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Research article

A national riparian restoration programme in New Zealand: Is it value for money?

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ABSTRACT

National scale initiatives are being attempted in New Zealand (NZ) to meet important environmental goals following land-use intensification over recent decades. Riparian restoration to filter agricultural spillover effects is currently the most widely practised mitigation measure but few studies have investigated the cumulative value of these practices at a national level. We use an applied economic land use model the benefits (GHG emissions, N leaching, P loss, sedimentation and biodiversity gain) and relevant costs (fencing, alternative stock water supplies, restoration planting and opportunity costs) of restoring riparian margins (5–50 m) on all streams in NZ flowing through current primary sector land. Extensive sensitivity analysis reveals that depending on margin width and cost assumptions, riparian margin restoration generates net benefits of between NZ$1.7 billion – $5.2 billion/yr and benefit-cost ratios ranging between 1.4 and 22.4. This suggests that even when not monetising the increase in biodiversity or components of stream ecosystem health and other benefits from planting riparian strips, the benefits to climate and freshwater are significantly greater than the implementation costs of riparian restoration.

1. Introduction

Governments are introducing national environmental policies that often struggle to achieve traction because the potential benefits and costs are rarely evaluated. However, demonstration of net benefits from implementation could foster support and drive local and regional initiatives. The large-scale restoration of riparian systems are emerging globally as national foci for policy and management because of their role in supporting large human populations, significant natural biodiversity and critical ecosystem services (Stella et al., 2013). An essential feature of riparian systems is their connectivity as part of larger watersheds and their interface with adjoining terrestrial environments. These features contribute to their functional importance for sustaining water quality and quantity, limiting soil erosion, maintaining in-stream biodiversity, sequestering nutrients and toxins derived from land use activities, and mitigating the impacts of climate change (Capon et al., 2013). However they also make restoration challenging as benefits are scale and context dependent, and often diffuse. Net positive outcomes are influenced by the location of impacts and benefits within the watershed. Additionally, terrestrial land use, human population pressures, and the typology of river networks are dynamic over different temporal and spatial scales making it difficult to evaluate the contributions to overall watershed health of either a single activity or management at one or a few locations.

Watersheds have multiple purposes and policy and management agencies are increasingly requiring models and frameworks that enable full evaluation of the economic and environmental outcomes of different options seeking to restore ecosystem functions (Burnett et al., 2017). This is to assist decision making where riparian restoration requires forgoing current or potential economic benefits from agricultural or urban activity in parts of the watershed. Moreover, outcome evaluation is increasingly recommended when multiple ecosystem services, derived from many natural sources, are required (Maseyk et al., 2016).

As ecologically diverse strips of vegetation along the riparian margin of waterways, riparian buffers can play a vital role in cleaning up waterways (Osborne and Kovacic, 1993; Naiman and

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Decamps, 1997; Duchemin and Hogue, 2009). Excluding stock from streams with fencing can greatly reduce sedimentation from bank erosion and stream contamination with N, P and pathogenic bacteria in dung (e.g., Di and Cameron, 2000; Nagles et al., 2002). Active or passive restoration of riparian vegetation will often add further benefits, particularly in capturing overland erosion flows, filtering unused nutrients and providing habitat and shading for both terrestrial and aquatic biota (e.g., Parkyn et al., 2003; Parkyn, 2004; Jowett et al., 2009; Zhang et al., 2010).

New Zealand has already implemented or is considering a range of major environmental policies nationally, including climate change mitigation (NZ Government, 2002) freshwater quality (MfE, 2014), and pest control (Russell et al., 2015). The latter has arisen in response to the expansion and intensification of the primary sector and the degraded quality of many waterways. In New Zealand, water quality limits are being set for each catchment in the country under the recently amended National Policy Statement for Freshwater Management (NPS-FM) of 2014. Through the NPS-FM, the agricultural sector will be required to take action to reduce their contribution to the degradation of water quality, particularly via nitrogen (N) and phosphorous (P) pollution, sediment deposition, and contamination by pathogenic bacteria. In addition, New Zealand has a domestic climate change mitigation policy that has been implemented through an emissions trading scheme since 2008. The scheme currently covers most sectors of the economy, including forestry, and has proposed to cover agricultural emissions at some point in the future.

Fencing stream banks and planting riparian buffers have been proposed in New Zealand as a key option to mitigate freshwater contaminants (LAWF, 2015; DairyNZ, 2013), with buffers also having the potential to reduce the country's GHG emissions (Vibart et al., 2015). Meurk and Swaffield (2000) even suggest targeted riparian restoration plans to help recreate the unique and culturally familiar landscapes of New Zealand. Despite the apparent value of buffers, riparian restoration programmes in New Zealand and elsewhere, tend to be piecemeal and to reflect individual industry or community actions. One key limitation is that unclear whether these initiatives will achieve the necessary environmental and biodiversity objectives for the nation. In addition, citizens are concerned that the benefits of implementing wide-scale restoration activities will outweigh the aggregate direct costs of developing riparian margins as well as the opportunity costs through lost agricultural revenues from reducing the area of productive land.

This objective of this paper is to assess the net benefits of uniformly implementing a national riparian restoration programme in New Zealand. We use an applied economic land use model to quantify the benefits and relevant costs of restoring riparian margins on all NZ streams flowing through land that is currently used for primary sector activities. The paper presents an analysis of the cumulative impact and costs of riparian restoration at different margin sizes, implementation costs, and mitigation effectiveness to estimate their net value in terms of enhancing water quality, carbon sequestration, and biodiversity. While the focus of the paper is on analysing the aggregate (i.e. nationwide) effects of a uniformly applied riparian restoration programme, we conduct extensive sensitivity analysis to determine where maximum net benefits could be attained depending on buffer width, primary sector, and spatial location across a total of 72 modelled scenarios. Our results support discussions of the value of having a riparian restoration network that effectively mitigates land-use impacts while restoring freshwater habitats and the multiple services they provide.

The foundation of our analytical model is similar to methods used in other analysis of policies in mixed agricultural-natural landscapes (e.g., Wätzold and Drechsler, 2005; de Bruin et al., 2009; Fernandez and Daigneault, 2016). That is, we integrate spatially explicit databases on land-use, farm profitability, and restoration costs with information on the impact-mitigating potential and biodiversity profiles of riparian margins. Our policy scenario approach is similar to landscape-scale studies focusing on valuing and analysing trade-offs of multiple ecosystem services that have recently emerged in the literature (e.g., Nelson et al., 2009). For example, Lawler et al. (2014) use analysed the impact of taxes, subsidies, and land use change restrictions on US carbon storage, food and timber production, and habitat provision, while Bateman et al. (2011) developed an integrated assessment model to analyse future oriented policy and decision-making in the UK. We build upon this literature by utilising a nationally comprehensive model of land use and various ecosystem services to estimate the potential benefits, costs, and trade-offs of uniformly applying a riparian restoration policy across all of New Zealand.

Extensive literature exists on the costs of restoration of riparian margins. Many of these studies estimated the construction, maintenance, and opportunity costs of riparian buffers applied to specific land uses such as agricultural crops (e.g., Nakao and Sohngen, 2000; Rickerl et al., 2000; Frimpong et al., 2007; Roberts et al., 2009; Sieber et al., 2010), and forestry (e.g., Carlén et al., 1999; Basnyat et al., 2000; LeDoux, 2006; Laurén et al., 2007). Other studies have looked at the impact to a watershed across several land uses (e.g., Chang et al., 2010; Trenholm et al., 2013). Watanabe et al. (2005) used an integrated bio-economic model to estimate the costs and benefits of passive versus active riparian restoration and found that the net benefits of each vary based on buffer width and the length of time since implementation. To our knowledge, no studies have analysed the benefits and costs of riparian restoration achieved via a uniform policy at the national-scale or over such a wide-range of land uses and environmental indicators, nor have they focused on the likely impacts of planting buffers in a livestock-dominant landscape such as New Zealand.

The paper is organised as follows. First, we present the theoretical foundation of the model and detail the data sources used for this study; next, we describe the mitigation potential from riparian planting options under consideration; following that, we present baseline land use, farm earnings, greenhouse gas (GHG) emissions, and other environmental outputs, followed by results from a series of riparian margin restoration scenarios; the final section provides a conclusion of our findings.

2. Model and parameterisation

2.1. Agri-environmental economic model

Our analysis uses a comparative-static agri-environmental economic model based on Daigneault et al. (2016) to estimate the benefits and costs of implementing a national riparian restoration programme along all permanent streams and rivers running through primary sector land. In the model, total economic returns from the New Zealand agriculture sector, calculated as annual net farm revenue (π), are measured as:

$$\pi = \sum_{r,s,l,e,m} \left\{ PA_{r,s,l,e,m} + Y_{r,s,l,e,m} - X_{r,s,l,e,m} \left[\omega^{live}_{r,s,l,e,m} + \omega^{vc}_{r,s,l,e,m} + \omega^{fc}_{r,s,l,e,m} \right] \right\} \tag{1}$$

where $\boldsymbol{P}$ is the product output price, $\boldsymbol{A}$ is the agricultural product output quantity, $\boldsymbol{Y}$ is other gross income earned by landowners (e.g., grazing fees), $\boldsymbol{X}$ is the area of specific farm-activity, and ω^{live}, ω^{vc}, ω^{fc} are the respective livestock, variable, and fixed input costs. Summing the revenue and costs of production across all regions (r),