Phosphorus Loss from Dairy Farms in New Zealand and Australia. *Journal of Environmental Quality, 41*(3), 680-693. doi:10.2134/jeq2011.0041

McDowell, R. (2012). *Challenges and Opportunities to Decrease Phosphorus Losses from Land to Water* (Rep.). AgResearch, Invermay Agricultural Centre.

McDowell, R., Wilcock, B., & Hamilton, D. (2013). *Assessment of Strategies to Mitigate the Impact or Loss of Contaminants from Agricultural Land to Fresh Waters* (Rep. No. RE500/2013/066). AgResearch.

McDowell, R. (2021, July 30). Ag Research [E-mail interview].

Melhem, Y. B. (2021, March 16). New Zealand's Troubled Waters. *ABC Foreign Correspondent*. Retrieved from https://www.abc.net.au/news/2021-03-16/new-zealand-rivers-pollution-100-per-cent-pure/13236174

Monaghan, R., Wilcock, R., Smith, L., Tikkisetty, B., Thorrold, B., & Costall, D. (2006). Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand. Agriculture, Ecosystems & Environment, 118(1-4), 1-222. doi:10.1016/j.agee.2006.05.016

National policy statement for freshwater management. (2021, May 28). Retrieved from https://environment.govt.nz/acts-and-regulations/national-policy-statements/national-policy-statement-freshwater-management/

Nightingale, T. (2008). Government and Agriculture: Subsidies and Changing Markets 1946-1983. In *Te Ara - the Encyclopedia of New Zealand*. Wellington: Te Ara. Retrieved from https://teara.govt.nz/en/government-and-agriculture/page-8.

Nutrient Stewardship. (n.d.). What are the 4Rs. Retrieved from https://nutrientstewardship.org/4rs/

Paterson, B. (2021, September 13). MyEnviro Software [E-mail interview].

Payn, T., Beare, M., Shepherd, M., Bayne, K., Botha, N., Collins, A. J., . . . Xue, J. (2013). *Nutrient management science: State of knowledge, use and uptake in New Zealand* (59th ed., Vol. 2013, MPI Technical Paper) (New Zealand, Ministry for Primary Industries, Soil and Land Use). Wellington: Ministry for Primary Industries.

Pepperell, S. (2021, February 11). The Future Shape of Water [Editorial]. *NIWA*. Retrieved from https://niwa.co.nz/news/the-future-shape-of-water

Quinn, B.F, Rajendram, G., 2019. RPR Revisited 6: Switching to reactive phosphate rock (RPR) based fertilisers reduces all forms if diffuse P losses, not just DRP. In: Nutrient loss mitigations for compliance in agriculture, (Eds L.D. Currie and C.L. Christensen). http://flrc.massey.ac.nz/publications.htmal. Occasional Report No. 32. Fertilizer and Lime Research Centre, Palmerston North, New Zealand.

Ravensdown. (n.d.). *IntelliSpread* [Brochure]. Author. Retrieved from www.ravensdown.co.nz/media/4467/intellispread-brochure.pdf

Recreational Water Quality. (n.d.). Retrieved from http://www.lawa.org.nz/explore-data/swimming

Robertson, HA, Ausseil AG, Rance B, Betts H, and Pomeroy E. 2019. Loss of wetlands since 1990 in Southland, New Zealand. N Z J Ecol 43

Rowarth, J.S., Roberts, A., Metherell, A. and Manning, M., 2019. Right P fertiliser, right place, right time. In Nutrient loss mitigations for compliance in agriculture. (Eds. L.D. Currie and C.L. Christensen). http://flrc.massey.ac.nz/publications.html Occasional Report No. 32. Fertiliser and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Srinivasan, M. S., & McDowell, R. W. (2009). Identifying critical source areas for water quality: 1. Mapping and validating transport areas in three headwater catchments in Otago, New Zealand. *Journal of Hydrology, 379*(1-2), 54-67. doi:10.1016/j.jhydrol.2009.09.044

Stafford, A., & Peyroux, G. (2013). *CLEARVIEW (BALLANCE PGP) – A FIRST LOOK AT NEW SOLUTIONS FOR IMPROVING NITROGEN AND PHOSPHORUS MANAGEMENT* (Working paper No. 13). Retrieved https://www.massey.ac.nz/~flrc/workshops/13/Manuscripts/Paper_Stafford_2013.pdf

Stats NZ. (2021, April 15). Fertilisers – nitrogen and phosphorus: Stats NZ, from https://www.stats.govt.nz/indicators/fertilisers-nitrogen-and-phosphorus#:~:text=Between 1991 and 2019, estimates, in nitrogen applied from fertiliser.

Stiles, W. (2021, September 10). The benefits of hedgerows and trees for agriculture. *Retrieved from* https://businesswales.gov.wales/farmingconnect/news-and-events/technical-articles/benefits-hedgerows-and-trees-agriculture. Aberystwyth University, *IBERS*, Wales

Tanner, C. C., Clayton, J. S., & Upsdell, M. P. (1995). Effect of loading rate and planting on treatment of dairy farm wastewaters in constructed wetlands—II. Removal of nitrogen and phosphorus. *Water Research, 29*(1), 27-34. doi:10.1016/0043-1354(94)00140-3

Tanner, C. C., & Sukias, J. P. (2011). Multiyear Nutrient Removal Performance of Three Constructed Wetlands Intercepting Tile Drain Flows from Grazed Pastures. *Journal of Environmental Quality, 40*(2), 620-633. doi:10.2134/jeq2009.0470

Tomscha, S. A., Bentley, S., Platzer, E., Jackson, B., De Roiste, M., Hartley, S., . . . Deslippe, J. R. (2021). Multiple methods confirm wetland restoration improves ecosystem services. *Ecosystems and People, 17*(1), 25-40. doi:10.1080/26395916.2020.1863266

Troup, C. (2007, September 24). Wetland Birds. In *Te Ara The Encyclopedia of New Zealand*. Retrieved from https://teara.govt.nz/en/wetland-birds/print

United Nations. (2017, June 21). World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. Retrieved from https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html

Wetlands. (n.d.). Retrieved from https://www.hbrc.govt.nz/hawkes-bay/rivers-and-lakes/wetlands/

Wetlands NZ: Wetlands Conservation: National Wetlands Trust. (2020, August 10). Retrieved from https://www.wetlandtrust.org.nz/

White, M. D., Metherell, A. K., & Roberts, A. H. (2017). The Use of Variable Rate Fertiliser Applications in NZ Hill Country (L. D. Currie & M. J. Hedley, Eds.). *Science and Policy: Nutrient Management Challenges for the Next Generation, Occasional Report No.30*. Fertiliser and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Workman, M. (2021, September 7). Ministry for the Environment [E-mail interview].

Wright-Stow, A., Stephens, T., Burger, D., Rutherford, K., & Tanner, C. (2018, March 20). Wetlands hold secret ingredient of future water quality. *Stuff*. Retrieved from https://www.stuff.co.nz/business/farming/dairy/102326878/wetlands-hold-secret-ingredient-of-future-water-quality

Vitalis, V. (2021, August 2). *International Trade Environment*. Address presented at Kelloggs Rural Leadership Phase 2, Wellington.