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Perspective

Implications of water quality policy on land use: a case study of the approach in New Zealand

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Abstract. Achieving good water quality through output controls is difficult. The New Zealand Government recently proposed enforceable bottom lines to protect ecosystem health of 1 mg L^{-1} dissolved inorganic nitrogen (DIN) and 0.018 mg L^{-1} dissolved reactive phosphorus (DRP), but has now delayed considering them. In examining whether these bottom lines could be met through mitigating DIN and DRP losses from existing land uses, we found that if all known strategies to mitigate N and P loss were implemented by 2035, the proportion of catchments exceeding these bottom lines would be predicted to be 4% for DIN and 9% for DRP. If bottom lines were enforced, land use would likely change, but to change successfully good advice and effective multilevel governance are required. Advice should expand and standardise elements of farm environment plans that spatially isolate critical source areas of N and P loss and apply cost-effective mitigations. Governance should focus on combining these plans with the national bottom lines and technical support to connect practices and land use at the farm scale to meeting water quality bottom line at the catchment scale.

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Introduction

To achieve good water quality, many jurisdictions set limits (thresholds or bottom lines) for the maximum concentrations of contaminants like nitrogen (N) and phosphorus (P) in streams and rivers. In doing this, it is assumed that land use practices can be adjusted to reduce discharges to levels that meet bottom lines. The ability to adjust practice is catchment specific, varying according to biophysical (e.g. climate and soil types) and socioeconomic factors (e.g. demographics, debt, ownership structures, willingness to change). However, in setting bottom lines, policy should determine the likelihood of them being met. Using existing and new research we explore the implications of enforcing bottom lines, using those that are still being refined in New Zealand as an example. We also provide some commentary on how land use change could be navigated should mitigations not be enough to meet bottom lines. Our aim is to inform the development and implementation of water quality policy to protect ecosystem health.

Background

Significant changes in land use have occurred in New Zealand over the past 30 years in response to market forces. However, this had led to widespread enrichment of surface and groundwater with N and P (Larned *et al.* 2020).

In 2009, freshwater stakeholders, led by primary sector, environmental, iwi Māori and hydroelectric interests, initiated the Land and Water Forum (LAWF) to propose reforms to the management of natural resources, which is devolved to regional authorities. LAWF's recommendations led to the first National Policy Statement for Freshwater Management (NPS-FM) in 2011, which was revised in 2014 (Ministry for the Environment 2014), 2017 (Ministry for the Environment 2017) and 2020 (Ministry for the Environment 2020*a*). More specifically, Land and Water Forum (2010) recommended that there should be clear environmental standards and 'bottom lines' across the range of water quality attributes important to human and ecosystem health.

Building on the work of LAWF and other consultation documents, the Government proposed national river and stream water quality bottom lines for dissolved inorganic N (DIN) and dissolved reactive P (DRP) of 1.0 and 0.018 mg L^{-1} respectively (Ministry for the Environment 2019). The proposed bottom lines used a 'weight of evidence' approach based on regressions between nutrient concentrations and multiple ecosystem health 'indicators', such as periphyton growth and macroinvertebrate community composition. This process was supported by many scientists and stakeholders, and through public opinion (McArthur 2019). The process aligned well with nutrient guidelines and policies in other countries, albeit more commonly using total not dissolved nutrient forms (Evans-White *et al.* 2013). However, the approach was also questioned (DairyNZ 2019; Local Government New Zealand 2019; National Institute of Water and Atmospheric Research 2019), because the explanatory power of individual regressions was sometimes weak. For example, linear regressions using measured nutrient concentration data explained only 6–13% of the variation in observed macroinvertebrate metrics (Canning 2020). Adding to the controversy is uncertainty about the ability of farmers in some catchments to reduce nutrient losses and meet these bottom lines.

The NPS-FM in 2020 did not set national bottom lines for DIN and DRP based on ecosystem health (Ministry for the Environment 2020*a*). Instead, it focused on preventing nitrate toxicity by setting a bottom line for DIN at 2.4 mg L^{-1}, which would be reconsidered in 1 year, as would the ability of a DRP bottom line to take account of natural variation (Office of the Minister for the Environment and Office of the Minister of Agriculture 2020).

Can bottom lines be met?

Recent work has characterised N and P losses under a baseline of 2015 land use and the extent to which farm types (i.e. classified based on factors such as slope, climate and soil characteristics) in New Zealand can reduce N and P losses based on implementation scenarios of all known mitigation strategies in 2015 and of all known plus developing mitigation strategies by 2035 (see Table S1, available as Supplementary material to this paper).

The proportion of catchments used for primary production that exceeded the proposed bottom line for DIN in the 2015 scenario was 6.7%, reducing to 5.5 and 4.2% in the 2015 and 2035 mitigation scenarios respectively (Fig. 1). The percentage area exceeding the proposed bottom line for DRP in 2015 was 25%, reducing to 17 and 13% for the 2015 and 2035 mitigation scenarios respectively (Fig. 1). Regions with the largest proportion of catchments whose estimated concentrations exceeded the proposed DIN bottom line were Canterbury and Southland (Table S1). For DRP, most regions still had >10% area at risk of exceeding the bottom line, caused largely by high-P volcanic geology, which were then exempted, reducing the areas at risk to 13 and 9% in the 2015 and 2035 mitigation scenarios respectively.

Costs of meeting bottom lines

Modelling in New Zealand and England showed that the cost-effectiveness of mitigations can be improved by targeting critical source areas of the farm that account for most losses (McDowell 2014; Zhang *et al.* 2017). For the New Zealand case study, which examined P, the cost of farm earnings before interest and tax (EBIT) for a few strategies was <1% for modelled sheep/beef properties and ~6% for dairy properties. However, to reduce P concentrations to the proposed bottom line often required 10 or more actions, resulting in a decrease in EBIT of 9–12%. Other work suggests that costs may be higher. For instance, Doole *et al.* (2019) estimated that dairy profit would reduce by half for an N reduction of ~35% on ~20 dairy farms in the Lake Rotorua catchment. Nationally, DairyNZ (2019) estimated the cost of meeting the bottom lines was NZ$6 billion annually by 2050. However, others disputed that there will be any negative cost (Environmental Defence Society 2019). The difference between the benefit and cost of meeting a toxicity bottom line in the NPS-FM was a NZ$190-million benefit per year (Ministry for the Environment 2020*b*). Benefits included improvements in swimming-related human health, water clarity, ecosystem health and wetland ecosystem services, whereas costs were associated with administration and implementing 12 mitigation actions (Muller 2020). The additional mitigations examined in that paper and elsewhere were not assessed in the NPS-FM due to either a lack of data or because they were deemed unnecessary because the toxicity DIN bottom line had already been met.

Potential path forward

Based on the estimated potential load reductions from the full implementation of mitigations, a combination of deintensifying land use and land use change would be required to meet the proposed bottom lines. To allow businesses to remain viable and thrive, practices and land use change need to be facilitated well and at a pace that allows time for production systems to adapt. There are two fundamental mechanisms to facilitate change and achieve bottom lines: (1) robust advice that is targeted to specific farms and catchment conditions to achieve change cost-effectively; and (2) effective oversight of plans to implement advice and monitor whether catchment water quality is improving, acting where it is not.

Robust advice

A common framework for the delivery of advice is the farm environment plan (FEP). Experience at regional and national levels suggests that reductions in sediment and P concentrations are attributable to actions implemented as part of FEPs (McDowell *et al.* 2019). The NPS-FM has made FEPs mandatory, but more work is needed on robust quality standards and the capability and capacity of providers and regulators to deliver and audit plans. FEPs provide a mechanism to capture complex farm systems (e.g. horticulture) where models may not yet accurately predict N and P losses.

Because the cost-effectiveness of mitigation actions improve when targeted to critical source areas, FEPs need to be spatially explicit. Furthermore, they need to deliver advice that is compatible with tactical (day-to-day) land management decisions and with long-term strategic land use or practice change. Linking FEPs to a catchment water quality objective may also require consideration of the speed and longevity of actions and, in relation to catchment limits, it may require an allocation framework for mitigation obligations between different types of land use.

If required now, ~40 000 FEPs would have to be generated and take ~5 years to complete based on the number of personnel qualified to generate a FEP, and the 2–3 days it takes to generate one. Capacity to generate FEPs will increase as the market for FEPs evolves and training institutes respond, but the lag time will be several years. Therefore, the New Zealand Government has suggested that FEPs be prioritised and phased for catchments at most risk (Office of the Minister for the Environment and Office of the Minister of Agriculture 2020). We concur, but also call for plans to be codeveloped with producers to engender a sense of ownership, and that FEPs be coupled with incentives to reward and accelerate the pace and scale of change.

Effective multilevel governance

Like many jurisdictions, New Zealand faces challenges in delivering water quality improvements by elected regional authorities.

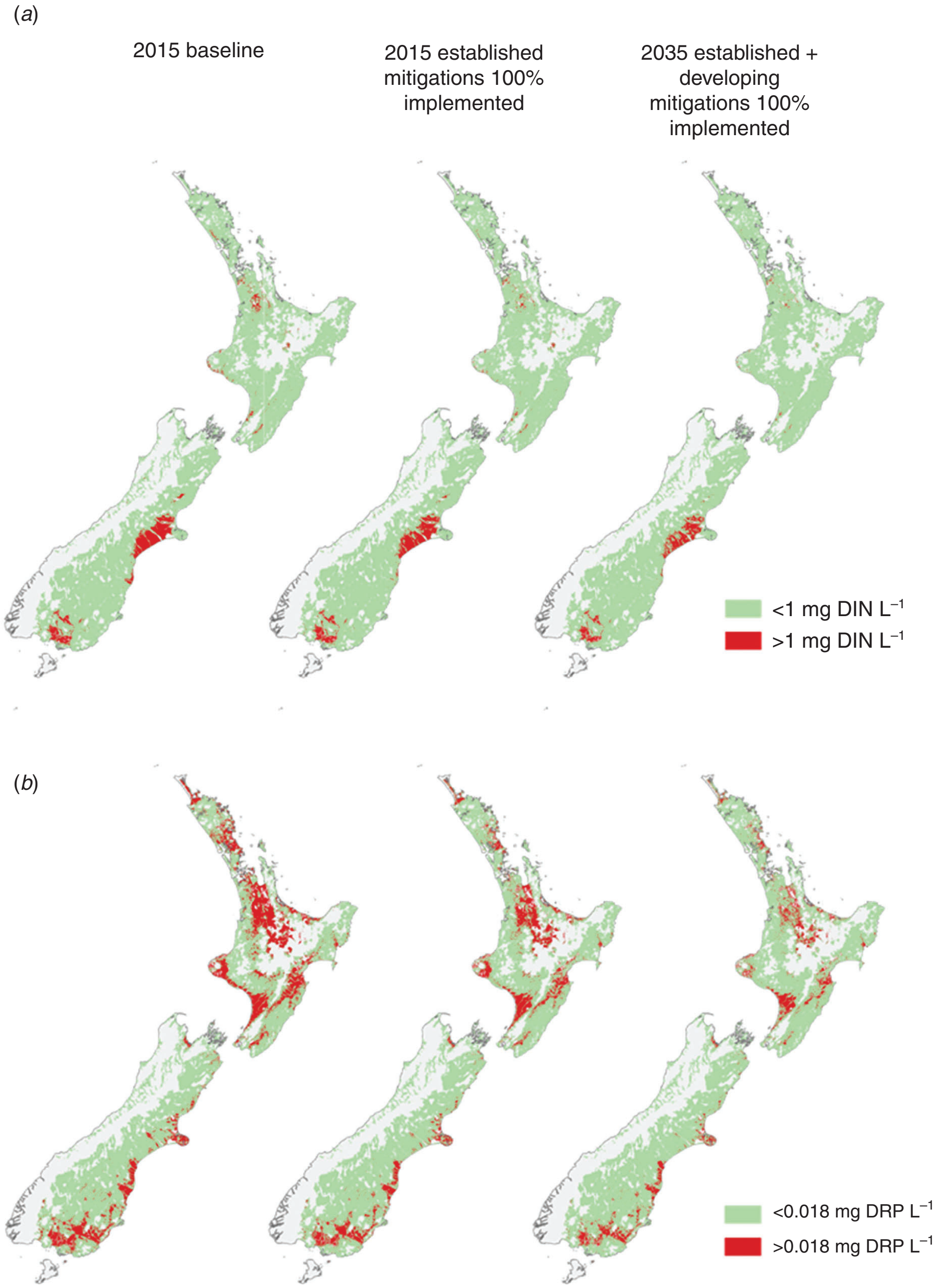

Fig. 1. Estimated catchments with median (*a*) dissolved inorganic N (DIN) or (*b*) dissolved reactive P (DRP) concentrations greater (red) or less (green) than the proposed bottom line for streams and rivers at the 2015 baseline and after established or established plus developing mitigation had been 100% implemented.

The tension between elected entities at regional and national levels is emphasised in New Zealand by small populations in most regions, their economic dependence on the primary sector and the vulnerability of regionally elected authorities to be captured by those they are supposed to be regulating (Bache and Flinders 2004; Ericksen *et al.* 2004). To provide oversight and direction, the Land and Water Forum (2010), Freshwater Leaders Group (2019), Kahui Wai Māori (2019) and many others advocated for a national water commission. These proposals envisaged different functions, powers and governance arrangements, which need further public discussion.

Discussions about multilevel governance often focus on monitoring lower-level entities, holding them to account and seeking corrective action when necessary. This approach is not well suited to New Zealand for two reasons. First, if left to degrade, many freshwater systems are difficult to remediate. Second, New Zealand's fresh water and climate objectives have, since 1992, needed regulation and incentives reflecting the polluter-pays principle for non-point source dischargers, along with proactive planning and advice for land use change, but very little of either has been forthcoming. These considerations suggest a need for stronger national control and resourcing of regional environmental management.

Transitioning land use change safely

New Zealand removed direct agricultural subsidies in 1986, causing a 60% reduction in land prices with ~1% of farmers leaving the sector. Land values, commodity prices and farm profitability had recovered by 1990 (Vitalis 2007), driven by markets with a diversification of land use and increased efficiencies. However, more recent change and practices have converged with those of the European Union (Knickel *et al.* 2011), including the use of agri-environment schemes, especially for restoration actions. Funding for such actions has been ad hoc but, as part of the NPS-FM, the Government has now allocated NZ $140 million per year to aid implementation, ~60% of which is focused on temporary job creation projects under the COVID-19 Relief and Recovery Programme. In addition, the One Billion Trees programme (NZ$24 million per year) supports native and exotic plantings that take social, environmental, cultural and economic priorities into account to help meet climate change objectives, and may also have water quality cobenefits (Te Uru Rākau 2018; *Climate Change Response (Zero Carbon) Amendment Act* 2019, Public Act 2019 number 61). Providing NZ$140 million per year will help farmers meet the NPS-FM in the short term but, for long-term improvement, consideration must be made for farmers to transition to land uses and practices with a lower DIN and DRP loss profile.

There is also an opportunity to build on existing catchment management groups, which has seen farmers and others taking collective responsibility to try to achieve desired water quality outcomes. Public support for this approach began with the formation of the NZ Landcare Trust in 1996, and considerable experience has accumulated. With further leadership and engagement, this approach could evolve into a more accountable, innovative and effective vehicle for advancing environmentally sustainable agriculture.

Interdisciplinary and stakeholder-engaged research

Implementation of the policy is not just a freshwater science matter. To be successful it requires an interdisciplinary approach that considers stakeholder views (Salmon 2019). Ultimately there is a value judgment by stakeholders on the importance of bottom lines. The Government's decision to delay a decision on DIN and DRP bottom lines could be viewed as a challenge for the science and policy communities to develop a more interdisciplinary and stakeholder-engaged approach to bottom lines.

Conflicts of interest

R. W. McDowell and A. Lim were members of the Freshwater Leaders Group that advised the Minister for the Environment on the practicality of policy options. R. W. McDowell is an Associate Editor for *Marine and Freshwater Research.* Despite this relationship, he took no part in the review and acceptance of this manuscript. The authors declare that they have no further conflicts of interest.

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