Tanner, C. Muirhead, R., Burger, D., Carrick, S., Close, M., Monaghan, R., Singh, S., Srinivasan, M. Stenger, R., Tipa, G. 2017. A framework for understanding the linkages between land and water quality impacts. In: *Science and policy: nutrient management challenges for the next generation*. (Eds L. D. Currie and M. J. Hedley). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 30. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 10 Pages

A FRAMEWORK FOR UNDERSTANDING THE LINKAGES BETWEEN LAND AND WATER QUALITY IMPACTS

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Abstract

Different soils, landscapes and water pathways vary at a range of spatial and temporal scales in their propensity to yield, transport and attenuate contaminants. This affects a land's suitability to various types and intensities of use. For instance, one national-scale study has found that, on average, 55% of nitrogen (N) and phosphorus (P) lost from productive land uses in New Zealand are attenuated as they make their way through catchments to the sea, but proportions attenuated vary widely across and between landscapes. Thus, the limit setting processes and the actual limits applied to land uses by regulators under the NPS-FM (National Policy Statement for Freshwater Management) to safeguard the life-supporting capacity of freshwaters and the associated health of people and communities need to take into account these differences in transport and attenuation between contaminant sources and sites where water quality attributes are defined. The Sources & Flows programme in the Our Land & Water National Science Challenge aims to develop a framework that will synthesise our existing knowledge of contaminant sources and pathways to predict the spatial and temporal effect of these attenuating factors on contaminant transport. The proposed framework will build on existing frameworks that operate at smaller scales e.g. the farm dairy effluent risk framework. This framework will be supported by a national scale "source-delivery-attenuation" analysis that will identify the gaps in the state of our current knowledge (with existing models) and measured stream loads. We will also investigate the use of "indirect" methods, such as hydrograph and pollutograph analysis, and tracers, to verify contaminant pathways. Such analyses will support development of the framework and allow us to extrapolate to areas where little base-line data are available. With appropriate knowledge, productive enterprises will have the opportunity to adapt and tailor their land use and management practices to work within the natural and built attenuation capacities of their landscape.

Introduction

Soils, landscapes and water pathways vary over space and thus their propensity to generate, transport and attenuate contaminants. These variations can significantly influence land's suitability to use. For instance, Elliot et al., 2005, based on a modelling study, concluded that as much as 55% of nutrients transported from productive land uses in New Zealand could be attenuated before they reach the sea. However, these proportions attenuated vary widely across and between landscapes. Thus, it is important that limits set on land uses under the NPS-FM (National Policy Statement for Freshwater Management) to safeguard the life-supporting capacity of freshwaters and the associated health of people and communities need to take into account these differences in attenuation between contaminant sources and pressure points where the impacts are measured. The development of a framework that combines the knowledge on sources, flows and attenuation of landscapes will allow productive enterprises an opportunity to adapt and tailor their land management practices and ensure they work within the natural and built attenuation capacity of their landscape.

The Sources & Flows programme within the National Science Challenge's Our Land & Water (OLW) aims to develop a framework by synthesising existing knowledge on tools and techniques at a range of scales, the complex, dominant, and spatially variable connections between contaminant sources, soils, vadose zone, ground- and surface-waters, and associated attenuation capacities. This integrated understanding in space and time of critical source areas, pathways and fluxes of water and contaminants through the landscape, and natural and engineered attenuation capacity will enable dominant pathways to be identified and key risks and mitigation opportunities to be recognised. Linking hydrological and biogeochemical signatures will provide powerful tools (Burt and Pinay, 2005; Kirchner, 2009; McMillan et al., 2014; Woodward et al., 2013) that can infer landscape-specific contaminant transport pathways from existing national databases of soils, geology, climate, flow and water quality.

The Sources & Flow programme will test four hypotheses:

1. Key flow pathways and contaminant fluxes in the landscape can be identified and mapped to inform suitability for land use and response at multiple spatial and temporal scales;
2. Production (or profit) per unit of contaminant loss can be increased by considering the suitability of a land use and mitigation strategies, and maximising attenuation along transport pathways;
3. When managed according to hypothesis 2, the scope for intensification without breaching defined limits as well as the constraints where new technologies or primary production systems are required can be more easily identified; and
4. Knowledge of flow pathways of contaminant fluxes can be used to identify if strategies to mitigate at the source of contaminants or along transport pathways will deliver better social, cultural, economic and environmental outcomes than intervening in receiving environments, or if re-design of enterprises is needed. This last hypotheses is aligned with the OL&W Suitability programme (Larned et al., 2017).

Approach

The Framework

The first step is to develop a framework enabling us to identify and predict dominant flow pathways, and mitigation and attenuation options based on data and information that is available for the majority of our agricultural land (Figure 1). Building the framework will involve the integration of knowledge from previous and emerging research on mitigations and attenuation options, soils, contaminants (nitrogen [N], phosphorus [P], sediment, faecal microbes), hydrology, surface water and groundwater flows and cultural values into an appropriate mapping system (Figure 2). Using this framework, which integrates multiple layers of information, we will be able to identify the specific input data required to connect contaminant transport pathways from the enterprise (i.e. source) right through to the receiving environment, across multiple scales and landscapes (Figure 1). We will identify where cultural values and knowledge will be able to inform and/or cross over this framework (Figure 2).

Figure 1: Schematic illustration of a catchment showing a range of land uses in different locations and the range of transport and transformation processes that need to be accounted for in understanding the delivered load of contaminants from different parts of the landscape.

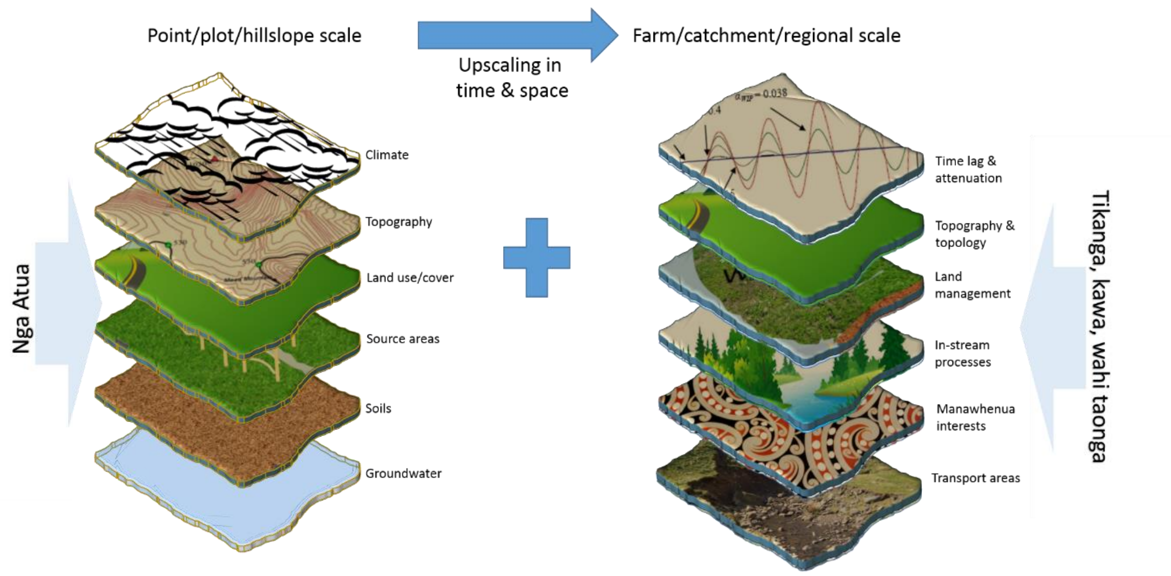

Figure 2: Conceptual illustration of the proposed framework for estimating the delivered load of contaminants from land to water in a catchment that is integrated into a spatial/mapping tool.

Figure 2 also illustrates how Maori interests need to be recognised throughout the framework. Māori conceptualise water as an undivided entity and as part of a system encompassing lakes, rivers, wetlands, lagoon's, swamps, their associated beds, and adjoining lands. An integrated, holistic and comprehensive approach is necessary to give effect to the principle of water being an undivided entity (Durette 2008a, 2008b). The framework therefore recognises:

- that all the tiles illustrated on the left hand side align with a domain that is controlled by ***atua*** (deities) related through ***whakapapa*** (genealogy) which describes bonds, relationships, and connections within a system. Maori, who today have responsibilities to understand contaminant sources and pathways and determine the potential impacts of cultural interests, derive their obligations as ***kaitiaki*** (guardians) through whakapapa. The focus of the present research is contaminant sources and pathways. Maori acknowledge that water is a medium flowing through a catchment that makes connections – ***ki uta ki tai*** – from source waters to coastal environments.
- On the right hand side of the figure, reference to "***tikanga, kawa, wahi taonga***" explicitly recognises that Maori have their own conceptualisations of (for example) attenuation, appropriate land management activities, and instream processes, and over generations have developed what they believe are the correct practices to ensure protection the ***mauri*** of an ecosystem (Rochford 2003, KTKO 2006, Mahaanui Kura Taiao 2013).

Mauri is about life in and around a waterbody. A healthy mauri is reflected in high water quality of sufficient quantities sustaining a range of aquatic and riparian habitats supporting diverse ***koiora*** (biodiversity). Mauri also describes the "working ability" of an aquatic ecosystem (Tau 1993), while others have commented that the headwaters of a waterbody, as the source of mauri (Gray, undated)[1], should be accorded protection. Protecting mauri

[1] Advised to Tipa by Maurice Gray – kaumatua in Otautahi / Christchurch.

ensures that **wahi tapu** (sacred places) and **wahi taonga** (treasured places), are recognised and provided for. A tile in the right hand stack recognises the diverse interests of Maori.

One of the challenges with developing these types of frameworks is the complexity of interactions between multiple layers of knowledge and the availability of appropriate data for each layer. While previous and current research programmes have focused on elucidating these processes in a small number of typically heavily instrumented research catchments (e.g. Stenger et al., 2016), here we focus on the development of a framework with national applicability. To help guide a way through this complex challenge, three work streams – Source-delivery-attenuation analysis, indirect methods, and case studies – are underway.

Source-Delivery-Attenuation

The second step will be to re-look at the national scale data on modelling of contaminant loads across NZ. We will update and reanalyse data with a focus on the apparent outliers (Figure 3). We will identify if these outliers, allowing for lag times, are due to very high or low attenuation capacity. If these outliers can be linked to landscape features and their effect on contaminant flow pathways, then this may help identify which layers in the framework (Figure 2) are critical to focus on.

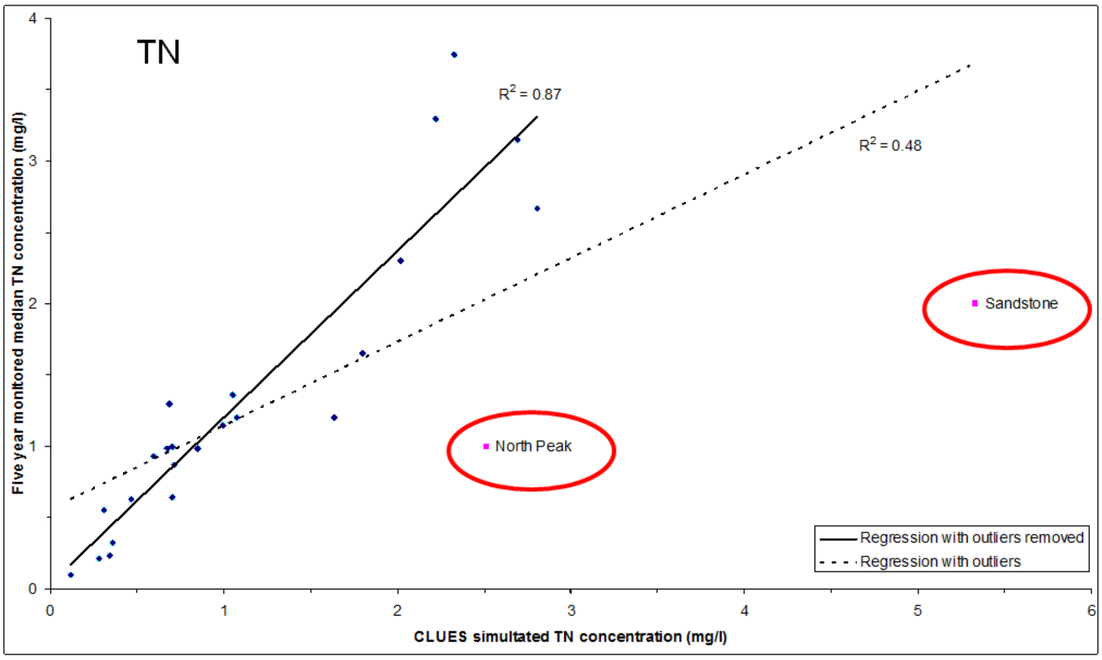

Figure 3: Example plot of modelled vs measured loads using the CLUES model, where the outliers identify gaps in our current ability to predict delivered loads to water (adapted from Elliot et al., 2005).

Indirect Methods

Direct methods for measuring contaminant fluxes from source to receiving environment are typically very expensive, time-consuming, and restricted to the lower end of the relevant range of scales (plot to hill slope). We will review the usefulness of indirect methods for identifying dominant sources and pathways of contaminants such as development of relationship between the flow and water chemistry time series ("signatures") measured at the catchment scale for partitioning flow and contaminant pathways. These techniques will encompass: identifying sources (e.g., Monaghan et al., 2009; Muirhead et al., 2011; Wilcock et al., 2013), mitigation and attenuation options (e.g., Ballantine and Tanner, 2010 & 2103; McDowell et al., 2014; Monaghan and De Klein, 2014; Muirhead, 2015; Tanner et al., 2013; Tanner and Kadlec, 2013; Tanner and Sukias, 2011; Houlbrooke et al. 2011), identifying flow pathways and loads (e.g., Woodward et al., 2013; McKergow and Davies-Colley, 2010; Stott et al., 2011; Wilkinson et al., 2011; Hughes et al., 2012; McKergow et al., 2010; Nagels et al., 2002; Gray et al., 2015; McLeod et al., 2014; Monaghan and Smith, 2012; Weaver et al., 2016) and spatial analysis (e.g., Close et al., 2016; McDowell et al., 2015; Carrick et al. 2013; McKergow and Tanner, 2011; Lilburne et al. 2010; Webb et al. 2010; McLeod et al., 2008). Where possible we will use less direct methods of: hydrograph analysis (e.g., McMillan et al., 2012), pollutograph analysis (e.g., Murphy et al., 2015), and fingerprinting approaches (e.g., Clague et al. 2015; Devane et al., 2013; Vale et al., 2015; Gibbs, 2008; Walling, 2013) to determine the dominant flow paths and travel times for the different contaminants as these techniques have advantages of lower cost and greater transferability relative to direct methods of measuring flow paths (McLeod et al., 2014; Monaghan and Smith, 2012). These indirect techniques could be used to confirm the landscape features identified in the source-delivery-attenuation work stream as being critical to the framework development.

Case Studies

The best way to test the availability of the data inputs to drive a model framework, and to test the value of potential outputs, is to apply the proposed framework to actual case studies. We propose to work with stakeholders and other programmes within OL&W to ensure integration between the research programmes and value of the outcomes to the end users. Case study catchments have been identified in three locations to assist with testing hypotheses and demonstrate the applicability of the framework. We will be working with the Mauri whenua ora programme in the Northland region. We will be working with Landcorp on their farms in the upper Waikato catchment to test our hypothesis number 2, and we will be working with the Suitability programme in Southland to test our hypothesis number 4.

Conclusions

The Sources & Flows programme will support more informed decision-making on investment in land use activities. Land managers and regulators will be able to identify the inherent risks of generating unacceptable environment pressures from particular land uses in a range of landscapes. They will be able to identify the relative risk of critical contaminants that will result in environmental impact from specific land uses and locations, as well as acceptable limits of discharge to enable the most cost-effective and appropriate level of mitigation for their enterprise. At the larger catchment scale, we will be able to identify which contaminants have potential headroom to allow for increased production within environmental constraints, or where catchment re-design utilising low environmental footprint land use options (Renwick et al., 2017) is required.

Glossary

Atua	God, supernatural being.
Kaitiaki	Guardian.
Kaitiakitanga	The exercise of customary custodianship, in a manner that incorporates spiritual matters, by tangatawhenua who hold Manawhenua status for particular area or resource.
Ki Uta Ki Tai	Mountains to the Sea.
Koiora	Life, biodiversity
Manawhenua	Those who exercise customary authority or rangatiratanga.
Mauri	Essential life force or principle; a metaphysical quality inherent in all things both animate and inanimate. (Ngai Tahu Fresh Water Policy)
Tikanga	Customary values and practices.
Wāhi Taonga	Resources, places and sites treasured by Manawhenua.
Wāhi Tapu	Places sacred to tangata whenua.
Whakapapa	Genealogy.

Acknowledgements

We acknowledge Our Land & Water National Science Challenge for funding the work described in the paper.

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