THE ECONOMIC IMPACTS OF NUTRIENT POLICY OPTIONS IN SOUTHLAND

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Abstract

We investigate impacts of nutrient caps and mandated farm practices in the Southland region on its economy and environment. We use the multi-agent simulation model RF-MAS to evaluate explicitly how individual farmers respond to the caps and mandates. The model uses data on farm parcels to estimate pasture productivity, links productivity to the options available for each farm, and uses behavioural rules to simulate farmers' choice of activities on their farms. We model a baseline out to 2037, and then compare 16 model scenarios that are combinations of caps on nitrate leaching (15 – 60 kg/ha) and phosphorus (0.5 – 2 kg/ha) loss applied uniformly across the region. We also analyse four scenarios that include non-uniform nutrient caps, grandparenting of dairy farms and mandated mitigation practices.

In the baseline, dairying is expected to increase in Southland, and sheep and beef is expected to decrease. These changes would increase the N discharges by 16% to 19,039 tonnes in 2037; P losses would increase 28% to 539 tonnes in 2037. The baseline projection is for total value of agricultural production to increase in real terms to $4.6 billion per annum.

We find a range of results, depending on how low the caps are set and other features of the policies. The economic costs arise from either land-use change from the baseline (lower amounts of dairying) or farm practice change – the use of techniques and technologies to reduce nutrient loss. Further, we find that the N cap is predominantly the binding cap, while the P cap is only binding in two scenarios.

Scenarios 1 and 2 have no impact on land use or dairy practices because the caps are not restrictive. Scenarios 3, 5, 6 and 7 deliver a 5% reduction in N leaching, a 23% reduction in P loss risk, and a 13% reduction in *E. coli* load for zero cost in the value of agricultural production. Scenarios 4 and 8 deliver a 19% reduction in N leaching, a 40% reduction in P loss, and a 14% reduction in *E. coli* load at a cost of 25% of the value of agricultural production. The economic cost is due entirely to land-use change, with a small offset for the increased productivity from improved farm efficiency. Scenarios 9, 10, 11 and 12 deliver a 25% reduction in N leaching, a 40% reduction in P loss, and a 14% reduction in *E. coli* load for a cost of 26% of the value of agricultural production. Nearly all of the cost in the scenarios is due to land-use change; mitigation accounts for less than 10% of the economic cost. Scenarios 13, 14, 15 and 16 deliver a 45% reduction in N leaching, a 59% reduction in P loss, and a 7% reduction in *E. coli* load for a cost of 81% of the value of agricultural production.

The non-uniform nutrient caps (scenarios 17 and 18) suggest that tailoring nutrient caps to farms' productive capacity and potential leaching rates provides mitigation that is more cost-

effective than uniform caps. Grandparenting of existing dairy farms (scenario 19) with nutrient caps is less cost-effective than other tools when it limits conversion to dairying. Scenario 20 focuses on farm practices rather than nutrient caps, and achieves a comparatively high level of mitigation while being more cost-effective than most policies.

Introduction

By international standards, New Zealand's water quality is generally good but declining (Parliamentary Commission for the Environment, 2013). The agricultural and urban uses have produced increased nutrient concentrations and sedimentation, which are leading to declining water quality. The Land and Water Forum created a collaborative, discursive process to try to work towards constructive engagement among stakeholders (Land and Water Forum, 2012). Southland is one region of New Zealand where there is concern about water quality. Increased intensity of agriculture coupled with the poor flushing characteristics of estuaries has led to poor water quality for some bodies of water.

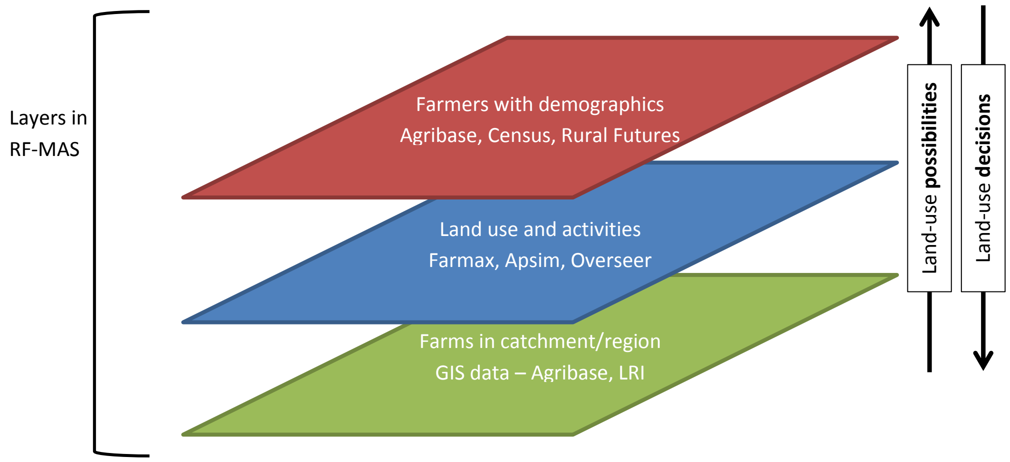
Environmental policies can be formulated in many ways, for example, mandating specific practices, setting limits or creating price mechanisms. They can also apply to different economic units or actors in the production or supply chain. Input-focused water quality policies aim to regulate farm practices or the intermediates used in agriculture, with a view to changing the eventual outputs. Output-focused policies target nutrient losses or water quality. Nutrient losses may be estimated using modelling, while water quality may be either estimated or based on actual measurements.

This paper examines the potential economic impacts of both input- and output-focused water quality policies. A defined set of policy tools for the agricultural economy of the Southland region was developed in consultation with the Ministry for the Environment and with input from the regional council. The tools were specified as strict limits on the amount of nitrogen (N) and phosphorus (P) discharges per hectare for all farms in Southland (output-focused), or as mandated farm practices (input-focused). Economic impacts were measured as the change in farms' output – total revenue from sale of agricultural products – and gross margin – revenue less direct costs of production. Each combination of N and P limits formed a different scenario or policy 'tool'. They were used as inputs for RF-MAS, a multi-agent simulation model of Southland agriculture. RF-MAS was used to model farmer responses to policies and the resulting land-use changes. These changes were then used to estimate changes in economic metrics and nutrient losses from farms.

Method

RF-MAS is a multi-agent simulation model of farmer behaviour and land-use change (Berger & Troost, 2012; Kaye-Blake et al., 2010). Conceptually, RF-MAS can be described by layers, as shown in Figure 1. The initial layer is a dataset of farms that describes their locations, sizes and productive capacity as indicated by their Land Use Capability classes. The second layer is a set of production budgets for all the land uses in a region. Each farm is linked to all the land uses technically feasible on the property. This forms a set of options for the farm. The third layer is the farmer-agents in the model. Their social, economic and demographic parameters are based on statistics for the region, and their modelled behaviours are based on historical data and research on farmer decision making. Farmer-agents are presented each period with the possibility of choosing a new land use for the farm, given the set of feasible options. Their decisions then determine land use for each farm, which then regional economic and environmental consequences.

Figure 1 Conceptual design of RF-MAS



A model run follows a series of steps:

- Initialisation: farms and farmers are loaded into the model. Farms and farmers are assigned to each other on a one-for-one basis. Farmers are also assigned to peer networks
- Pre-processing: farmers are aged by one year. Age affects several aspects of farmer behaviour, in particular their economic objectives, as described below
- Main processing: farmers make their decisions about land use for their farms. Farmers review the feasible options, which are based on the physical resources of the farm and the impacts of policies. Each farmer decides probabilistically whether to change land use, and then selects the land use that best meets the economic objective
- Post-processing: the model calculates output values for each farm, such as quantity of production, value of production, profit, nitrogen and phosphorus losses and greenhouse gas emissions.

Land layer

The land data used in the model are partially derived from GIS land information and the Agribase database. Environment Southland provided the boundaries to the three water management zones: Lowland, Basin and Hill. The zones are areas of Southland that may be approached similarly from a policy perspective. Data are also taken from the New Zealand National Soils Database Spatial Extension. The land parcels in the Southland region that are presently in a 'pastoral' or 'forestry' land use and of LUC 1-7[1], were analysed. In all, we model almost 1,100,000 hectares within the MAS model. This represents 65.2% of the total area of the zones; the remaining area (towns, waterways, native bush) is not considered.

Land use/activities layer

The land use layer defines the farm activities available for each farm. Farm activities are described as per-hectare production budgets, and are organised in libraries of options. Options are available to farms depending on several factors. First, if resources are insufficient then the activity is unavailable. This would be the case for properties that are too small to support a dairy farm, for example. Secondly, activities are linked to the physical resources, defined by a pasture productivity parameter based on LUC and a drainage parameter. Well drained soils, for example, produce greater nutrient losses and those losses are reflected in the

[1] Land Use Capability (LUC) is used to classify land parcels according to their agricultural potential, with LUC 1 and LUC 2 land being the most productive and versatile.

activities libraries. Finally, policy constraints can make specific activities unavailable for a farm. An output-focused policy might proscribe an activity whose nutrient losses are too high. An input-focused policy might require specific practices, such as fencing streams.

The Southland RF-MAS focused on the three main land uses in the region: dairy, sheep and beef, and forestry. Dairying was described using Dairy NZ systems 2, 3, and 4, which are different intensities that require different amounts of off-farm feed. Sheep and beef was described using a pasture productivity parameter, which adjusted the number of stock units that could be run on farms. The production budget libraries were developed through modelling using Farmax and Apsim. Further modelling with Overseers estimated the N and P losses from the different farm systems.

Dairy farming is by far the most profitable of the three industries. However, it has the highest amount of N and P leaching (Table 1).

Table 1 Typical farm parameters

Industry	N leaching (kg/ha)	P loss risk (kg/ha)	Gross margin, 2012 ($/ha)
Dairy	29-49	0.8-2.1	$3,000-$4,500
Sheep and beef	8-18	0.1-0.5	$50-$800
Forestry	2	0.1	$250

Source: AgResearch
Note: The gross margin figures are for 2012 data on prices, costs and productivity.

The activities layer was expanded to include on-farm mitigation practices for both dairy and sheep and beef farms. Mitigation practices were grouped into three bundles, labelled M1, M2 and M3. A summary of the mitigation bundles available to dairy farmers to help meet an environmental cap is shown in Table 2, and a complete description is in Kaye-Blake et al. (2013). These mitigation bundles are based on work by AgResearch on methods for reducing environmental impacts of farms, and they were assembled by farm systems experts with knowledge of Southland farming systems. They are cumulative, so that M3 includes both M1 and M2.

Table 2 Description of mitigation bundles

Bundle	Activities	Description
M1	Stock exclusion from waterways Improved nutrient management	Minor improvements in efficiency
M2	M1 Improved animal productivity	Major productivity improvements
M3	M1 M2 Restricted grazing using animal shelters Grass buffer strips	Capital investments that deliver mitigation at a cost

The implications of the mitigation bundles at the farm level are shown in Table 3 as average impacts by bundle. Mitigation bundle M1 improves profitability slightly and mitigates a small amount of N and P. Mitigation bundle M2 delivers a larger profit gain than M1, as well as slightly more N mitigation. Mitigation bundle M3 costs the farmer money, but delivers the largest amount of N mitigation.

Table 3 Farm-level impacts of mitigation bundles on nutrient losses

Bundle	**N mitigation (kg/ha)**	**P mitigation (kg/ha)**	**Change in profitability (2012 $ /ha)**
M1	4.3	0.6	$24
M2	5.3	0.7	$213
M3	13	0.6	-$315

In addition, we modelled reduction in *E. coli* as an output from changes in farm activities. Current land use and current *E. coli* levels were taken as a baseline, and adoption of mitigation options (e.g., excluding stock from waterways) could produce reductions. Richard Muirhead (AgResearch) provided the reduction factors shown in **Table 4**. Of the mitigations practices, only fencing off streams and farm dairy effluent practices on dairy farms would have an effect on E. coli losses during base-flow conditions. A single estimate for all mitigation bundles was appropriate across LUC class and drainage types[2].

Table 4 Reductions in *E. coli* loads from mitigations
Percentage change in loads entering waterways

Bundle	**Dairy**	**Sheep and beef**
M1	-69%	0%
M2	-69%	58%
M3	-69%	58%

Source: Richard Muirhead, AgResearch, pers. comm.

Farmer layer

Relying on Burton (2009), we assume that farmers have a lifecycle that affects how they run their farms. The MAS model has three different goals for farmers. The economic term for these goals is ‘objective function’: they are what the farmer is targeting. The three goals are cost minimisation, profit maximisation, and high profit maximisation. The goal is linked to age, which the model has in five cohorts. It is also linked to the presence of a successor – someone to take over running the farm.

Probabilistic analysis of Census data for 2001 and Agricultural Census data for 2002 and 2010 was used to estimate two sets of proportions:

- the proportion of farmers in each age cohort
- the proportion of type of farmer in each age cohort.

[2] Muirhead, R., pers. comm., 28 March 2013.

Data for scenarios

Scenarios were designed with a range of N and P caps to get a sense for the scope of possible economic and environmental outcomes. The higher (less strict) limits were expected to have little effect on farming, but would allow the modelling to produce results that could be analysed for their impacts on water quality indicators. The lower, stricter limits, on the other hand, might be required in order to reach specific water quality targets. It was therefore important to model their potential economic impacts.

To begin, we modelled 16 scenarios that were combinations of N and P limits on nutrient losses. The four N levels were 15, 30, 45 and 60 kgs N per ha, and the four P levels were 0.5, 1.0, 1.5 and 2.0 kgs P per ha. The levels produced 16 combinations of limits. The limits were modelled as applying uniformly to all farms in the three water management zones. The policies were applied as if they took effect immediately and achieved full compliance from farmers. Full compliance was produced in the model by changing the land-use options available to farmer. After the policies were put in place, only those activities that complied with policy were available. Farmer-agents were then required to choose from amongst those compliant options.

We also considered two non-uniform caps based on soil drainage (Table **5**). Scenario 17 imposed a 45 kg N/ha cap on well-drained soils, but a lower N cap on poorly-drained soils. Scenario 18 imposed a 37 kg N/ha limit for farms on well-drained soils that cannot meet 30 kg N/ha by mitigation alone, but a lower limit on poorly-drained soils. These scenarios mimicked policies based on concepts of natural capital or ecosystem services, in which the ability of the natural resources to absorb or mitigated nutrient losses are taken into account in setting limits.

Table 5 Non-uniform cap scenarios

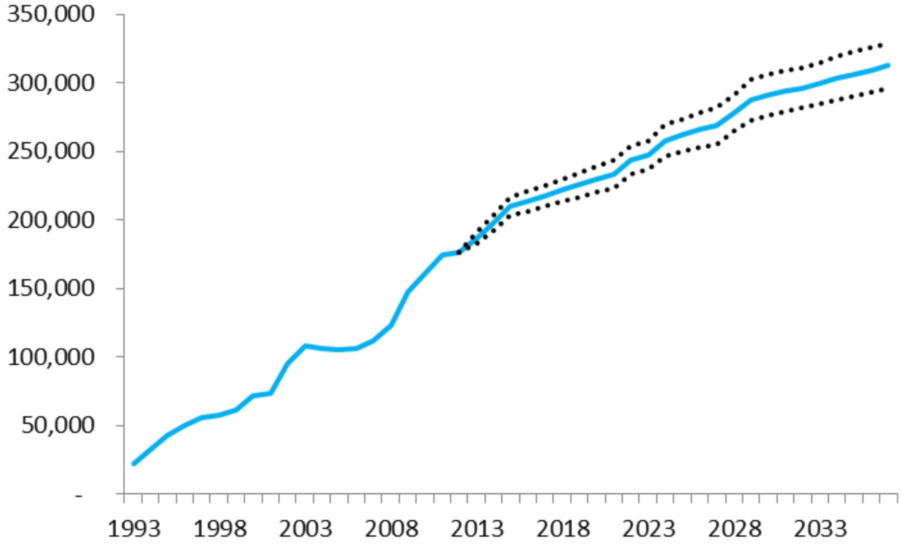
Scenario	**Soil drainage**	**N cap kg/ha**	**P cap kg/ha**
17	Well-drained	45	0.6
	Poorly-drained	38	1.2
18	Well-drained	37	0.6
	Poorly-drained	30	1.2

There were two final inpute-focused scenarios. The first considered the impact of grandparenting. The modelled policy was that dairying was restricted just to those farms that currently engage in dairying. No new dairy conversions were permitted. The last policy considered the impact of mandating mitigation practices for all pastoral farms in the region.

Results

RF-MAS was first used to create a baseline future. Using an unconstrained model in which farmer-agents were free to choose farming systems that met their objectives, we projected that dairy would continue to grow strongly over the next few years. However, over the 25 year simulation period, growth in dairying started to taper off. By 2037, dairying covered 303,000 hectares of Southland. This is an increase of 127,000 hectares over the period. Total N losses increased by 2,590 tonnes in the region, or 16%, while P losses increased by 118 tonnes, or 28%.

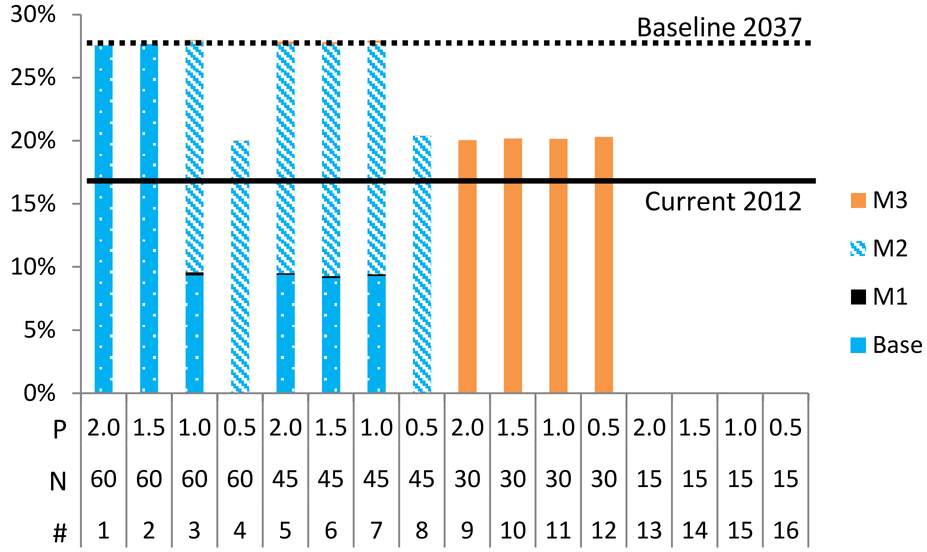
Figure 1 Dairy projections in RF-MAS baseline
Hectares. Dotted lines = 1 standard deviation



Results for the policy scenario were compared to this baseline. The results reported here focus on the dairy sector, which continued to expand in the baseline and was affected by policy constraints.

The 2037 share of dairy hectares with each uniform nutrient limit scenario is shown in Figure 2. The total height of the bar shows the share of the region in dairying. The bars are colour-coded to show which dairy mitigation practice is being used. The figure also includes two reference lines: the current 2012 share of dairying (17%), and the baseline 2037 share of dairying (28%). When the bar is under the 2037 baseline, this means the scenario forces land-use change away from dairy (to sheep and beef predominantly). When the bar changes colour or shading, the change means the scenario forces dairy practices towards mitigation options.

Figure 2 Dairy share of land use in Southland
% hectares, 2037

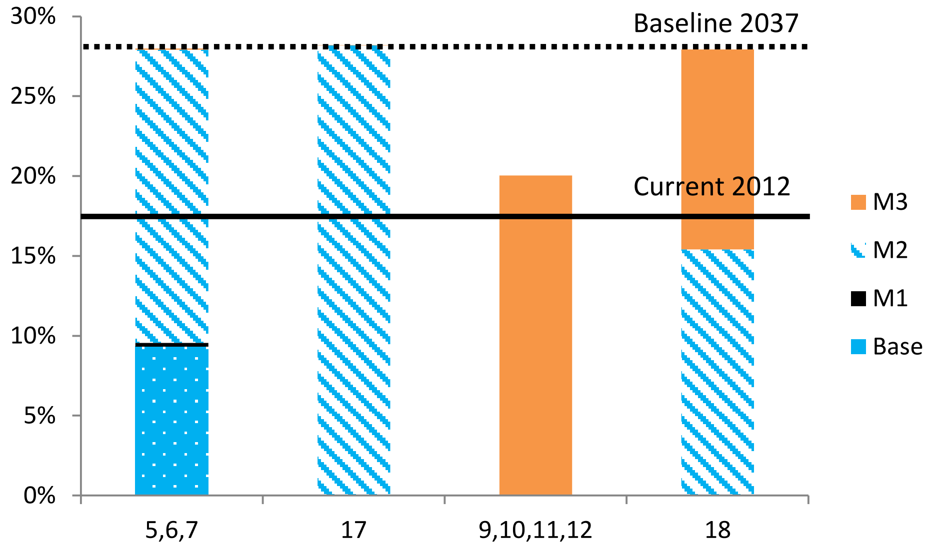


- scenarios 1 and 2 – an N limit of 60 kg/ha or over and a P limit of 1.5 kg/ha or over did not restrict dairying in any significant manner
- scenarios 3, 5, 6 and 7 – these scenarios resulted in the same total amount of dairying in 2037 as there would be under the 2037 baseline, with most of the area using mitigation bundle M2
- scenarios 4, 8, 9, 10, 11 and 12 – they reduced the total amount of dairying in Southland in 2037 from the baseline 28% to about 20%. This was still higher than the 2012 level, meaning that dairy still expanded under these scenarios
- scenarios 4 and 8 – all dairy farms used mitigation bundle M2, as base dairy farming did not comply with a P cap of 0.5 kg/ha
- scenarios 9, 10, 11 and 12 – all dairy farms used mitigation bundle M3, as this is the only dairy farming practice to comply with the N cap of 30 kg/ha
- scenarios 13, 14, 15 and 16 – there was no dairy farming in Southland as the modelled dairy farming practices did not comply with the N cap of 15 kg/ha.

Results from the two non-uniform cap scenarios are shown in **Figure 3**, set alongside similar uniform scenarios. The non-uniform scenario 17 resulted in a similar level of conversion to dairying, but greater uptake of mitigation technologies as a result of the lower limit on poorly-drained soils. Scenario 18, compared to other policies with a uniform limit of 30 kgs N/ha, resulted in greater conversion to dairying, similar to the forecast baseline for 2037. Much of the conversion used mitigation bundle M2.

Figure 3 Dairy share of land use in Southland

% hectares, 2037



Grandparenting (scenario 19) was modelled by not allowing any farmer-agents to convert from sheep and beef to dairy, and requiring all dairy farms to use mitigation bundle M3. The result was that the dairy share of land use remained at the 2012 baseline level. The final scenario (scenario 20), calculated the impact of requiring that all pastoral farms used mitigation bundle M3. The land use change was as modelled in the baseline to 2037, and the economic performance and nutrient losses were calculated based on M3.

The results in terms of economic impacts and nutrient losses are summarised in Table 6. Results are summarised as aggregate impacts at the regional level. The N and P limits for scenario numbers 1 to 16 are noted in Figure 2; scenarios with similar results are grouped together. Scenarios 17 to 20 are as described above. The table provides the changes in amounts (tonnes, dollars) and the percentage changes as compared to the estimated baseline for 2037. N mitigation is the change in the tonnes of nitrogen loss at the farm level, aggregated over the region. P mitigation provides a similar figure for phosphorus. Gross margin measures revenues less costs of production at the farm level, so is an indicator of profitability. The table provides the change in gross margin for the region. The value of production is a measure of farmgate revenue. The final column gives a measure of the efficiency of policies under the different scenarios by providing the change in production (revenue) divided by kilograms of N mitigated.

Table 6 Regional results for 2037
Financial results in real (2012) dollars

Scenario numbers	N mitigation (tonnes)	P mitigation (tonnes)	Change in gross margin ($ million)	Change in value of production ($ million)	Change in production / kg N mitigated ($)	Change in *E. coli* load
1, 2	0	0	0	0	0	0%
3, 5, 6, 7	-1,000 (-5%)	-125 (-23%)	+120 (+5%)	0 (0%)	0	-13%
4, 8	-3,500 (-19%)	-215 (-40%)	-670 (-24%)	-1,200 (-25%)	-330	-14%
9, 10, 11, 12	-4,900 (-25%)	-215 (-40%)	-850 (-31%)	-1,200 (-26%)	-250	-14%
13, 14, 15, 16	-8,500 (-45%)	-315 (-59%)	-2,200 (-82%)	-3,700 (-81%)	-440	-7%
17	-1,400 (-7%)	-175 (-33%)	+$180 (+6%)	0 (0%)	0	a
18	-2,500 (-13%)	-180 (-33%)	+$30 (+1%)	-$61 (-1%)	-24	a
19	-4,700 (-25%)	-225 (-41%)	-$980 (-36%)	-$1,500 (-32%)	-320	a
20	-6,300 (-33%)	-254 (-47%)	-190 (-7%)	0 (0%)	0	57%

[a] *E. coli* reductions not calculated but are expected to be similar to scenarios 3 to 12, i.e., 13% to 14%.

Discussion

In the modelled scenarios, farmers achieved compliance with the nutrient limits in two ways. They could adopt on-farm mitigation practices, modelled as three bundles of increasingly effective and cumulative mitigation practices (M1-M3). Alternatively, they could shift their land use to another industry with a smaller environmental footprint. The cost of compliance through land-use change was much higher than the cost through adoption of mitigations, as shown by comparing results across scenarios. Some scenarios (3, 5, 6, 7) induced adoption of mitigation bundles but no land-use change. They delivered a 5% reduction in N leaching and a 23% reduction in P loss without reducing the value of output from the agricultural sector. Other scenarios (4, 8, 9, 10, 11, 12) induced both land-use change and adoption of mitigation practices. Because the land-use change was similar, the reduction in agricultural output was also similar. However, scenarios that resulted in the adoption of M3 rather than M2 produced more reduction in N losses. Using M3 delivered 1,400 tonnes of N mitigation more than using M2, for a negligible cost to economic production. Some uniform policies (13, 14, 15, 16) had N limits that did were too low for any of the dairy systems modelled, regardless of mitigation practices. These scenarios produced the greatest reduction in N losses and were the most costly in loss of economic production. The reduction in N leaching was also the most expensive across the scenarios modelled: $440 lost production per kg N reduction.

Most scenarios still led to an increase in the area of the region in dairying. The only scenarios that did not see an increase in dairying were (a) policies in which the N limit was low enough to remove all dairying from the region, and (b) the grandparenting scenario in which dairying was not permitted to expand as a matter of land-use policy. These were relatively expensive policies in terms of aggregate economic production from the region and cost per kg N.

Scenarios 17 and 18, which modelled limits based on the natural resources of the farm (LUC classes), suggested two findings. First, non-uniform caps had the potential to be more cost-effective than uniform caps because they tailored the discharge cap to the potential of the farm for mitigation. In some situations, non-uniform caps could achieve significant reductions in nutrient discharges for little economic cost. Secondly, non-uniform caps encouraged the use of lower-cost options, but across a wider range of farms. As a result, non-uniform caps helped lower the overall cost of meeting a given total N or P load.

Sheep and beef farm practices were generally not affected by the output-focused policies. Nutrient losses from sheep and beef farms tend to be low, so the systems modelled here tended to be compliant across all the soil types and LUC classes. The lowest N limit modelled (15 kg/N cap) led to adoption of mitigation M2 on 14% of sheep and beef farms. In those scenarios, sheep and beef farmers contributed 5% of mitigation. In all other scenarios, over 99% of the mitigation occurred on dairy farms.

Two scenarios considered input-focused policies. The modelling for scenario 19, grandparenting, suggested two findings. First, policies that put strict limits on conversion to dairying imposed large opportunity costs. They did not disadvantage farmers who had dairy farms in the base year, but did disadvantage farmers who would want to convert to dairying. The costs from grandparenting were higher than the economic costs of all uniform nutrient caps except scenarios that did not allow for dairying at all in the region. Also, grandparenting that limited conversion to dairying was less cost-effective than model scenarios that improved farm practices without limiting land-use change. Scenario 20 (mandated practices), did produce greater change in sheep and beef farms' use of mitigation practices. As a result, the scenario had the second-highest level of mitigation but a relatively low cost. The scenario modelled widespread use of M3, which created the largest reduction in nutrient leaching for each type of farm but at the highest cost. The result was a reduction in 6,300 tonnes of N leaching (around one-third of the 2037 baseline) at a cost of just $190 million in gross margins. This equated to a cost to the farmer of $30/kg N mitigated. In addition, because the N mitigation was achieved through changes in farm practice rather than changes in land use, there was no cost to total agricultural production. The difference in costs arose because the scenario relied on widespread mitigation rather than land-use change. Under the uniform caps, sheep and beef farms tended not to mitigate N leaching. However, the baseline projection for 2037 had sheep and beef farms as 65% of land use and 39% of N leaching. Using M3 could mitigate over a third of their N leaching.

Conclusion

This analysis used an agent-based simulation model of agriculture, RF-MAS, which was calibrated to the Southland region of New Zealand, to investigate the impacts of water quality policies. A baseline was estimated from 2012 to 2037, and then the impacts of several scenarios were modelled. Output-focused policies included uniform limits on N and P across all farms and non-uniform limits that varied by soil type and LUC class. Input-focused policies included bans on conversion to dairying (grandparenting existing dairy farms) and mandated mitigation practices across all farms. The discussion of model results has focused on the percentage of area in dairy farming in 2037, a key descriptor of overall land use in Southland. The outputs from the modelling were both economic, in terms of gross margin and total revenue, and environmental, in terms of reductions in N, P and *E. coli* losses from farms.

The modelling results provided some overall lessons. One lesson was that restricting farms from moving into economically valuable land uses tended to be expensive. This was likely a function of the large differential between sheep and beef farms and dairy farms in terms of gross margin and revenue. It was less expensive to adopt or mandate mitigation practices as a way to reduce nutrient losses. However, there were limits to the amount of reduction that could be achieved solely through mitigation. The largest reductions in the modelling were achieved through restricting dairying. On the other hand, smaller reductions were achieved with little economic impact, particularly by using mitigation technologies that have efficiency gains. Finally, mandating mitigation practices across all land uses was effective at achieving large reductions in nutrient losses for relatively low cost, and led to the largest reduction in *E. coli* of any scenario. The reason for the policy’s effectiveness was that it brought mitigation practices to the largest land use – sheep and beef – thereby increasing the region’s potential for reduction of nutrient losses.

The modelling has provided some information on the costs and impacts of nutrient discharge caps on Southland, but some limitations should be acknowledged:

- wintering-off – the figures reported above did not account for wintering-off practices, in which dry cows are sent away from the core dairy operation to graze elsewhere. We have calculated that including wintering-off would increase N losses by up to 13%
- bundling mitigation options – mitigation options were grouped into three bundles, whereas farmers would actually be able to choose from a number of specific options. The impact was that the modelling overstated the total impact of each policy by an unknown amount because farmers were mitigating more than necessary to meet the caps, rather than making a decision at the margin
- barriers to adoption – the model did not account for hurdles or barriers to adoption that affected the total cost of selecting new farm practices or changing land use

- capacity of regional resources –the capacity of regional resources, including water, to sustain the growth in dairying in the baseline was not considered
- farmer debt and stranded assets – debt and access to credit could affect a farmer's ability to adopt new practices, but were not modelled
- technological improvements over time – baseline growth in agricultural productivity was based on the gains over the last 20 years. The modelling did not include any growth in the performance of current mitigation practices or any possible new 'silver bullets' that significantly reduce agriculture's environmental footprint.

The modelling is another step in understand the linkage between economic and environmental impacts, and makes the necessary links between decisions by farmer about their own properties and the aggregate impact at the regional level. It also demonstrates that water quality policies can have different economic and environmental impacts, depending on how they are formulated.

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