Valuing Changes in New Zealand Marginal Land: Water Quality, Carbon, and Afforestation

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Abstract: With its varied landscape of hills and mountains, New Zealand has an abundance of marginal land on its slopes. This land is currently used in a variety of enterprises, such as pasture and farm land. However, marginal land is typically associated with higher rates of erosion, shallow topsoil, expensive fencing, and other issues like livestock deaths from falls. There is currently interest in deploying these marginal lands to different uses to align with several environmental and production related goals. This paper contributes to the discussion on marginal land by exploring three different scenarios related to afforestation in the Manawatu area. To analyse these scenarios we bring together several complex and spatially explicit datasets, which are linked using economic modelling tools and benefits transfer. The thin local literature and preference for local studies produce several methodological challenges familiar to smaller countries. We illuminate several tradeoffs in a large valuation exercise, in particular between current advances in international and local studies.

Keywords

Climate change; Benefit transfer; Economic land use model; Manawatu catchment

I. Introduction

The sustainable management of marginal land poses significant challenges to New Zealand due to its physical, economic, and cultural complexities (Cameron, 2016; Scrimgeour, 2016; Lynn et al., 2009). Although marginal land represents approximately 40 percent of the total land area in New Zealand, it only contributes a small proportion to total national income (Walsh et al., 2017; Blaschke et al., 1992). This land is currently used in a variety of enterprises, such as pasture and farm land. However, marginal land is typically associated with steep slopes, higher rates of erosion, shallow topsoil, and is prone to several climatic hazards such as flooding and storm events (Lynn et al., 2009). Fragmentation of the land and disconnection with supply chains also constrain the productivity of several land uses (Scrimgeour, 2016).

There is currently interest in deploying these marginal lands to different uses to align with several environmental and economic national targets such as carbon neutrality by 2050, and enabling 90 percent of New Zealand's main rivers and lakes to be swimmable by 2040 (MFE, 2011; NPS, 2017). Recently, the government has incentivised the conversion of pasture farming to more sustainable land uses by introducing national programs such as the Emissions Trading Scheme (ETS), Permanent Forest Sink Initiative (PFSI), and the Afforestation Grant Schemes (AGS) (Jiang et al., 2009; MPI, 2015; MPI 2018). These programs aim to provide alternative cash flows to sustainable land uses through environmental payments mechanisms that stimulate a fast transition path towards the climate and water quality national targets. Several local sources have had success with exotic forestry and Manuka production on marginal lands, which could provide several important ecosystem services and fulfil regulatory goals. Both exotic plantation forestry operations and indigenous afforestation represent carbon sinks, with several important trade-offs in marginal costs, production revenue, and complementary ecosystem services.

As several land uses could maintain forest cover for long-term profit while reducing adverse environmental outputs, assessing the impacts of permanent forests compared with plantation forests and other land uses is a key step in understanding how to enhance the economic and environmental performance of marginal land. Although the issues with marginal land discussed here are encountered in many countries, there are currently very few tools available to analyse these trade-offs in a holistic manner. This paper highlights some of the central reasons for that, including the need for spatially explicit, locally tailored environmental data, modelling outputs, and non-market valuation. While some of the main components of our analysis have been used before in New Zealand, such as carbon emissions modelling (Scrimgeour et al. 2005), water quality valuation (Tait et al.), and land use modelling (Daigneault et al.), this is one of the first papers to combine and integrate a variety of tradeoffs in a modelling framework for policy analysis. Data, modelling, and analysis tools from multiple fields are all used to estimate policy impacts.

This paper contributes to the discussion on marginal land by exploring three different scenarios related to afforestation in the Manawatu area of the North Island. Most of the Manawatū catchment is covered by pasture, as much of the original indigenous forest has been cleared for farming. The clearing of the indigenous forest has led to erosion and other environmental problems on steep slopes in the area (Ausseil et al. 2013). Based on guidance from the Ministry for Primary industries (MPI), we focus on three scenarios: one where exotic plantation trees are used for afforestation, and two variations of an indigenous afforestation scheme. To analyse these afforestation scenarios we bring together several complex and spatially explicit datasets, which are linked using economic modelling tools and benefits transfer. We model several important outcomes related to each of these scenarios, including primary ecosystem services associated with afforestation, as well as opportunity costs associated with land conversion. After using several spatial resources and models to identify potential marginal land for our afforestation scenarios, we use benefit transfer to assign non-market values where possible. Overall we find that two out of three of our scenarios have monetised net benefits. However, there are several important benefit categories, such as cultural services, which were not monetized and could justify the third scenario.

II. Background and Setting

The Manawatū catchment is located in the Manawatū-Wanganui Region in the North Island of New Zealand (Figure 1). Most of the Manawatū catchment is covered by pasture, as much of the original indigenous forest has been cleared for farming over the last 150 years or so. The clearing of the indigenous forest has led to erosion and other problems on steep slopes in the area (Ausseil et al. 2013).

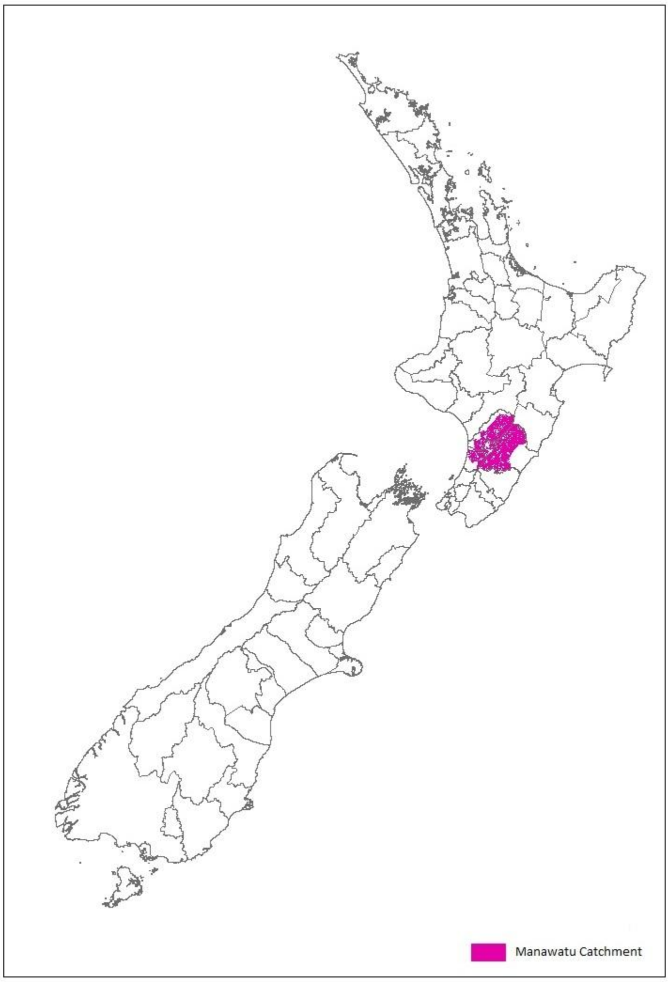


Figure 1: The Manawatu catchment.

The focus of this analysis is on the afforestation of marginal lands—those with steep slopes. However, many marginal land areas are unsuitable for afforestation, so we first need to identify appropriate locations. A previous project funded by the SLMACC programme explored several afforestation suitability classes, using the New Zealand land cover database, temperature data, other environmental variables, and land use capability maps (Watt et al. 2011)[1]. Using the most recent land cover map (2012–2013), and data and input from that study's authors, we have reproduced their main options. [2] For our analysis, we use Watt et al.

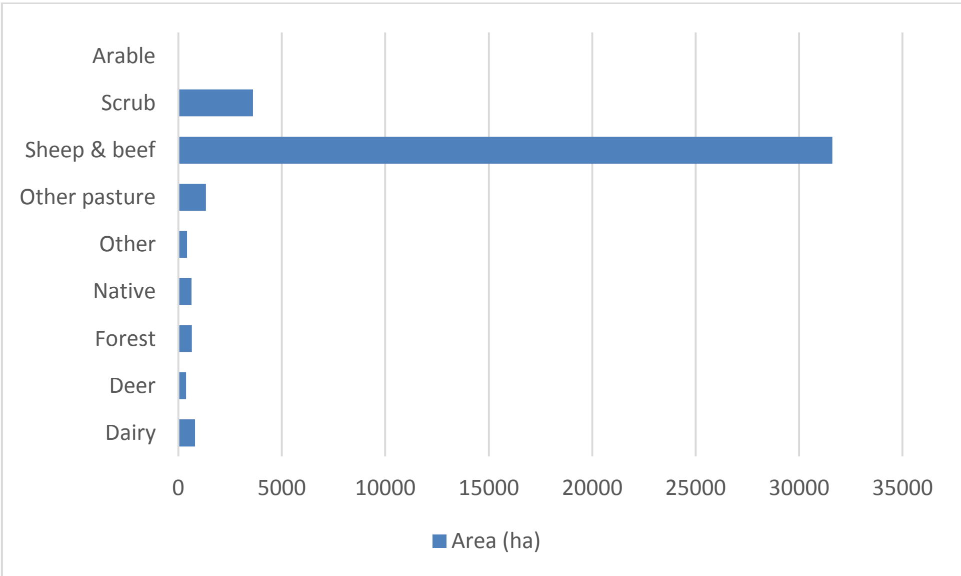
[1] Sustainable Land Management and Climate Change (SLMACC) Research Programme: https://www.mpi.govt.nz/funding-and-programmes/farming/sustainable-land-management-and-climate-change-research-programme/

[2] The most recent version of the NZ LCDB, which was released across 2012/2013, can be found at: https://lris.scinfo.org.nz/layer/423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/.

(2011)'s most conservative scenario, which has the smallest afforestation area as it excludes the steeper sloped parcels of land. That land is less likely to face competition for other higher value agricultural uses, and it is therefore the least disruptive policy option.

Figure 3 depicts the identified marginal lands that could be used for afforestation in dark green.[3] Approximately 40,000 ha of land were identified for new afforestation in the Manawatū catchment. The distribution of current land uses in the new afforestation areas is found in Figure 2, where the most prevalent existing land use is sheep & beef, at approximately 32,000 ha.

Figure 2: Current land uses in identified afforestation areas of the Manawatū catchment



[3] Note that we omit all conservation and reserve land from the analysis, as it is highly unlikely that those lands would be converted .

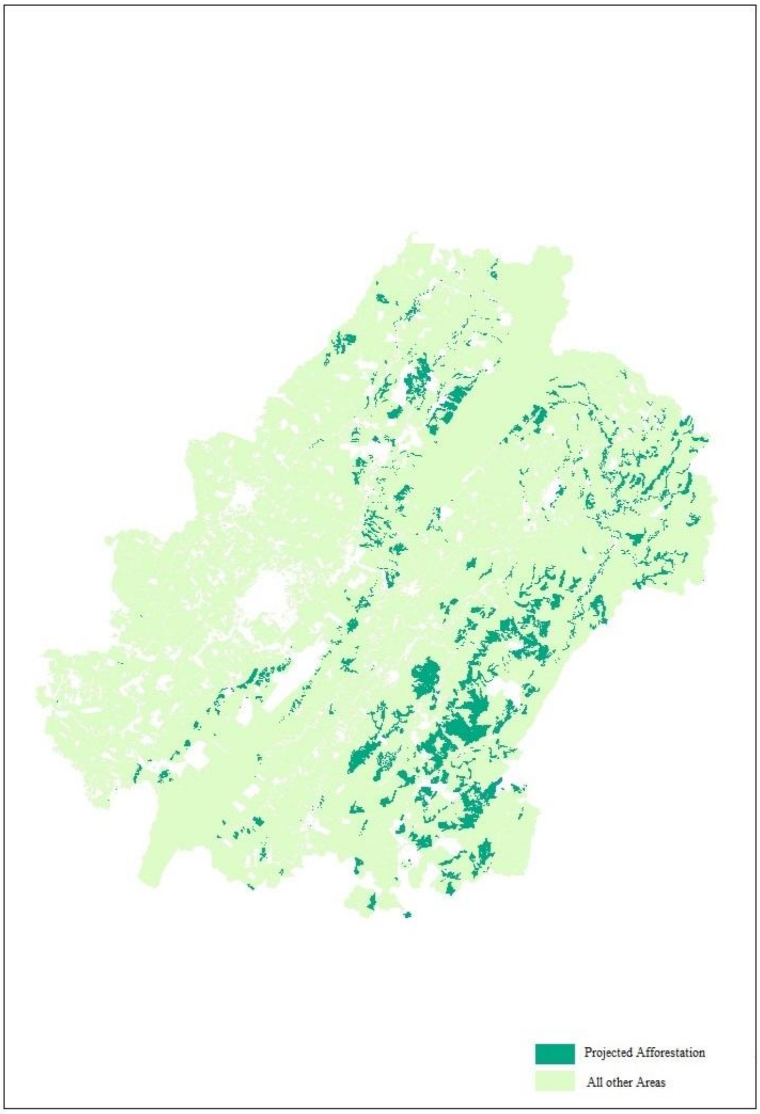


Figure 3: Afforestation areas in the Manawatu catchment.

We also explored the potential of these lands for natural afforestation. In some areas of New Zealand, active afforestation is required for indigenous forest. The probability of natural reversion depends on landscape and location-based factors. We use models from Mason et al. (2013) to identify areas of active afforestation. Mason et al. (2013) selected 10,061 plots from New Zealand's National Vegetation Survey Databank (surveyed from 1982-2008), and analyzed them to identify central environmental and land cover influences that affect the occurrence probability of indigenous vegetation.

Mason et al. (2013) found that the most important environmental variable was mean annual temperature, while the most predictive land cover variables were local woody cover and distance to forest. We obtained the model results and GIS maps from the authors of Mason et al (2013). Results indicate that the Manawatu is quite suitable for indigenous afforestation, with only a few hectares in the south west of the region needing active afforestation (less than 4 ha of identified afforestation areas were identified as needing active planting, so for our purposes this was assumed to be effectively zero).

In consultation with MPI, this paper models three scenarios for the afforestation areas. In the first scenario, hereafter **Scenario E**, afforestation areas are planted with exotic pine for plantation forestry. The second scenario (**Scenario I)** assumes the areas are afforested with permanent, non-rotation indigenous forest. Those areas are therefore removed from production. The third scenario (**Scenario IM**) assumes the land suitable for mānuka/kānuka in the new afforestation areas remain in mānuka/kānuka and are used for enterprises such as medical or commercial honey production.

Mānuka and Kānuka Suitability

Honey production has received significant attention in New Zealand due to the recent expansion of Mānuka honey products. In addition to its use as a luxury sweetener, Mānuka honey has antibacterial properties that lend it to several surgical and medical applications. Very high-grade honey can sell for a significant premium over traditional honey. The number of registered beekeeping enterprises rose from 3,267 in 2011 to 6,735 in 2016.[4] Due to this rapidly increasing production, which depends on indigenous trees, we model the potential for the afforestation land to support Mānuka operations. For Scenario IM, we therefore estimate where mānuka/kānuka is more likely to occur and potential differences in the opportunity

[4] See the apiculture reports at https://www.mpi.govt.nz/news-and-resources/publications/ for more information.

cost between keeping that land in honey production versus leaving to indigenous forest. The Manawatu area is currently one of the most productive areas in New Zealand in terms of existing production.[5]

To estimate honey production areas, we adapted Watt et al. (2012)'s predictive model of mānuka/kānuka suitability, where the growth of mānuka/kānuka stands were modelled using a physiologically based growth model (CenW 4.0). Mean annual temperature and precipitation were identified as the best predictors, so we used equations from Watt et al. (2012) to define the probability of occurrence of mānuka/kānuka as a function of temperature and precipitation.[6]

Using those models, in areas where the probability of occurrence from both temperature and precipitation are greater than 50%, the land is designated as having the potential for mānuka/kānuka stands. Of the almost 40,000 ha identified as new afforestation areas, approximately 24,000 ha are suitable for mānuka/kānuka. The identified areas are coloured purple in Figure 4, while the new afforestation areas not suitable for mānuka/kānuka appear in dark green.

[5] Annual production figures for the combined area of Hawke's Bay/Wairarapa/Manawatu/Taranaki/Wellington are the highest in the country, as per MPI's 2017 Apiculture Monitoring Programme Report.
[6] Given the difficulty in predicting mānuka and kānuka, it is important to emphasize that this model may miss other characteristics related to their growth, such as soil conditions. More detail regarding these equations is found in the extended MPI report related to this paper.

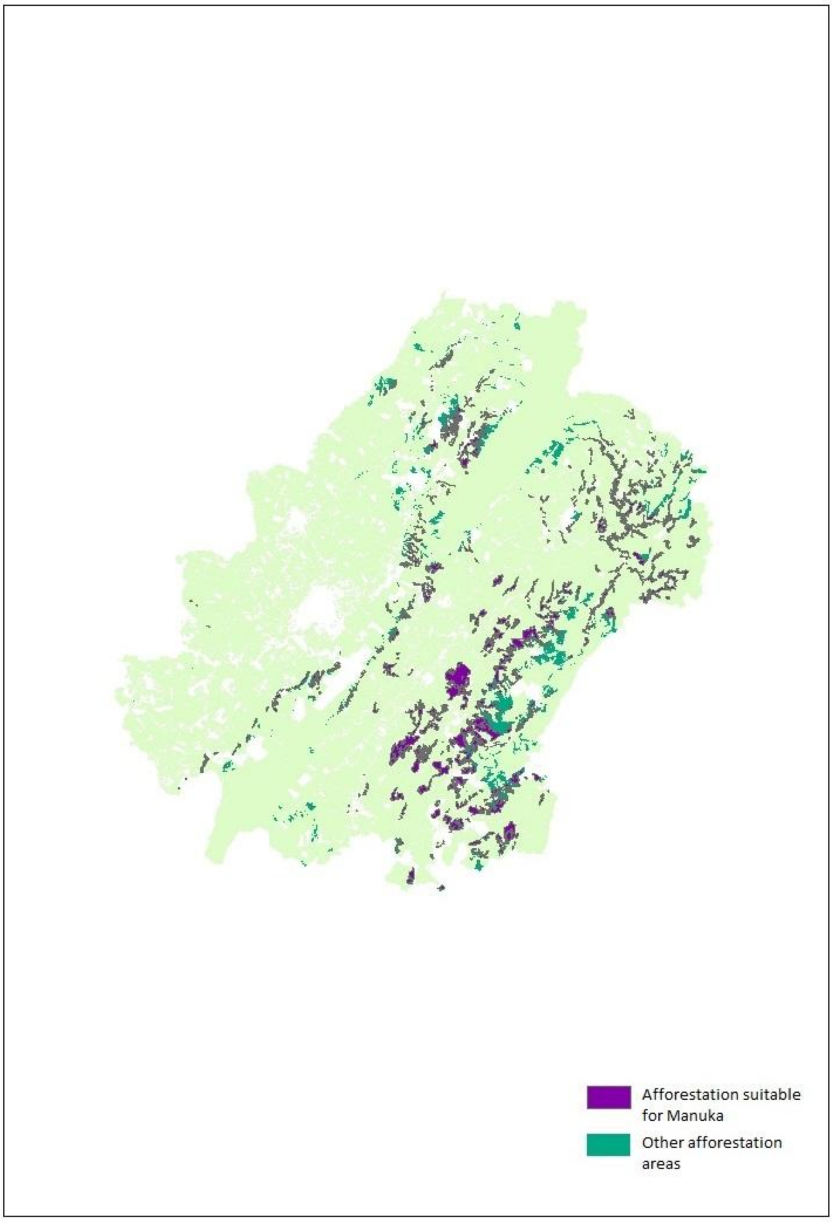


Figure 4: Areas suitable for mānuka/kānuka in the Manawatu catchment.

Given the potential areas for mānuka/kānuka, the next step is to obtain potential honey revenue. This is inherently difficult, as there is limited information on the profitability of honey production in New Zealand. There also appears to be significant variability in profits and honey quality.[7] For our purposes, it is more important to estimate the total ratio of different types of honey production at a broad level, as opposed to pinpointing the location of high versus low profitability areas of honey production.

[7] For instance, the April 2017 issue of *New Zealand Beekeeper* highlights significant variation in honey yields over the past year, even on the same plot of land.

We use information gathered from trade associations and beekeepers by Daigneault et al. (2015) to estimate the EBIT from honey.[8] Based on that report, we developed three profitability types for honey production. The least profitable honey operation is a self-managed operation. The next operation involves hiring a beekeeper, which is marginally more profitable than a self-managed operation. The most profitable honey operation involves the use of a beekeeper and the production of high UMF honey, which is quite rare. There is unfortunately a dearth of information in the literature and from the trade associations about predicting UMF level on a particular landscape. Discussions with Apiculture New Zealand indicated that some of the central influences on UMF include: history of production on a landscape, soil quality, rainfall, climate, altitude, and genotype.[9]

Since several of those factors are included in the Watt et al. (2012) prediction equations we use to identify land suitable for mānuka/kānuka, we have adapted them to predicting the potential of honey operations. Those equations produce probability scores for each area on the ability to support mānuka. As a fairly conservation assumption, we assume that only the 99th percentile of mānuka afforestation areas, in terms of rainfall and temperature probability, are suitable for high UMF production. The remaining area with mānuka is assumed to be split between the other two profitability types.

Modelling Methodology

In this paper, we use a cost-benefit analysis framework that compare the benefits from reducing the adverse environmental outputs and additional revenues from forestry to the opportunity cost of lost production due to changing land from its current use (e.g. pastoral) to forestry. This framework integrates economic land use model (i.e. New Zealand Forestry and

[8] The final report can be found at: http://www.maniapoto.iwi.nz/wp-content/uploads/2016/04/1.-Economic-Analysis.pdf

[9] There is a new MBIE programme "Building resilience and provenance into an authentic Māori honey industry" led by Landcare Research that is starting to address some of these challenges.

Agricultural Regional Model − NZFARM) with a benefit transfer (BT) approach (Daigneault, Greenahlgh, & Samarasinghe, 2018; Walsh et al., 2017). NZFARM model will estimate net revenues of old and new land uses as well as quantifying the adverse environmental outputs. The BT approach will monetize those environmental outputs that were estimated by NZFARM. By doing so, all the costs and benefits components in our framework will be expressed in dollar terms and will be comparable.

In the NZFARM model, total earnings from different land uses are calculated as discounted annual net revenue of each farm type as follows:

$$\pi = \sum[PQ_i - C_i(L_i, F_i, V_i)]A_i$$

where π is the total net revenues, P is the output price, Q_i is the output quantity of farm type *i*, C_i is the cost of farm type *i which is determined by the livestock density* (L_i), *fixed costs* (F_i) *and variable costs* (V_i). A_i is the total area of farm *i*.

In order to estimate the total revenue, we first identify the land uses in the Manawatū catchment based on a land use map developed by integrating the New Zealand Land Cover Database (LCDBv4) and Agribase[10] (MfE, 2018). Economic information on the inputs and outputs of the production process was obtained from several literature sources (MPI, 2013a, b; Lincoln University Budget Manual, 2013; Newsome et al., 2008). In addition, the model tracks several environmental externalities such as Greenhouse Gas (GHG) emissions, nitrogen (N) leaching, and phosphorous (P) loss. GHG emission rates were derived using the national GHG inventory methodology (MfE, 2014). N and P leaching were estimated using the OVERSEER v6 nutrient budgeting tool and other literature (Wheeler, 2012; Lilburne et al., 2010; Parfitt et al., 1997).

Ecosystem services classification

[10] https://www.asurequality.com/our-solutions/agribase/

To better evaluate the full range of costs and benefits for the afforestation scenarios, we use the ecosystem services classification (MA 2005). The Millennium Ecosystem Assessment (MA)[11] defined ecosystem services as "the benefits people obtain from ecosystems," which the MA classify as provisioning, regulating, supporting, and cultural services (**Table 1**).[12]

Table 1: Ecosystem services categories

Provisioning Services	Regulating Services	Cultural Services
Crops	Air quality regulation	Recreation & eco-tourism
Livestock: milk	Climate regulation	Ethical & spiritual values
Livestock: meat	Water regulation: flow	Educational & inspirational values
Capture fisheries	Water regulation: quality	
Wildfoods: honey	Erosion control	
Timber & wood	Water purification & waste treatment	**Supporting Services**
Fibres & resins	Biological control	Habitat Provision
Ornamental resources	Disease regulation	
Biomass fuel	Pollination	
Freshwater	Natural hazard regulation	
Genetic resources		
Biochemicals, natural medicines & pharmaceuticals		

a: adapted from MA (2005).

Provisioning services include the direct products from ecosystems that people use. Many of the agricultural products, such as meat, milk, and honey fit into this category (MA 2005). According to Statistics NZ, approximately 8 percent of New Zealand's GDP was derived from primary industries in 2009, which includes agriculture, fishing, forestry, and mining, illustrating the large amount of resources dependent on these ecosystem services. Regulating services include the impacts from the ecosystem people obtain that help regulate ecosystem processes, such as the regulation of air pollution by trees, the control of erosion by

[11] The MA was created by an active group of scientists, along with representatives from governments, private sector, and nongovernmental organizations.

[12] For more information on the MA, see http://millenniumassessment.org/en/index.html

tree roots, and the purification of water by plants (MA 2005). The NZETS creates a market for the climate regulating services provided by nature.

Cultural services are the non-material benefits that people receive from ecosystems (MA 2005). New Zealand has a variety of sites that have specific cultural significance to many people, and rapid landscape change is likely to affect these values. There are many areas with a history of spiritual practices, experiences, and values that depend on the composition of the landscape. For instance, historic vistas might be significantly altered by large exotic forestry plantations. In elevated, erosion prone areas these areas' visibility may be quite expansive. A transition from pasture farming to forestry may also affect farming lifestyle and the associated cultural experience. Similarly, the degradation/improvement in water quality from changing land uses will affect cultural values. Recreation-related benefits were recently found to have a very high value in Turner et al. (2011), although those benefits were related to mountain biking and walking trails, which were quite unique to the setting of their study.

Finally, supporting services are seen as inputs into the other ecosystem services categories, which can be necessary for their production (MA 2005). For instance, the provision of habitat for pollinators is a necessary input to a range of agricultural products. Although the term "ecosystem services" was formalised and popularised by the 2005 MA report, economists have valued many of these services for decades (Freeman 2003; Atkinson et al. 2012). Estimating these values serves an important role in policy analysis, and is enshrined in the official requirements for regulatory analysis in several countries.[13] Placing values on these services helps to convey their importance, and the integral role they can play in various sectors of the economy. For instance, Gallai et al. (2009) suggest that insect pollinators contribute approximately ($US) 190 billion to the pollination of crops used for

[13] See, for example, the US EPA's Guidelines for Preparing Economic Analysis: https://www.epa.gov/environmental-economics/guidelines-preparing-economic-analyses

human consumption. However, significant challenges continue in this research, especially in the areas of ecological production functions and related complexities in quantifying changes in environmental outputs (Boyd & Banzhaf 2007; Ferraro & Hanauer 2011; Atkinson et al. 2012).

The analysis and valuation of ecosystem services has progressed significantly since the initial 2005 MA report. When monetising ecosystem service values, some economists such as Boyd and Banzhaf (2007), recommend classifying ecosystem services as either intermediate or final services to avoid double counting. Water quality, for example, is an intermediate service for the production of fish. However, the issue is nonetheless quite complex, as water quality is also a final service for recreators such as swimmers.

The concept of ecosystem services is being used in New Zealand to provide a consideration of the wider impacts of land management decisions.[14] Greenhalgh and Hart (2015), for example, detail several important lessons from recent New Zealand applications, and find that it holds considerable promise for future policy analysis and planning.

NZFARM Market-Based Impact Estimates for the Manawatū catchment

We use NZFARM[15] to estimate a range of the provisioning services (**Table 1**), in particular those related to agricultural or forestry land uses, for each of the three afforestation scenarios. These market-based impacts differ across each scenario.

Scenario E: the new afforestation areas convert from their previous land use to exotic forestry, so the land remains in productive use. The direct market impacts in this scenario are represented by the increase in profit (EBIT) from exotic forestry, minus the profit that would be made from the previous land use (the opportunity cost). These impacts are summarised by

[14] http://www.landcareresearch.co.nz/science/portfolios/enhancing-policy-effectiveness/best/integrating contains several recent examples of ecosystem service approaches in applied policy.

[15] The version of NZFARM we use has the most up-to-date input data available. For instance, we are now using the most recent version (4.1) of the New Zealand Land Cover Database (LCDB).

Territorial Authority (TA) in **Table 2**, where the first column contains the new profit from afforested areas, the second column presents the opportunity costs from the previous land use, and the final column contains the net impacts between the first two columns.

This increase in forestry EBIT represents the monetised change in timber and wood ecosystem services. There are also several other ecosystem services that can either be quantified or described qualitatively. The new exotic forest area may directly or indirectly effect a number of cultural services. For example, nearby recreational opportunities may increase such as birdwatching and hiking. Alternatively, aesthetic values (related to scenic views) may increase or decrease as some people prefer indigenous vegetation over exotic vegetation (Brown & Mortimer 2012). Moving from a pastoral land use to forested land may increase aesthetic values.[16]

There are some important caveats to these results. First, a large expansion in forestry would require a parallel expansion in the underlying local infrastructure, such as nearby mills, durable roads, and skilled workers.[17] Second, the likelihood of farmers converting pastoral land to exotic forestry is probably mixed. The large upfront costs and long lag time before the trees are harvested means that exotic forestry may not be considered a viable option for some farmers, particularly those more risk averse farmers. Risk-averse farmers tend to be the older and more experienced farmers – who are becoming the majority.[18] Conversely, current and future carbon prices may send strong incentives for the conversion of marginal lands to exotic forestry

The Tararua TA has the largest expansion in forestry, with over 17 million dollars in exotic forest EBIT. Across the Manawatu region, there is an increase of approximately 17.6

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[16] See http://www.doc.govt.nz/Documents/conservation/human-values/evaluating-non-market-impacts-of-wilding-conifers-on-cultural-values.pdf for further discussion of cultural values and views.

[17] A recent New Zealand Herald article discussed future infrastructure problems with the current forestry rotation: http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11692463.

[18] See the results from the Survey of Rural Decision Makers http://www.landcareresearch.co.nz/science/portfolios/enhancing-policy-effectiveness/srdm2015/15-demographics-education-and-community/15-1-demographics

million dollars per year from the expansion of exotic forestry. The final row of the table contains a 50 year forecast of those annual returns, discounted at 8%, indicating an approximately 233 million dollar increase.[19] [20] Since we do not have any *a priori* assumptions or forecasts about trends in profitability, a constant flow of EBIT likely represents the best estimate of those values.

Table 2: Scenario E Annual and 50 Year Market Impacts

Territorial Authority	EBIT ($) from exotic afforestation	**Lost** EBIT ($) from existing land use[a]	Net Market Impacts
Central Hawke's Bay District	220,618	-59,213	161,406
Horowhenua District	349,148	-28,949	320,199
Manawatū District	3,142,778	-1,268,287	1,874,491
Masterton District	6,043	0	6,043
Palmerston North City	363,589	-337,062	26,527
Tararua District	17,072,045	-1,843,688	15,228,357
Total annual EBIT	**21,154,221**	**-3,537,199**	17,617,022
Total EBIT over 50 years			
8% Discount rate	**279,493,023**	-46,734,045	232,758,978
3% Discount rate	**560,621,905**	-93,741,622	466,880,283

Scenario I: the new afforestation areas convert to indigenous forest. This assumes the new afforestation areas are purchased by the government and set aside for indigenous afforestation. The land is removed from production in this case, so there are two important sources of market-based costs, and no market benefits (non-market benefits are discussed below). The first opportunity cost is the profit from the previous land use. The second cost is the value of the converted land. Since the land is removed from production, its value can no longer be used as an asset. Note that the land value and the profit it generates can be closely

[19] Note that these EBIT estimates are annualised estimates extrapolated from industry figures. They therefore account for harvesting and planting costs and revenues.

[20] Throughout the paper, we use discount rates of 3 and 8% to capture a broad range. There is a current debate on the proper discount rate to be used in New Zealand for cost benefit analysis, particularly with respect to social benefits, illustrated in this Treasury Working Paper https://treasury.govt.nz/sites/default/files/2017-06/twp17-02.pdf

tied together. By separating them out here, we potentially overestimate the costs. **Table 3** contains the market impacts for Scenario I, where the first column contains the lost value of land, the second column contains the lost profit (EBIT) from the previous land use, and the final column contains the total market impacts. The Table indicates that the total market impacts of this scenario are approximately negative 323-649 million dollars per year.

Table 3: Scenario I Annual and 50 Year Market Impacts

Territorial Authority	Lost Value of Land	**Lost** EBIT ($) from existing land use[a]	Net Market Impacts
Central Hawke's Bay District	-223,062	-59,213	-282,275]
Horowhenua District	-299,046	-28,949	-327,995
Manawatū District	-3,380,893	-1,268,287	-4,649,180
Masterton District	-5,638	0	-5,638
Palmerston North City	-367,483	-337,062	-704,545
Tararua District	-16,670,522	-1,843,688	-18,514,210
Total annual EBIT	**-20,946,644**	**-3,537,199**	**-24,483,843**
Total EBIT over 50 years			
8% Discount rate	**-276,750,484**	**-46,734,045**	**-323,484,529**
3% Discount rate	**-555,120,773**	**-93,741,622**	**-648,862,395**

Scenario IM: the new afforestation areas convert to indigenous forest, but the areas suitable for mānuka/kānuka are used for productive purposes. In this instance for medical or edible honey production. A portion of the afforestation areas will therefore remain in production, so the land is not assumed to be purchased by the government. The market-based impacts of Scenario IM appear in **Table 4**. The first column of figures contains the lost value of land, which is smaller than the figures in **Table 3**. The third column contains an estimate of the gains in EBIT from honey production. Overall, this scenario is estimated to lose approximately 6 million dollars per year in market-related impacts.

Table 4: Scenario IM Annual and 50 Year Market Impacts

Territorial Authority	Lost Value of Land	**Lost** EBIT ($) from existing land	EBIT **Gains** from Honey	Net Market Impacts

		use[a]		
Central Hawke's Bay District	-164,913	-59,213	23,580	-200,546
Horowhenua District	-159,939	-28,949	186,853	-2,035
Manawatū District	-2,232,817	-1,268,287	484,053	-3,017,051
Masterton District	-2,891	0	1,730	-1,161
Palmerston North City	-195,845	-337,062	79,116	-453,791
Tararua District	-5,560,100	-1,843,688	4,920,116	-2,483,672
Total annual EBIT	**-8,316,505**	**-3,537,199**	**5,695,448**	**-6,158,256**
Total EBIT over 50 years				
8% Discount rate	**-109,879,029**	**-46,734,045**	**75,249,196**	**-81,363,878**
3% Discount rate	**-220,401,162**	**-93,741,622**	**150,938,809**	**-163,203,975**

Each of the last three tables contains estimates of the lost EBIT from previous land uses. To better illustrate the distribution of those previous land uses, **Table 5** provides some additional details on those areas. The highest land uses occupying the new afforestation areas are dairy and sheep & beef.

Table 5: EBIT in afforestation areas, by previous land use

Land use	**EBIT ($/yr)**	**Area (ha)**
Arable	115	< 1
Dairy	1,550,303	804
Deer	365,178	367
Exotic forestry[a]	403,314	658
Fruit	110	0
Native forestry	0	4,303
Other	0	419
Other pasture	26,973	1,353
Sheep & beef	1,299,791	31,548
Vegetables	833	0

Water quality valuation

Increased afforestation will affect several important regulating ecosystem services, such as water quality and water quantity. Water quality should improve as land is converted from agricultural uses to forested land. Afforesting land can reduce nutrient runoff, mitigate erosion, and prevent excess stormwater runoff. On the other hand, afforestation reduces water yield, meaning there may be less water available for irrigation and other activities (Ausseil et al. 2013). Due to data and time constraints for this analysis, we focus primarily on the changes in water quality. Additionally, the changes in water quantity produce uncertain changes in values. On one hand, it may be more expensive for farmers to irrigate their crops. However, that may only have an impact at certain levels of existing water which are hard to predict. On the other hand, recent literature indicates that citizens may have a positive willingness to pay for water going to forests instead of to agriculture (Baskaran et al. 2009). To value the benefits of water quality improvements, we employ a benefit transfer approach. Benefit transfers use estimated non-market values from a study (or studies) to evaluate another area or policy (Freeman 2003). Benefit transfer is commonly employed when time or budget constraints prevent original analysis. Although there are a variety of water quality valuation in the US and Europe, the New Zealand literature is much thinner. There are several different types of benefit transfers, including unit transfers, function transfers, and meta-analysis function transfers (US EPA 2014).

We use a function transfer, which allows us to correct for the characteristics of the local population. Function transfers are generally recommended over unit transfers, as they allow for some correction between the population of the original study and that of the site the values are being transferred to (US EPA 2014). Unfortunately, there are not enough water quality valuation studies in New Zealand that use comparable measures of water quality, to construct a meta-analysis function transfer solely based on New Zealand studies.

In choosing water quality valuation studies for benefit transfer purposes, there are several central criteria. Most important, the studies must use water quality parameters that match the outputs of our policy simulations. From NZFARM, we have data on the projected reduction in nutrient loadings, so studies that value changes in nutrients are ideal. We are also looking for stated preference studies in order to capture more aspects of people's willingness to pay (WTP) for water quality improvements. It is also important that the study is done in New Zealand, ideally in an area similar to the Manawatū.

After reviewing a range of potential studies, we selected Baskaran et al. (2009) for our benefit transfer.[21] Baskaran et al. (2009) estimates the value of percentage reductions in nitrate leaching from agricultural activities, which is a good match to the outputs of NZFARM. Baskaran et al. (2009) ask respondents about their WTP for either a 10% or 30% reduction in nitrate leaching. Their econometric model estimates different WTP values at different income levels, which then allows us to tailor their results to the Manawatū area. We use TA median household income data from the 2013 New Zealand Census to derive incomes for the Manawatū catchment.

In their paper, Baskaran et al. (2009) present WTP values for 10% and 30% nitrate reductions at several different income levels. We harness the variation in their estimates to create linear and non-linear approximations of their WTP functions at different income levels to estimate the WTP for the NZFARM estimated changes in nutrient runoff. Our preferred results are the non-linear approximations, since they allow for diminishing WTP as the percent change in water quality decreases, and because they allow WTP to approach zero as the percent change approaches zero. Both the linear and non-linear approximations are shown in **Figure 5**, where the lighter lines represent the linear approximations and the darker lines are the corresponding non-linear approximations. They show the relationship between the percent change in nutrients and the estimated WTP.

[21] In addition to general internet searches, we used the New Zealand Non-Market Valuation Database (http://selfservice.lincoln.ac.nz/nonmarketvaluation/default.asp), the Environmental Valuation Reference Inventory (https://www.evri.ca/Global/Splash.aspx), and the University of Waikato working paper "Review of freshwater Non-Market Value Studies" (https://www.waikatoregion.govt.nz/assets/PageFiles/30275/2997672Review_of_Freshwater_Non-Market_Value_Studies.pdf).

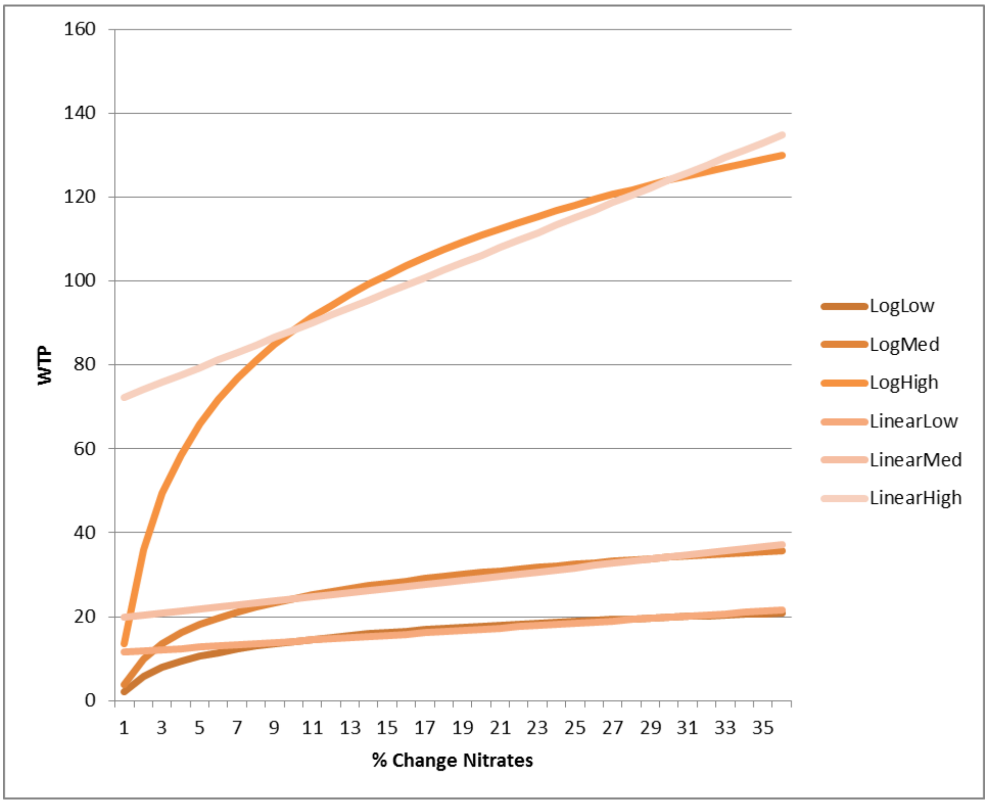

Figure 5: Baskaran WTP approximation functions.

We calculate the total WTP for water quality changes at the TA level, based on the water quality outputs of NZFARM. To estimate the water quality benefits across a 50 year timeframe, we also need an estimate of population growth for each TA. For this, we base our population growth estimates on the most recent Census. **Table 6** contains the NZFARM results for predicted reduction in nitrogen (N) leaching. The first three columns show the total N leaching based on current land use and the two afforestation scenarios. The next two columns convert the change from baseline to each scenario into a percent. However, this percent assumes that all new afforestation areas have been afforested. To estimate the annual change, the total change is split into time increments, which depend upon the time a tree species takes to reach maturity. For this analysis, we assume it takes 30 years for exotic forest to reach full maturity, and 50 years for an indigenous forest to reach full maturity (Carver and Kerr, 2017). Based on those assumptions, the exotic areas see reductions in nitrogen leaching for the first 30 years, and none thereafter, which is why the Scenario E annual reductions in the last two columns are larger than the Scenario I reductions – they are spread over a shorter time period.[22]

Table 6: Predicted changes in nutrients

	N Leaching (kg)			**Estimated % Change**		**Annual % Change**	
Territorial Authority	Current	Scen. E	Scen. I	Scen. E	Scen. I	Scen. E	Scen. I
Central Hawke's Bay	5,251	789	473	0.850	0.910	0.028	0.018
Horowhenua	5,929	1,390	834	0.766	0.859	0.026	0.017
Manawatū	69,776	12,479	7,488	0.821	0.893	0.027	0.018
Masterton	128	40	24	0.686	0.812	0.023	0.016
Palmerston North City	6,516	1,507	904	0.769	0.861	0.026	0.017
Tararua	370,242	62,701	37,621	0.831	0.898	0.028	0.018

We apply the benefits transfer function to the water quality change in each TA[23] in each year to calculate annual WTP. The WTP figures were then applied at the household level, which is the unit of analysis in the Baskaran et al. (2009) study. The 2013 Census population growth figures are used to extrapolate population out 50 years to calculate the full path of benefits (**Table 7**). Finally, the net present value of the benefits stream is calculated using two alternate discount rates. The first discount rate, 8%, is the recommended rate by the NZ Treasury. The second discount rate, 3%, is a common rate recommended in the general valuation literature to discount social welfare benefits (US EPA 2014). The alternate discount rate is used because the 8% figure is more representative of capital expenditures, and likely does not represent social discounting of WTP (US EPA 2014). At both discount rates, Scenario E has a higher WTP than Scenario I (**Table 7**).

[22] It is also likely that there is a pulse of nutrients during and shortly after harvesting, followed by some additional reductions. Modelling that change is outside of the scope of this work, so for simplicity we assume that it is zero leaching after the first harvesting

[23] This estimate uses 2013 Census data for income (inflated to 2017 dollars).

Table 7: Total WTP for water quality benefits in the Manawatū catchment over 50 years (NZ$a)

	Scenario E 3%	**Scenario E 8%**	**Scenario I 3%**	**Scenario I 8%**
Central Hawke's Bay District	1,413,481	799,167	1,335,079	611,987
Horowhenua District	1,916,060	1,076,445	1,864,398	841,829
Manawatū District	3,061,206	1,697,848	3,032,572	1,327,608
Masterton District	2,364,891	1,320,119	2,391,795	1,063,530
Palmerston North City	7,716,217	4,348,821	7,454,413	3,391,467
Tararua District	1,749,103	1,001,482	1,614,293	762,041
Total WTP over 50 years	**18,220,958**	**10,243,883**	**17,692,549**	**7,998,462**

a: values are in 2017 New Zealand dollars

In terms of water quantity, the expected change in value is uncertain. On one hand, it may be more expensive for farmers to irrigate their crops, given there is likely less water available for irrigation. However, this may only be an issue at river low flow times. Without detailed hydrological modelling, the availability of water and when water restrictions may occur are difficult to predict. On the other hand, recent literature indicates that citizens may have a positive WTP for water going to forests instead of agriculture (Baskaran et al. 2009). The value of the water quantity reductions is therefore uncertain.

Carbon benefits

Using NZFARM, we estimate changes in net GHGs (avoided GHG emissions plus carbon sequestered) with each afforestation scenario. Scenario E has lower net GHG emissions than Scenario I (**Table 8**). For instance, in Central Hawke's Bay District there are approximately 960 tonnes CO_2e emitted under the existing land use. However, when Scenario E is fully implemented and the trees are mature, that district is a carbon sink of almost 5,000 tonnes. Under Scenario I, the district is only a 1,000 tonnes carbon sink

Table 8: Change in net GHGs in the Manawatū catchment

TA	**Existing**	**Scenario E**	**Scenario I**	**Scenario E**	**Scenario I**

	land use emissions (tonnes CO_2e)	**Sequestered (tonnes CO_2e)**	**Sequestered (tonnes CO_2e)**	**Total Change (tonnes CO_2e)[a]**	**Total Change (tonnes CO_2e)[a]**
Central Hawke's Bay District	960	–4,857	–237	5,817	1,197
Horowhenua District	586	—8,226	–417	8,811	1,002
Manawatū District	11,614	–69,122	–3,744	80,735	15,357
Masterton District	16	–244	–12	260	28
Palmerston North City	597	–9,836	–452	10,433	1,049
Tararua District	62,945	–392,951	–18,810	455,895	81,755
TOTAL	**76,718**	**–485,236**	**-23,672**	**561,951**	**100,388**

a: a positive number means carbon is being sequestered.

The GHG figures presented in **Table 8** represent the steady state levels of GHG emissions. To estimate the benefits over 50 years, we need to know the emissions transition path rather than the steady state levels. In the absence of forest modelling to forecast the time paths for the afforestation scenarios (which are beyond the scope of this analysis) we use the 2015 New Zealand Ministry for Primary Industries ETS lookup tables[24] to estimate the growth of various tree species, including *Pinus radiata* and indigenous species. The lookup tables provide carbon sequestration rates for different regions of New Zealand.

For our calculations we assume that the exotic forest (Scenario E) is a harvest in year 30, while the indigenous forest (Scenario I) keeps growing over the 50-year time period. The lookup tables allow us to control for the size of the harvest, as well as carbon remaining after the harvest in stumps and the soil, which diminishes over time. We incorporate both effects in our estimates. The valuation assumes that credits generated are sold in the same year, and that credits have been purchased to cover any harvest-related GHG emissions.[25] Note that an estimate based solely on the ETS lookup tables is likely an underestimate, since it only values

[24] https://www.mpi.govt.nz/document-vault/4762

[25] Although common in the literature, these assumptions can affect the economic viability of these of these options, depending on whether the carbon price is expected to increase or decrease.

the carbon sequestered as a result of the new land use. The reductions in emissions from the previous agricultural land use are not included in these calculations.[26]

We use the NZETS price at discount rates of 3% and 8% and SCC at 3%. A constant NZETS price is a strong assumption, particularly if new sectors are covered by the NZETS in the future which changes market conditions. Additionally, future international agreements, and New Zealand's integration into them, could significantly affect the market price. A recent report by the Parliamentary Commission for the Environment projects that 2030 carbon prices could be as high as $150 per tonne CO_2e, with a low estimate of $20 per tonne CO_2e.[27] The US EPA SCC 3% is used to account for potentially higher future carbon prices. Exploring SCC values across time is somewhat complicated since the social cost of CO_2e is both dollar year and emissions year dependent. We only use the 3% estimate here for comparison to the NZETS 3% estimate.

There is a wide international literature recommending lower values for social welfare, particularly those related to environmental benefits (Pearce 2003; Guo et al. 2006; David et al. 2009). Given the PCE forecasts and the higher US EPA SCC values, our estimates are likely conservative and may therefore be underestimates of the true value of carbon for each of the afforestation scenarios.

The monetised benefits of carbon sequestration, by TA, for Scenario E are outlined in **Table 9**. All estimates in the table represent the net present value across 50 years. Depending on the price assumption, benefits range from approximately $105 million to almost $700 million for the Manawatū catchment.

Table 9: Carbon benefits for Scenario E over 50 years

	NZETS 3%	NZETS 8%	SCC 3%

[26] To more accurately model the impact of a particular policy, such as the PFSI, would require a more detailed analysis. For instance, areas of forest over 100 ha would require a field measurement approach, which might differ from the lookup tables.
[27] http://www.pce.parliament.nz/media/1292/covec-final-report-19-07-10.pdf

Central Hawke's Bay District	1,732,879	1,046,857	7,071,811
Horowhenua District	3,052,358	1,843,973	12,291,778
Manawatū District	27,410,838	16,559,281	110,382,821
Masterton District	88,109	53,228	354,811
Palmerston North City	3,310,675	2,000,027	13,332,014
Tararua District	137,724,026	83,201,060	554,611,514
Total	**173,318,885**	**104,704,425**	**698,044,750**

Estimates are presented in 2017 dollars (NZ)

The benefits for Scenario I and IM are outlined in (**Table 10**) and produce slightly lower carbon monetised benefits than Scenario E. For example, the NZETS 3% price is estimated to generate $118 million in carbon benefits in Scenario I as opposed to $173 million in Scenario E. Although the average tree density – and hence sequestered carbon – of exotic forests is more than indigenous forests, they are periodically harvested.

Table 10: Carbon benefits for Scenarios I and IM over 50 years

	NZETS 3%	**NZETS 8%**	**SCC 3%**
Central Hawke's Bay District	1,182,273	521,915	5,367,236
Horowhenua District	2,082,500	919,321	9,393,804
Manawatū District	18,701,300	8,255,702	84,358,394
Masterton District	60,113	26,537	271,159
Palmerston North City	2,258,739	997,122	10,188,790
Tararua District	93,963,502	41,480,252	423,853,425
Total	**118,248,428**	**52,200,848**	**533,432,808**

Estimates are presented in 2017 dollars (NZ)

Biodiversity-related benefits

To estimate changes in biodiversity, we employ a measure of 'ecological integrity.' This measure was originally defines by Lee et al. (2005) as ''the full potential of indigenous biotic and abiotic factors, and natural processes, functioning in sustainable communities, habitats, and landscapes" Carswell et al. (2015). Indicators of ecological integrity are now widely employed, and the New Zealand Department of Conservation uses ecological integrity as their primary biodiversity goal. Our measure of ecological integrity is based on catchment-scale natural regeneration of indigenous forests on agricultural lands, and has been used in several recent papers (Mason et al. 2012; Carswell et al. 2015; Mason et al. 2016). The measure is called the “restored significance,” and it is a measure of the potential gain in environmental representation through natural regeneration. Larger restored significance values indicate that there is a larger potential increase in biodiversity from converting a particular plot of land to indigenous forest. The units of this indicator are parts per billion (ppb), where one billion represents the ideal ecological utopia of natural (prehumen) conditions (Carswell et al. 2015).

The distribution of restored significance (hereafter referred to as “SRS”) throughout the Manawatū catchment is shown in **Figure 6.** The darker the blue indicates a higher SRS score, indicating that more biodiversity could be gained from allowing those areas to revert to indigenous forest. Similarly, the lighter blue areas indicate there is less to gain from allowing an area to revert to indigenous forest. The two large lighter areas in the map are areas that are already heavily forested and surrounded by other forested land, and hence have little to “gain” by being “converted.”

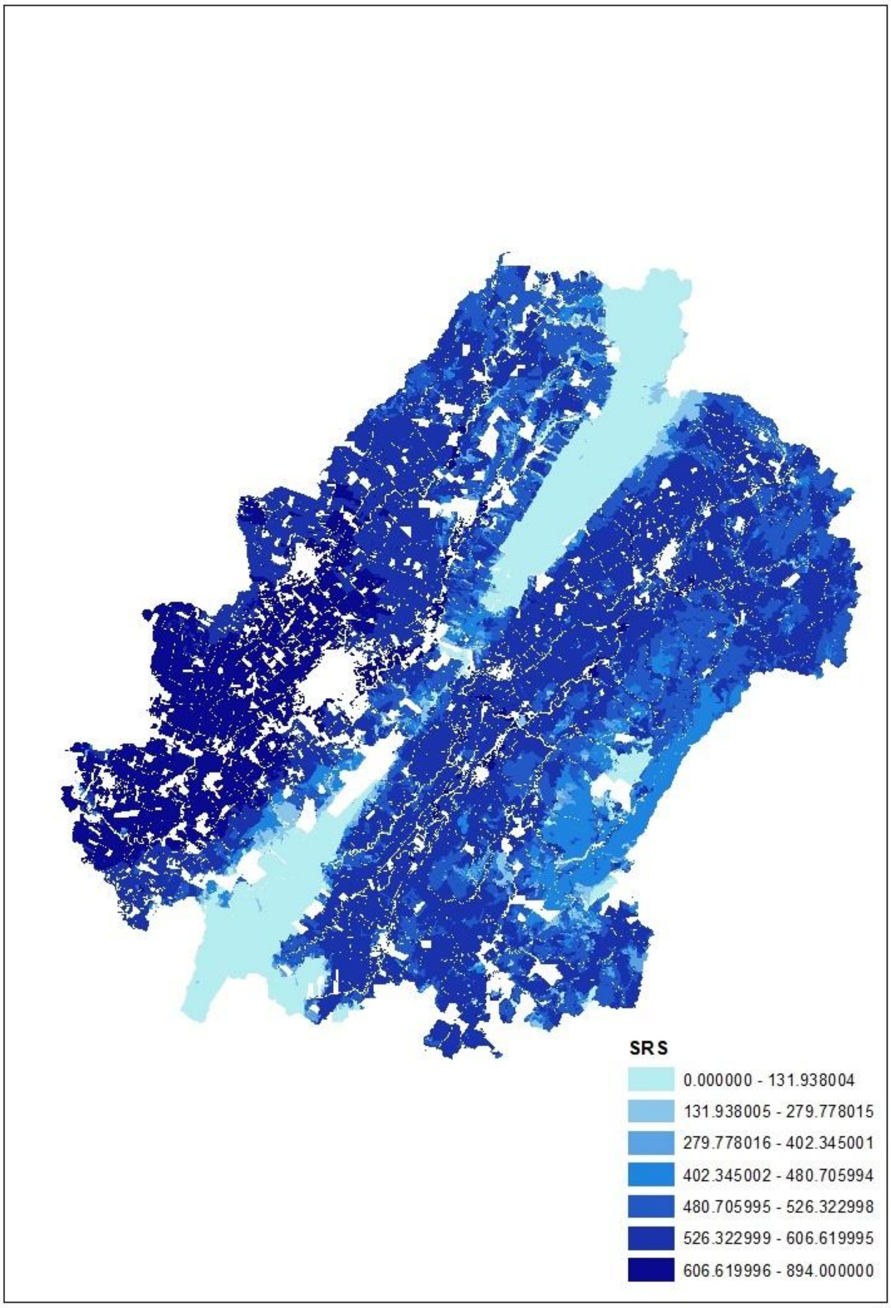

Figure 6: SRS in the Manawatū.

To gauge the potential biodiversity benefits from indigenous afforestation, we overlay the new afforestation areas with the SRS ecological integrity data. **Table 11** contains several descriptive statistics on the new afforestation area. **Table 11** applies specifically to indigenous afforestation, and hence represents the potential ecological benefits for Scenario I. Note that the SRS score is based on several detailed local criteria and assessed at the hectare scale. That detailed focus helps explain the average SRS scores for the areas previously classified as native and forest, which at first glance seem counter-intuitive. Average SRS for indigenous forest areas, for example, is higher than sheep & beef areas. As suggested by **Figure 6**, most of the new afforestation areas are on marginal lands that could see significant benefit from conversion to indigenous forest. These estimates also represent the maximum potential biodiversity once the area has been fully restored. These SRS calculations require two important caveats. First, although our SRS estimates are based on very spatially explicit underlying data, the actual realized biodiversity may differ from the predicted estimate. We therefore present multiple descriptive statistics to better gauge the distribution of potential benefits. In addition, the SRS estimates represent the full benefits once the plot of land is fully regenerated. According to the underlying studies the derivation of SRS is based on, regeneration is likely to take 40–50 years. Therefore, the SRS is approximating the biodiversity potential at the end of that time period.

Table 11: SRS in afforestation areas by existing land use, for Scenario I

Enterprise Class	Minimum SRS	25th Percentile SRS	Mean SRS	Max SRS	Std Dev. SRS
Scrub	0.0	426.901	455.3	647.9	99.8
Deer	114.9	398.513	455.7	633.7	113.3
Native	0.0	436.056	465.0	715.0	122.3
SNB	0.0	451.316	468.8	740.6	104.2
Other	0.0	473.2595	485.1	750.8	106.1
Forest	0.0	479.3905	497.3	655.0	88.2
Dairy	0.0	483.875	497.6	655.0	99.3
Other pasture	0.0	485.231	506.7	655.0	69.8

The estimates for **Table 11** use an SRS value that was developed for indigenous afforestation. Biodiversity for Scenario E will differ from Scenario I due to differences in forest type. Scenario E will have much less plant diversity, which will support less diversity of other species. Another fundamental difference in exotic forestry is the periodic harvesting where land will be harvested shortly after reaching peak potential biodiversity potential.

Harvesting is likely to damage biodiversity significantly. We, therefore, update the SRS estimate for exotic forest based on several studies that compare biodiversity under native and exotic forests, including Pawson et al. (2008) and Deonchat et al. (2009). The updated SRS values for Scenario E are outlined in **Table 12**.

Table 12: SRS in Afforestation areas by existing land use, for Scenario E

Enterprise Class	Minimum SRS	25th Percentile SRS	Mean SRS	Max SRS	Std Dev. SRS
Scrub	0.0	192.1055	204.9	291.6	44.9
Deer	51.7	179.3309	205.1	285.1	51.0
Native	0.0	196.2252	209.3	321.8	55.0
SNB	0.0	203.0922	211.0	333.3	46.9
Other	0.0	214.2	218.3	337.9	47.7
Forest	0.0	212.9668	223.8	294.8	39.7
Dairy	0.0	215.7257	223.9	294.8	44.7
Other pasture	0.0	217.7437	228.0	294.8	31.4

Assuming that the exotic forests will be harvested roughly twice in a 50 year period, the level of biodiversity presented in **Table 12** are only likely to be achieved twice in this period. Therefore, the average annual biodiversity benefits will therefore be much lower.

Summary of benefits and costs in the Manawatū Catchment

When assessing the benefits and costs of the three afforestation scenarios for the Manawatū catchment it is important to consider those that can be monetised, those that can be quantified and those that can only be qualitatively described.

The previous sections outline a number of impacts related to the afforestation scenarios that can be quantified and/or monetised impacts. While it is possible to quantify and/or monetise other impacts, the budgetary and time constraints for this project mean that no additional primary data or ecosystem modelling could be undertaken. In terms of benefits and costs, the benefits are often more challenging to quantify. For instance, aesthetic values are difficult to quantify, and aesthetic preferences can vary significantly across the population and across time. To estimate those benefits properly, a stated preference survey would be ideal (Freeman 2003). Similarly, more advanced ecosystem modelling would be needed to quantify the indirect impacts of changes in biodiversity.

In the absence of additional data collection and ecosystem modelling we use an ecosystem services framework to describe the broader range of impacts and the subsequent benefits and costs of the afforestation scenarios. **Table 13** presents a summary of ecosystem service impacts, including effects that can be quantified or monetised as well as a short narrative on the potential impacts. The narratives in the table, in particular for those ecosystem service impacts that are qualitatively described, are not comprehensive. The table does, however, draw on expected ecosystem service relationships and insights gained from other situations which are likely transferable to this context.

Table 13: Summary of ecosystem service impacts

Category	Ecosystem Service	Effect of Afforestation Scenario	Quantified	Monetized	Methods/ Notes
Provisioning	Crops	Reduced production	X	X	NZFARM was used to examine agricultural impacts
	Livestock: milk	Reduced production	X	X	NZFARM was used to examine agricultural impacts
	Livestock: meat	Reduced production	X	X	NZFARM was used to examine agricultural impacts
	Capture fisheries	Likely improvement			Fish habitat is expected to improve as water quality improves and with additional stream shading expected with the afforestation scenarios. Decreased stream flows associated with afforestation, however, may have some negative impacts on fish habitat. Improved fish habitat is likely to enhance commercial fishery harvest for freshwater species such as eel or recreational trout catch. To estimate the full effects would require hydrological and fish modelling which is beyond the scope of this project. Any impacts on the ocean fishery are unknown.
	Freshwater	Improvement in quality/decrease in quantity			Water quality is expected to improve due to decreases in nutrient inputs and other forms of farm runoff associated with pasture land, and thereby improving drinking and stock water quality. In addition, freshwater contact recreation should be improved, yielding human health impacts. Water yield, however, is expected to decrease with greater areas of forested land. This may affect irrigation in the area. Hydrological modelling is required to determine the spatial and temporal impacts on water flows.
	Wildfoods	Likely increase			Wildfood harvests should increase, particularly in indigenous afforestation scenarios (Scenario I). Trout and eel habitat should improve with better water quality leading to greater fish abundance and catch. Honey will increase particularly in Scenario IM).
	Timber & wood	Increase in Scenario E	X	X	NZFARM was used to examine forestry impacts.
	Fibres & resins	Potential Increase			Afforestation may yield products in addition to timber.
	Biomass fuel	Potential increase			Forestry by-products could be used for biomass fuel.
	Ornamental resources	Potential increase			With indigenous forest (Scenario I) we expect greater availability of ornamental resources such as flax.
	Biochemical, natural medicines and pharmaceuticals	Potential increase			High-grade mānuka honey, among other products, has several medical applications. Mānuka is one of the first successional species that is anticipated after reversion from pastoral farming to indigenous vegetation. Rongoā is also likely to increase in Scenario I.

Category	Ecosystem Service	Effect of Afforestation Scenario	Quantified	Monetized	Methods/ Notes
Regulating	Air quality and climate regulation	Improvement	X	X	NZFARM outputs and ETS materials are used to quantify and value changes in carbon, in particular the carbon sequestration potential of forests. Forests also improve air quality in terms of reduced particulates. Pine pollen, however, could be an issue in some areas.
	Water regulation	Mixed			The afforestation scenarios will likely decrease water yield in the area as runoff from erosion-prone and pastoral areas is reduced. Alternatively, improvements in water quality will reduce water treatment costs for drinking and agriculture water.
	Erosion control	Improvement			Afforestation will improve erosion control.
	Water quality or purification	Improvement	X	X	NZFARM nutrient outputs are used for a benefit transfer of stated preference WTP values to monetise the value of improved water quality.
	Pollination	Potential improvement			We expect an increase in native pollinators with indigenous forest (Scenario I); the extent, however, will depend on the availability of floral resources. There is also an increase in honey production (from honey bees) under Scenario I that will likely have additional indirect pollination benefits.
	Natural hazard regulation	Improvement			A reduction in water yield should reduce stormwater impacts, such as stream scouring, and potentially reduce peak flooding flows
Cultural	Recreation and Ecotourism	May increase			Increased afforestation may induce greater local recreation, particularly in areas with greater public accessibility. This could be hiking, biking or similar recreation. Improvements in water quality should improve the swimability of streams and also improve the recreational experience and the health of the recreational fishery (e.g. trout). There is some evidence of aesthetic preferences for indigenous species over exotic species (Brown et al. 2012), which may mean greater recreation and ecotourism services are provided by indigenous forest (Scenario I).
	Ethical and spiritual	Expected improvement			With indigenous forest (Scenario I) there is an expected increase in the spiritual values associated with the landscape, especially when native species increase (e.g. taonga species).
	Aesthetic values	Expected improvement			Views will be changed, particularly when afforested areas are elevated. The local value of changing viewscapes depends on the local population and the particular scenario. In a farmer workshop on ecosystem services in the Manawatū in 2015, the farming community noted the importance of the aesthetic value of their catchment and how these attracted international visitors.
	Cultural heritage values	Expected improvement			Indigenous afforestation scenarios (Scenario I) may promote the return of indigenous species with particular cultural values. Water quality improvements in culturally important waterbodies should provide additional benefits.

Category	Ecosystem Service	Effect of Afforestation Scenario	Quantified	Monetized	Methods/ Notes
	Social relations	Mixed			There is likely to be a change in the rural population with afforestation. With less farm labour required there is likely to be an initial reduction of people in the catchment. However, over time different people are expected to move into the area, but with different employment preferences. Anecdotally, this is what happened in the Taupō catchment when a portion of the land was afforested leading to an initial decrease in social relations/cohesion followed by an increase when new people moved into the catchment (Mike Barton, Farmer Lake Taupō, March 2016).
	Sense of place	Mixed			The 'look' of the catchment will change with a move from pastoral land to forested land in the marginal areas. Therefore, the sense of place may be altered (and potentially reduced), especially for those who grew up surrounded by pastoral land. However, older generations may feel a greater sense of place with a reversion to forest.
	Cultural diversity	Unclear			The expected initial reduction in the rural population is likely to decrease cultural diversity. However, as noted above this will likely change over time as new people are expected to move into the catchment.
Supporting	Habitat Provision	Increase	X		The habitat for native species is expected to increase, particularly in the indigenous scenario (Scenario I and IM).

A summary of the monetized benefits and costs for the Manawatū catchment for the three afforestation scenarios are provided in **Table 14**. All figures are in 2017 dollars, and use a discount rate of 8%.[28] There are a variety of issues (not presented here) involving the magnitude of the discount rate.[29]

Scenario I has the highest discounted net present value of the opportunity cost at approximately $317 million, whereas Scenario E has the lowest opportunity cost at $43 million. Each of the scenarios faces same loss of EBIT ($43 million) associated with the existing land use before afforestation. The opportunity cost for Scenarios I and IM, however, also includes the additional converted value of land as well. This value reflects the policy context we used for this analysis which involved the government purchasing the land from the current owner. Other policy context, e.g. using covenant, may not include the converted value of land as part of the opportunity cost.

In terms of discounted benefits, Scenario E yields the largest monetized benefits, at approximately $400 million, which includes increased profit from exotic forestry, water quality benefits, and carbon-related benefits. Scenarios I and IM have lower carbon and water quality benefits, as well as production-related revenue (which is zero for Scenario I). These differences in benefits between scenarios are important, as they each come with their own caveats. Future policy, climate change, and farmer preferences can significantly affect the benefits realised by each scenario in different ways.

The overall NPV and the benefit-cost ratio show all scenarios as having a positive benefit-cost ratio. However, Scenario I has a negative NPV of $190 million, while Scenarios

[28] The traditional default discount rate recommended recommended by Treasury was 8%: http://www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis/discountrates/discount-rates-jul08.pdf. Note, however, that recent (2016) guidance has suggested alternate discount rates http://www.treasury.govt.nz/publications/guidance/planning/costbenefitanalysis/currentdiscountrates. A full comparison of these rates is outside the scope of this analysis. By using 3 and 8 percent in most sections, we should capture a wide range of sensitivity.

[29] For instance, higher discount rates may penalize “lumpy” effects that occur in the future, as opposed to up-front costs.

E and IM have a positive NPV. The negative NPV for Scenario I is largely driven by the opportunity cost of the converted value of land. As noted above, this portion of the opportunity cost is related to the policy context we used in this analysis. Therefore, these results should be viewed as the upper-bound of estimates.

In a different policy context that does not involve land sales, the opportunity costs are lower and only reflect on the loss of EBIT from the existing land uses. Where only lost EBIT is included in the opportunity cost, both the NPV and benefit-cost ratio increase for Scenarios I and IM, but are unchanged for Scenario E. Overall, Scenario E has the highest NPV and benefit-cost ratio.

Although Scenario E has the highest monetised net benefits, there are many other benefits that were not monetised. For instance, biodiversity benefits were found to be considerably higher for indigenous forest, although they were not assigned dollar values. Cultural, recreation, aesthetic, and human health impacts were also not monetised or quantified. The preferable afforestation scenario therefore depends on the preferences and constraints of the policy makers. Overall, we find that both exotic and indigenous permanent forest have the potential to produce significant benefits. With flexible policy that provides balanced incentives to producers, both types of forest can achieve multiple regional and national goals.

Table 14: Monetized benefits and costs across 50 years (8% discount rate)

	Scenario E	**Scenario I**	**Scenario IM**
Opportunity Costs			
Lost EBIT	42,851,048	42,851,048	42,851,048
Converted value of land		276,750,447	109,879,029
Total opportunity cost	42,851,048	316,660,879	152,730,078
Increases in EBIT			
Forestry	279,493,023		
Honey			75,249,196
Ecological Benefits			
Water quality	10,243,883	7,998,462	7,998,462

Carbon Benefits			
Carbon valuation (Current NZ ETS price)	104,704,425	118,248,428	118,248,428
Total monetized benefits	394,441,331	126,246,890	201,496,086
Overall NPV	351,590,283	-190,413,989	48,766,008
Benefit-cost ratio	9.2	0.40	1.3
Sensitivity Analysis			
Overall NPV – Lost EBIT only	351,590,283	83,395,842	158,645,038
Benefit-cost ratio – Lost EBIT only	9.2	3.0	3.7

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