Economic evaluation of sediment reduction measures at farms in New Zealand

by Utkur Djanibekov, Patrick Walsh, and Tarek Soliman

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Abstract

We assess the costs and benefits of introducing the sediment reduction target and consequent adoption of erosion and sediment control (ESC) measures in New Zealand. We use New Zealand Forest and Agriculture Regional Model (NZFARM) to analyse the impact of sediment reduction measures in each catchment on farm incomes and environmental outputs. We use NZFARM outputs to monetise environmental benefits of sediment reduction by applying a benefit transfer method. The NZFARM model results show that that to achieve the sediment reduction targets requires the adoption of both whole-farm planning and afforestation, where afforestation is most adopted. Farm profits increase with ESC measures due to low profits of farms and carbon sequestration revenues. In addition, depending on the discount rate, the monetised long-term environmental benefits of sediment reduction can be larger by $0.1 and $24.7 billion than their costs. The main returns from these benefits are from carbon and water clarity.

Keywords

Integrated economic modelling; Environmental valuation; Mitigation of environmental pollution; Freshwater policies; Multiple effects.

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[1] Manaaki Whenua – Landcare Research, Auckland, New Zealand

[2] United States Environmental Protection Agency, Washington, D.C., USA

1 Introduction

Pastoral agricultural production in New Zealand increases soil erosion and subsequently sedimentation into streams (Hicks et al., 2019), where it is estimated that 44% of total soils lost annually are in pasture (MfE and StatsNZ, 2018). This can have detrimental effects on water quality, aquatic life and cause landsliding, flooding, and siltation. To mitigate sedimentation in waterways, the policy and farm practice approaches need to be implemented by catchments. Over the last several years the New Zealand government has been developing policies within the National Policy Statement for Freshwater Management, National Objectives Framework and the Hill Country Erosion Fund to manage sedimentation. One of these policies can be the introduction of sediment reduction targets at each catchment that considers the catchment specific sediment loads. Achieving sediment reduction targets necessitates implementation of erosion and sediment control (ESC) practices and/or land management change at farms (Fernandez and Daigneault, 2017). For example, it was reported that ESC practices on 10% area of the most erodible farms can reduce sediment loads in catchments by 50% (Dymond et al., 2010).

Previous studies analysed the economic impacts on farms from implementing sediment reduction targets and adoption of ESC practices (Dymond et al., 2012). Fernandez and Daigneault (2017) analysed the erosion target policy and found out that this policy leads to adoption of mitigations, can be expensive and results in farm revenue decrease. Assessing particular ESC practice, Schwartz et al. (2016) showed that afforestation on eroded pastureland can significantly reduce sedimentation, yet, some studies argued that it can be uneconomic to farmers when evaluated in terms of tangible returns due to mainly reduction in pasture production and high establishment costs (Guevara-Escobar et al., 2007). At the same time, sediment reduction measures can provide various on-site and off-site benefits such as reduction in sediment, greenhouse gas (GHG) emissions and nutrient leaching, as well as increase in water clarity, carbon (C) sequestration and biodiversity (Dymond et al., 2012; Tait et al. 2016). Barry et al. (2014) estimated the value of avoided sedimentation to be about $5 per tonne through afforestation. Considering the various benefits of sediment reduction measures in the development of policies, can influence their implementation but can be difficult to value in economic terms.

To our knowledge previous studies have not assessed simultaneously the impacts of introducing sediment reduction policies and adoption of ESC practices on farms, and their subsequent various economic and environmental costs and benefits across catchments of New Zealand. To address this gap, the objectives of our study are (1) to analyse the impact of sediment reduction targets on adoption of ESC measures, environmental outputs and direct profits of farms, and (2) to monetise different environmental benefits from sediment reduction measures. We used both ex ante and econometric modelling approaches. First, we simulate the economic land use model for investigating the impacts of sediment reduction targets and adoption of ESC practices on farms at each catchment. Afterwards, using the results of the economic land use model, we monetise the value of environmental services from sediment reduction measures. For conducting these analyses, we obtain data from sediment model and other sources.

2 Methods

2.1 Economic land use modelling

We use New Zealand Forest and Agriculture Regional Model (NZFARM) to determine the impact of adoption of ESC measures in each catchment that can achieve the proposed sediment reduction targets on farm incomes and environmental outputs. NZFARM is an agri-environmental economic optimization model that NZFARM maximizes farm profits subject to available farms' land areas and environmental constraints (e.g. Daigneault et al. 2018; Figure 1). The model estimates costs from introducing ESC mitigation scenarios on the available mitigatable area subject to available mitigatable area (hereafter we refer to area) and constraint on meeting the sediment reduction targets at catchment scale. The NZFARM model is spatially explicit and considers all relevant farms across catchments where sediment reduction targets can be achieved. The study area catchments are only the catchments containing mitigatable land (suitable for ESC measures), which in total are 444 catchments across New Zealand. For simplicity of results interpretation, we present the results by regions for ESC adoption and for the entire country for the remaining results. Performance indicators tracked within NZFARM include economic indicators (e.g. costs and revenues), environmental indicators (e.g. sedimentation (from NZeem® model), greenhouse gas emissions (GHG), C (i.e. CO_2) sequestration, nitrogen and phosphorous leaching) and ESC measures (i.e. whole-farm planning (WFP), afforestation). Nutrient leaching and GHG emissions are modelled in physical units (i.e. not monetised) and thus are not reflected in the cost-benefit structure of NZFARM. Only C sequestration from afforestation is monetised in this model, because they directly affect land users' decision making.

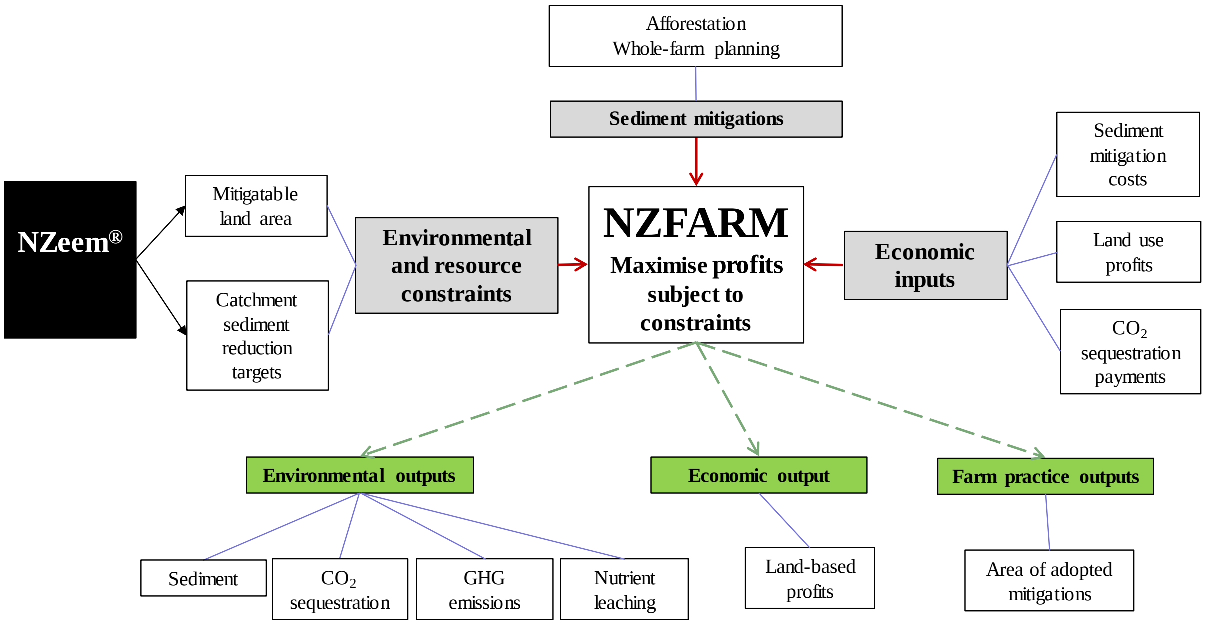

Figure 1. Schematic view of the NZFARM model (adapted from Daigneault et al. 2018).

Note: Grey boxes show the model input parameters. Green boxes show the outputs of the model. Black box shows the inputs from outputs of sediment modelling (NZeem®) for sediment reduction targets and sediment mitigatable area.

NZFARM models the following policy scenarios:

- A baseline scenario (Baseline) – includes the present pattern of farms' areas and sediment generation in catchments. We consider land use areas that have not adopted mitigations. We do not simulate any environmental policies to make a distinction between the effects of the sediment reduction target scenario from the baseline scenario;

- A sediment reduction target scenario – includes the target level of sediment reduction for each catchment and ESC measures. A sediment reduction target is included as a constraint and limits the sediment output in each catchment. We estimate the reduction target to be about 6.6 million tonnes from all study catchments of New Zealand. Sediment can be reduced by implementing ESC measures at farms such as afforestation and whole-farm planning (WFP; Table 1). Neverman et al. (2019) identified that the WFP and afforestation can be currently highly suitable practices to reduce sedimentation at farms. The model selects the optimal mitigation that allows for the sedimentation reduction target (or the highest sedimentation reduction level) to be achieved while maximising profits. We assume afforestation is not harvested and has an opportunity cost (from alternative land use). To make the mitigation costs comparable over time, we use the interest rate for establishment costs of mitigations. To reflect the existing Emission Trading Scheme policy, we include a payment of \$25/tCO_2 for CO_2 sequestration in the afforestation mitigation option. We assume CO_2 sequestration levels in afforestation reflect the permanent sequestration of *Pinus radiata*.

Table 1. Costs and environmental outputs of afforestation and whole-farm planning mitigations

Mitigation practice	Establishment cost, \$/ha	Establishment cost after applying interest rate, \$/ha	Nitrogen leaching reduction, %	Phosphorous loss reduction, %	C sequestration, tCO_2/ha
Afforestation	1,000	166.68	0.04	0.15	23
Whole-farm planning	300	17.90	0.2	n.a.	n.a.

Note: n.a. shows that whole-farm planning does not have information on phosphorous loss and C sequestration.

2.2 Environmental valuation and cost-benefit assessment

We use cost-benefit analysis to explore the overall benefits and costs of the sediment reduction scenario. We focus on use and non-use values of non-commercial applications, and the public's willingness to pay (WTP) for those values. For estimating benefits of environmental values, we use a benefit transfer method, where values from existing studies are transferred to the present context (Johnston et al. 2005). For valuation of co-benefits of sediment reduction, we use as the information from other approaches such as NZFARM, and modelling on relationship between sediment loads, turbidity and water clarity (Figure 2).

We look at two alternative values for the avoided cost of erosion. The lower value is from the Dymond et al. (2012) estimate of \$1/tonne, updated for inflation. For an alternative value, we use the inflation adjusted midpoint between the Dymond et al. (2012) and the Barry et al. (2014) estimates, which is about \$3/tonne.

Sediment is also associated with changes in water clarity, so we use the outputs of the NZFARM results. Tait et al. (2016) is the most appropriate study to be used in a benefit transfer for deriving WTP for improvements in water quality. To reflect the fact that thresholds differ across areas and rivers, they sorted values into poor (less than 1.2 m), moderate (between 1.2 and 2.4 m), and good (2.5 m or more). The WTP values for this estimate are updated to 2019 values via the Reserve Bank of New Zealand's inflation calculator.[3] Then the WTP values are adjusted by median household income of the region.

When there are increased levels of sediment in the water, it imposes additional costs on public utilities and hydroelectric companies, through equipment damage, and increased filtration costs. These companies conduct dredging in nearby waterbodies to reduce the sedimentation entering their facilities. We obtained a list of the lakes and reservoirs that are associated with hydropower generation and used estimates from Hicks et al. (2019) on the sediment load entering those waterbodies, as well as the sediment retained by the waterbody after its output into other waterbodies. To calculate the potential reduction in sediment load, we identify which of these waterbodies are in feasible catchments, as identified by NZFARM outputs. We received information from several industry projects on costs of dredging, producing a low and high values from these projects.

Mitigations to control sediment can also have impacts on climate change mitigation through GHG emissions and C sequestration. We use the outputs of changes in GHG emissions and C sequestration from NZFARM and price of $25/tCO_2$ in Emission Trading Scheme to reflect climate change mitigation benefits of sediment mitigations. We use the social cost of carbon prices of 2.5%, 3%, and 5%, which are discount rate and year dependent, as alternatives to the Emission Trading Scheme price and to have a comparison of the potential value of C changes.

We use a timeline of 50 years and calculate the net present values (NPV). This timeframe was developed with Ministry for the Environment to represent at least two generations and capture the main effects. We use 4% and 6% discount rates as suggested by the New Zealand Treasury.[4]

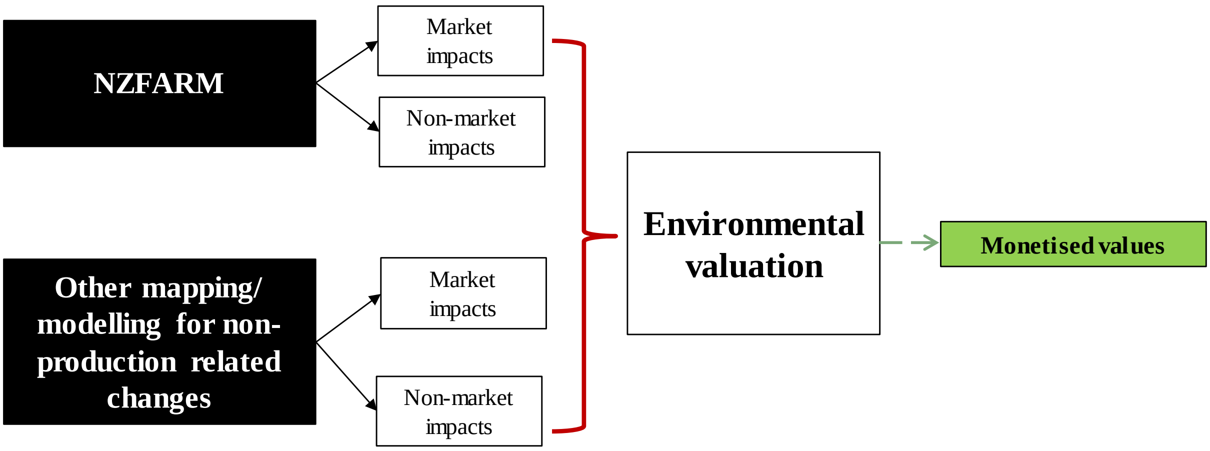

Figure 2. Cost-benefit analysis approach.

Note: Green box shows the outputs of the model. Black boxes show the inputs from outputs of NZFARM modelling and other mapping/modelling approaches.

2.3 *Data sources*

To estimate the economic impact of ESC measures, we need to identify land use areas that are affected by sedimentation and suitable for ESC measures to meet the sediment target. The required catchment sediment load reduction is the average sediment load reduction for all

[3] https://www.rbnz.govt.nz/monetary-policy/inflation-calculator

[4] https://treasury.govt.nz/information-and-services/state-sector-leadership/guidance/financial-reporting-policies-and-guidance/discount-rates

stream segments within the defined catchment. Data on sediment loads within the catchment and sediment load reduction requirements for each catchment are obtained from Neverman et al. (2019). Neverman et al. (2019) applied the New Zealand Empirical Erosion Model (NZeem®) to calculate the sedimentation rates and targets, and effect of sediment mitigation. NZeem® is fully described in Dymond et al. (2010). The study area catchments are only the catchments containing mitigatable land (suitable for ESC measures), which in total are 444 catchments across New Zealand. For simplicity of results interpretation, we present the results by regions for ESC adoption and for the entire country for the remaining results.

We consider information for pastoral land uses that do not have forestry plantations. We derived the spatial land use information on profits, GHG emissions, CO_2 sequestration, and nutrient leaching based on data collected from DairyNZ, Beef+Lamb New Zealand economic data, MfE (2017), and Daigneault et al. (2018). Data on ESC costs and environmental outputs are from Daigneault et al. (2017). We also use NIWA's water clarity data, which used national modelling to estimate relationships between sediment loads, turbidity, and water clarity.[5] We used information from Tait et al. (2016) for the water clarify analysis in a benefit transfer.

3 Results

3.1 Area of mitigations

The baseline NZFARM results show that about 1.8 million ha of land is suitable for afforestation and WFP mitigations and can meet the sediment reduction targets (i.e. feasible in the Baseline column of Table 2), and about 0.45 million ha of land is suitable for mitigations but cannot meet the sediment reduction targets (i.e. infeasible in the Baseline column of Table 2). The feasible area is land in which catchment sedimentation reduction targets can be met through the two mitigation options. The infeasible area represents area that cannot meet the catchment sediment reduction targets even after implementing afforestation, which has the highest sediment reduction potential (90%).

To meet the sediment reduction targets, afforestation is needed on about 1.056 million ha and WFPs on 6,055 ha. After meeting the catchment sedimentation reduction targets, about 1.2 million ha do not need any mitigations and remained in the current land use. The area of afforestation in feasible catchments is about 606,000 ha, and the afforestation area in infeasible catchments is about 450,000 ha. Afforestation is needed on the entire infeasible area that is suitable for mitigations to approach as close as possible the sedimentation reduction target levels (see Table 3). The region with the most afforestation is Otago, which needs about 53,000 ha and 376,000 ha of afforestation on feasible and infeasible catchments respectively. Such large-scale adoption of afforestation is due to its high sediment reduction effectiveness, revenues from C sequestration and low annualized costs (see Table 1).

[5] As detailed in https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/Sediment_Attributes_Stage%201_0.pdf

Table 2. Land area allocated for no mitigation, whole-farm planning and afforestation across regions in baseline and sedimentation reduction target scenarios, in 1,000 ha.

Regions	Baseline		Sedimentation reduction target scenario: Area that does not require further mitigation	Sedimentation reduction target scenario: Whole-farm planning	Sedimentation reduction target scenario: Afforestation	
	Feasible	Infeasible	Feasible	Feasible	Feasible	Infeasible
Auckland	4.7	1.1	3.5	0.0	1.2	1.1
Bay of Plenty	39.3	0.6	30.0	0.4	8.8	0.6
Canterbury	501.7	35.1	280.1	0.2	221.3	35.1
Gisborne	134.3	0.1	89.4	0.0	44.9	0.1
Hawke's Bay	245.2	n.a.	215.5	0.0	29.7	n.a.
Manawatu-Wanganui	3.2	3.3	1.4	0.04	1.8	3.3
Marlborough	119.4	0.04	94.1	0.0	25.3	0.0
Northland	63.3	0.2	41.3	0.0	22.1	0.2
Otago	136.6	375.9	83.5	0.5	52.6	375.9
Southland	135.8	30.3	83.1	2.8	50.0	30.3
Tasman	10.5	n.a.	10.1	0.0	0.5	n.a.
Taranaki	2.0	0.7	0.7	0.7	0.6	0.7
Waikato	321.5	0.1	197.1	1.1	123.2	0.1
Wellington	100.9	0.8	76.9	0.2	23.8	0.8
West Coast	0.2	1.4	0.1	0.0	0.1	1.4
Total	1,818.6	449.6	1,206.7	6.1	605.8	449.6

Note: The feasible column includes the area of regions with catchments that can meet the sediment reduction target. The infeasible column includes the area of regions with catchments that cannot meet the sediment reduction target. n.a. for Hawke's Bay and Tasman means there are no infeasible catchments in these regions.

3.2 Sediment and other environmental outputs at farms

Sediment load reduction targets are about 3 million tonnes on feasible area, and 3.6 million tonnes on infeasible area. By implementing afforestation and WFP on land in feasible and infeasible catchments, sediment load can be reduced by about 4 million tonnes (13%; Table 3). Even after adopting sediment mitigations, sediment load is highest for Gisborne, and this region has about 1.6 million tonne (12%) reduction from the baseline (not presented here). In relative terms, West Coast region has the largest sediment reduction, i.e. about 88% reduction from the baseline (not presented here). Afforestation leads to the largest sediment load reduction due to its 90% sediment reduction effectiveness and the large area of afforestation implementation. WFP has a lower reduction because of lower sediment reduction effectiveness (70%) and smaller implemented area than afforestation. Large areas remained under land uses that did not require any modelled mitigations and thus substantial sediment load is from these areas.

Table 3. The modelled sediment load levels in baseline and sedimentation reduction target scenarios, in 1,000 tonnes.

Scenarios	Mitigation options	Feasible (loads from feasible area)	Infeasible (loads from infeasible area)
Baseline	n.a.	28,531	1,048
Sedimentation reduction target			
	Sediment load from area that does not require further mitigation	25,228	0
	Afforestation	329	105
	Whole-farm planning	5.6	0

Note: The feasible row includes the sediment load with catchments that can meet the sediment reduction target. The infeasible row includes the sediment load with catchments that cannot meet the sediment reduction target. The baseline and scenario results are presented for the mitigatable areas of the catchments while the required reduction targets are those set for the whole catchment (mitigatable and non-mitigatable land).

Farms also can have substantial GHG emission reduction with ESC mitigations, i.e. GHG emissions are lower by 2.3 million tCO_2 (34.5%) than in the baseline (Table 4). The largest share of GHG emission reductions are from catchments in regions that cannot meet the sediment reduction targets because these infeasible catchments entirely afforest their land area and are thus assumed not to emit GHG. In addition, there is 19.8 million tCO_2 sequestered above the baseline through establishing afforestation. We do not consider C sequestration in the baseline scenario, because in the baseline we assume only pastoral land uses without forestry. The net GHG emissions (subtraction of C sequestration from GHG emissions) in the sediment reduction target scenario is 15.4 million of tCO_2 sequestrated.

The total nitrogen leaching at farms reduces by 338 tonnes from the baseline when sediment mitigations are implemented. However, it should be noted that due to a lack of data, we did not consider the change in nitrogen leaching from WFP. Phosphorous loss reduces by 65 tonnes after the implementation of sediment mitigations.

Table 4. GHG emissions, CO_2 sequestration, nitrogen leaching and phosphorous loss outputs in baseline and sedimentation reduction target scenarios, in 1,000 tCO_2.

Scenarios	GHG emissions	CO_2 sequestration	Nitrogen leaching	Phosphorous loss
Baseline	6,703	0	26,811	1,264
Sedimentation reduction target				
Feasible area	4,393	12,090	23,759	1,081
Infeasible area	0	7,675	2,714	118

Note: The feasible row includes the GHG emissions, C sequestration, nitrogen leaching and phosphorous loss for catchments that can meet the sediment reduction target. The infeasible row includes the GHG emissions, C sequestration, nitrogen leaching and phosphorous loss for catchments that cannot meet the sediment reduction target. The baseline and scenario results are presented for the mitigatable areas of the catchments.

3.3 Direct impacts on farm profits

Implementing the mitigation options (WFP and afforestation) directly affects farm profits (Table 5). The afforestation establishment costs have the largest costs related to mitigations, which amount to about $176 million (almost 56% of costs). Opportunity costs amount to $140 million (44% of costs). If not considering C sequestration revenues (under $25/t$CO_2$), the total profits from mitigatable land areas reduce by $315.7 million (39% reduction) from the baseline. Including C sequestration payments generates about $494 million in revenue. As the pine forest are permanent, not harvested, and receive C sequestration payments, this leads to the high revenues. Taking the difference between the revenues ($494.1 million from C sequestration payments) and costs ($240.8 million from establishment and opportunity costs) of the mitigations, $253.3 million in profits is gained from the mitigations in each year. Thus, modelled sediment reduction mitigations along with C sequestration payments increase land use profits.

Table 5. Annual profit in baseline scenario, and costs and revenues in sedimentation reduction target scenario across regions, in $ million.

Scenarios	Types of costs and revenues	Costs and revenues in feasible and infeasible areas	
		Feasible	Infeasible
Baseline	Total net returns	709	94
Sedimentation reduction target			
	Whole-farm planning establishment costs	0.1	0
	Opportunity costs	46	95
	Afforestation establishment costs	101	75
	C sequestration revenues	302	192
	Net returns	864	117

Note: The feasible row includes the profits, costs and revenues by regions for catchments that can meet the sediment reduction target. The infeasible row includes the profits, costs and revenues by regions for catchments that cannot meet the sediment reduction target. The baseline and scenario results are presented for the mitigatable areas of the catchments.

3.4 Cost-benefit of sediment reduction

There are also non-monetised benefits and impacts on wider society via the change in environmental outputs from introducing sediment reduction measures. Using the NZFARM results on sediment outputs, we determine the resulting clarity, GHG emissions, C sequestration, sediment output, and dredging improvements. A summary of the national effects of monetising benefits and costs of sediment reduction scenario is given in Table 6. The results show that the NPV of the sediment reduction benefits over 50 years with 4% discount rate are $75 million and $226 million with $1/tonne and $3/tonne respectively of the marginal avoided cost of sedimentation. Under 6% discount rate the 50-year NPV of sediment benefits are $51 million and $154 million with $1/tonne and $3/tonne respectively of the marginal avoided cost of sedimentation.

With the sedimentation reduction scenario that uses ESC measures, New Zealand has about 3% improvements in water clarify. The discounted NPV of water clarity benefits over 50 years for 4% and 6% discount rates are approximately $334 and $504 million respectively. Sediment reduction also brings the dredging benefits. For estimating dredging benefits, we have identified 20 waterbodies, this resulted in an average sediment load reduction of 2 to 16%. That amount is applied to the amount of sediment retained in each waterbody as a result of the modelling. For the 20 waterbodies identified, the average reduction is 10,000 tonnes. Consequently, we calculate the average costs per tonne of dredging, producing a low and high value from several different industry projects. The estimates of dredging benefits ranges from $19 million to $31 million.

In addition to NZFARM outputs on C sequestration benefits, we value carbon benefits. To value these benefits, we include both changes in GHG emissions and increases in carbon sequestration. The 50-year NPV of carbon benefits varies between a low of $5 billion at the 5% social carbon cost rate and a high of $31 billion at the 2.5% social carbon cost rate.

Besides environmental benefits of implementing ESC measures, there are also associated costs. There are several important differences in costs between the baseline and the modelled scenario. As modelled in NZFARM, these include the lost profit from switching land uses, the additional establishment costs involved with afforestation, and the costs associated with setting up whole farm plans (for description of annual costs see section 3.3.1). The NPV of these costs over 50 years ranges are $5.3 and $7.1 billion for 6% and 4% discount rates respectively.

When bringing together all the monetised environmental benefits of ESC measures (i.e. sediment reduction scenario) and their costs, the net returns of NPV over 50 years ranges between $1.5 and $31.8 billion with 4% discount rate, and between $0.1 and $16.2 billion with 6% discount rate.

Table 6. Monetised benefits and costs over 50 years, NPV in $millions.

Description of costs and benefits	4% discount rate	6% discount rate
Cost		
Lost profit, increased costs	7,098	5,292
Benefits		
Avoided cost of dredging	27–31	19–22
Avoided cost of sediment	75–226	51–154
Carbon benefits	8,000–31,000	5,000–21,000
Water clarity benefits	504	334
Net returns (benefits – costs)	1,508–31,761	112–16,218

4 Conclusions

Our study shows that successfully reaching sediment reduction targets requires the adoption of afforestation and WFP mitigations. The adopted areas of mitigation substantially differ across regions, with the afforestation option being most adopted. Two reasons for this higher rate of adoption are that afforestation has higher sediment reduction effectiveness than WFP and it earns revenues from C sequestration. While afforestation can meet the sediment reduction target and generate C sequestration revenues, in many catchments there are some areas where WFP is applied to avoid the opportunity costs of land-use change to afforestation. Also, imposed sediment reduction targets in some catchments are unrealistic to achieve given the current mitigations.

Introducing the sediment reduction measures can increase the direct farm profits (i.e. considering currently marketed benefits). Increase in such profits is due to currently low profits of pastoral farms on these sedimentation areas. With C sequestration revenues the sediment reduction target scenario increases annual profits. The large C sequestration revenues are because of the model's assumption that the afforested areas will not be harvested and will continue to sequester C and generate its revenues.

There are several environmental benefits from ESC measures that we monetised such as sediment reduction, water clarity, dredging, GHG emission reduction and C sequestration. When monetising these environmental outputs, the net benefits of sediment reduction measures are substantially larger than their costs. It should be noted that these are likely underestimates of the true values. For example, we calculate the value people have for changes in water clarity in their region. It is likely that they also have use and non-use values for waterbodies outside of their region. We also assume that the changes to water clarity in urban areas are zero, as this study did not consider urban catchments. In addition, as recommended by Treasury of New Zealand we use discount rates of 4% and 6% to calculate NPV, which are fairly high as noted in Social Cost of Carbon literature (Weitzman 1994) and thus will reduce the value of longer-term benefits, e.g. C sequestration, and increase the value of shorter-term costs. At the same time, there are currently several policy goals committed to by the New Zealand government that might push C prices even higher and could provide increased incentives for afforestation. The C benefits in this study may therefore be underestimates. Moreover, several other benefit categories that can be monetised from ESC measures, such as biodiversity and habitat benefits, nutrient leaching reduction benefits, as well as the benefits to threatened and endangered species.

The study shows high economic and environmental benefits from having sediment reduction measures, especially considering that afforestation is established on large areas. However, afforestation on such large areas might not be possible in a short time frame. Based on historical observations, the largest area of afforestation in a single year was about 90,000 ha. Institutional support is needed for large scale afforestation, such as credits to farmers to assist with initial planting costs. Additionally, New Zealand currently does not have sufficient number of nurseries to provide the amount of tree saplings that would be needed for large-scale afforestation. Increasing the number of nurseries will be vital to address the sedimentation reduction objectives. Furthermore, such large-scale afforestation might reduce water yield, which could affect nearby agriculture.

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