Afforestation and ecosystem services in the Hawke's Bay region

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Hawke's Bay landscape illustrating the soil erosion protection provided by planted forests and the vulnerability of steep slopes to erosion when woody vegetation is absent. Source: Peter Scott of Above Hawke's Bay

Abstract

Plantation forests provide benefits beyond timber. However, these non-timber benefits (avoided erosion, avoided nutrient leaching) do not have market values and are often overlooked in decision-making. This study describes a spatial economic assessment of the timber and non-timber values of potential plantation forest areas in the Hawke's Bay. The assessment tool – the Forest Investment Framework (FIF) – was used to spatially quantify the value of timber, carbon sequestration, avoided erosion and avoided nitrogen leaching provided by a 28-year rotation of radiata pine grown on identified highly erodible sites in the region. Spatially explicit estimates of timber and non-timber values can support targeted forestry investment decisions, and thus address the issue of limited resources. If the purpose of a potential forestry programme was to improve the environment, areas that provide the highest non-timber values can be identified and prioritised. Spatial estimates of values can also be used to prioritise areas with high timber values.

Introduction

Plantation forests provide benefits beyond timber and fibre, including carbon sequestration, erosion control, flood mitigation, improved water quality, biodiversity and recreational resources (MEA, 2005; Dhakal et al., 2012; Yao et al., 2013; Barry et al., 2014). Together, the benefits people gain from the environment are known as ecosystem services, but many of these services provided by forests do not have a market value. As a result, benefits (such as avoided erosion or avoided nutrient leaching) are usually less understood or appreciated for plantation forests compared with log and timber values.

The invisibility of the less tangible ecosystem services in decision-making has provided the opportunity for researchers, practitioners and businesses to work together to address this issue (MEA, 2005; TEEB, 2010). Various models and frameworks have been developed to quantify and value these services so as to account for them in decision-making (Neugarten et al., 2018).

One group of frameworks increasingly gaining attention are the spatially explicit economic models that use ecosystem services approaches to help decision-makers account for the broader value of forest ecosystems (Villa et al., 2009; Sharp et al., 2014; Yao et al., 2016). The frameworks not only account for both the market and non-market values of ecosystem services, but also for space, time and geographic scale, which enables the presentation of an increasingly holistic view of the goods and services for managing and sustaining their provisions. In New Zealand, an ecosystem service assessment tool – the Forest Investment Framework (FIF) – has been designed to assess the financial viability of forests in this country in combination with the non-market ecosystem services they provide (Yao et al., 2019a).

Valuing ecosystem services using the FIF

Around 120,000 ha of land in the Hawke's Bay has been identified as highly vulnerable to erosion. Planting production or permanent forests would be one way to reduce erosion on this vulnerable land. We used the spatial economic tool, the FIF, which combines economic valuation techniques, environmental modelling and Geographic Information System (GIS) technology (Yao et al., 2016) to quantify the broader value of potential plantation forests on highly erodible land in the Hawke's Bay. The tool has already been used in more than 20 New Zealand case studies that have assessed the value of ecosystem services in existing and proposed planted forests (Yao et al., 2019a).

Market values – logs and carbon

The FIF's log viability component has been used to model radiata pine log production costs and revenues from sites identified for afforestation in the Hawke's Bay. Production costs include the expenses associated with establishment, silviculture, internal roading, landing, harvesting and transport. The FIF accounts for impedance factors such as slope and soil type. Areas in steeper slopes and harder soils would have higher roading costs.

The Carbon C-change model is embedded in the FIF (Beets et al., 2009), which quantifies the volume of carbon sequestered, allowing the sequestration value over one or more forestry rotations to be calculated. The quantification of carbon sequestration net benefits includes the cost of monitoring the carbon sequestration credit units and revenues from carbon credits. As the identified, highly erodible sites exclude areas with existing plantation forests, all these new forests will be classified as post-1989 and are therefore compliant with the accreditation requirement of the New Zealand Emissions Trading Scheme (ETS).

The carbon sequestration value that we estimate here for one rotation of radiata pine therefore represents the market value of carbon. The estimated return for carbon is calculated based on productivity using the non-declining yield approach (Buongiorno & Gilles, 2003) so the revenue may be slightly underestimated. The formula for carbon sequestration value can be found in Barry et al. (2014, p. 9). At the time of the study (29 August 2019), the price of one New Zealand Unit (NZU) of carbon dioxide sequestered was $24.75.

Non-market values

The FIF incorporates environmental models such as the New Zealand Empirical Erosion Model (Dymond et al., 2010) and the land use spatial function from Ausseil et al. (2013). We used the FIF to quantify and value the non-market environmental benefits of avoided erosion and nutrient mitigation. A value for avoided erosion was calculated as the potential volume of sediment movement that can be avoided by afforesting the target sites. The calculation includes a component that accounts for higher levels of erosion after planting and before canopy closure, and the harvesting and post-harvest period.

Details for calculating the value of avoided erosion can be found in Barry et al. (2014). In this study, we used a social discount rate of 3% to calculate the value of avoided erosion and avoided nitrogen leaching (Maseyk et al., 2015). To calculate the value of avoided nitrogen, we used the nitrogen leaching rate based on Ausseil et al. (2013) and assumed that this rate will change to about 3 kg/ha/yr with afforestation (Menneer, 2004). We then multiplied this difference by a one-off payment of $400/kg of nitrogen leached (Duhon et al., 2011). This product is then annualised using the social discount rate of 3%.

Results

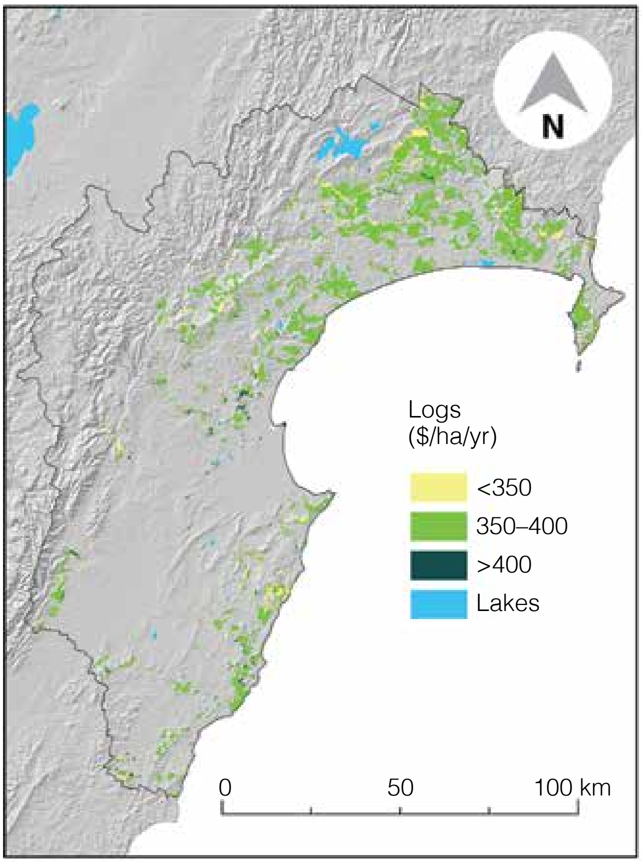
The market and non-market ecosystem services values calculated for a 28-year rotation of radiata pine grown on highly erodible sites in the Hawke's Bay are summarised in Table 1. Areas where the greatest values could be obtained are shown in Figure 1a (log values), Figure 1b (carbon sequestration), Figure 1c (avoided erosion) and Figure 1d (avoided nitrogen leaching). The value of carbon is expected to be higher in the future, rising from $24.75/tonne of CO_2 equivalent as of August 2019 to $30/tonne of CO_2 equivalent in 2024 (CommTrade, 2020).

As expected, afforesting the steepest areas would provide the highest average avoided erosion values (greater than $200/ha/yr). The results also suggest that the greatest average value of avoided nitrogen from afforestation would be gained if the areas shaded in red (Figure 1d) were converted from their existing land use to forestry.

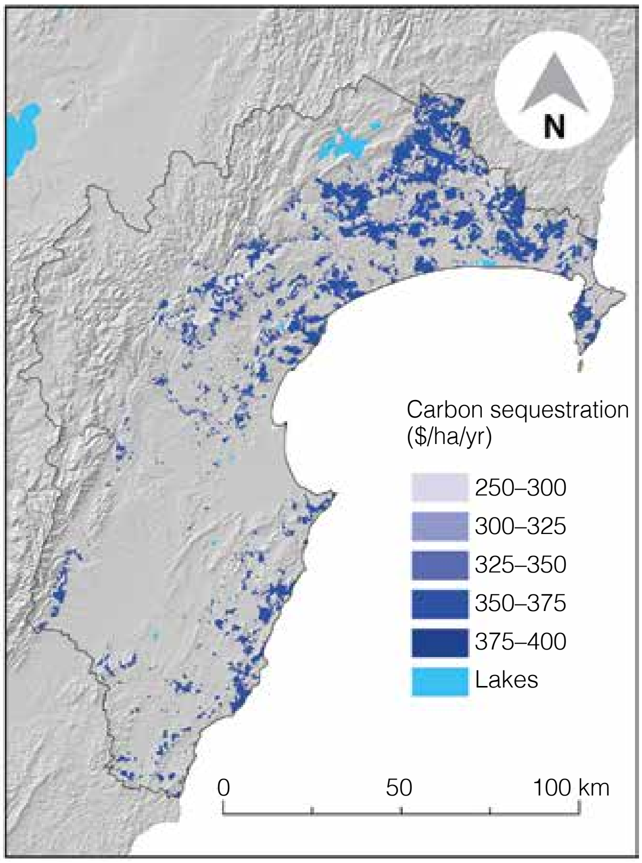
Table 1: Market and non-market ecosystem services values calculated for a 28-year rotation of radiata pine grown on highly erodible sites in the Hawke's Bay

Ecosystem service	Value* ($ ha^{-1} yr^{-1})
Logs	330–640
Carbon sequestration	260–380
Avoided erosion	150–300
Avoided nitrogen leaching	50–270

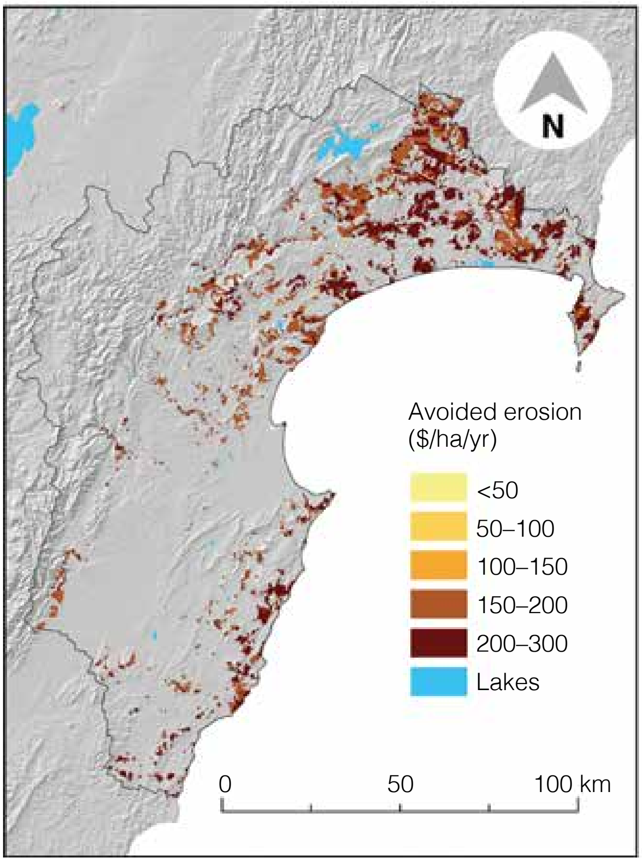
*Assuming an annualised net present value (NPV), with a financial discount rate of 6% for logs and a social discount rate of 3% for the environmental values of carbon sequestration, avoided erosion and avoided leaching



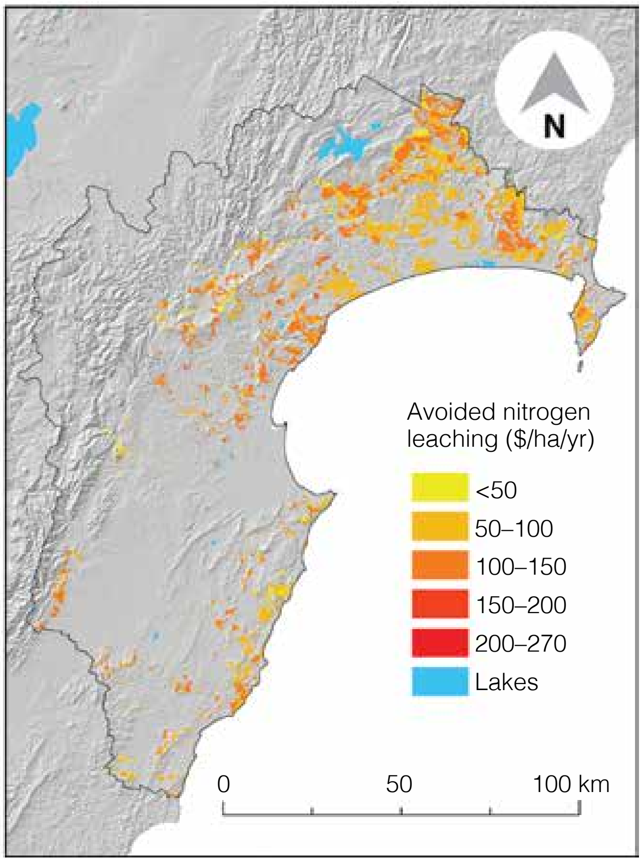
a: Annualised radiata pine log value



b: Annualised carbon sequestration value



c: Annualised avoided erosion value



d: Annualised avoided nitrogen value

Figure 1: Ecosystem services values for highly erodible sites identified as suitable for afforestation in the Hawke's Bay

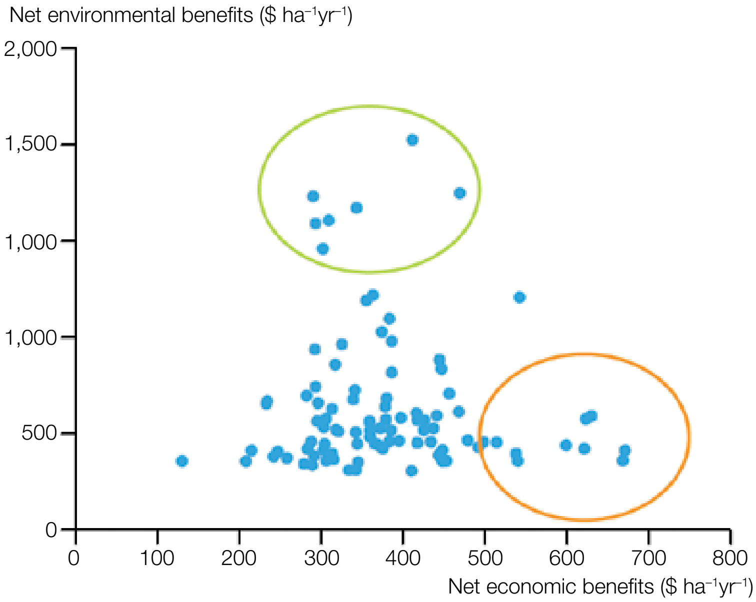


Figure 2: Net environmental vs net economic benefits of afforestation of marginal livestock areas in the Hawke's Bay where the environmental benefits are carbon sequestration, avoided erosion and leaching reduction (after Pannell, 2008)

Making targeted investment decisions

In general, resources for afforestation programmes are limited and it is unlikely that new forests would be established in all the highly erodible sites identified as suitable for afforestation. There is a need for targeted efforts depending on the objective of an afforestation programme. The quantified value of ecosystem services can be used to carry out an analysis that takes into account both the net public (environmental) and net private (economic) benefits of afforestation.

Using a framework developed by Pannell (2008), the net public benefit from forest ecosystem services and net private benefits from logs, for example, can be visualised (Figure 2). If the objective of afforestation were to provide environmental benefits, afforestation in the areas circled in green should be prioritised. If economic benefits or log profits are given precedence, the data points for the areas circled in orange should be prioritised.

We have taken the ratios between the total value of the non-log ecosystem services and logs to identify areas in the Hawke's Bay that produce a higher proportion of public benefits. Figure 3 shows that afforestation of a few marginal livestock areas in the region provides ecosystem services to log ratios of 3:1 or higher. That is, for every $1 in annual profit provided by new forests, the value of non-log ecosystem services is at least $3. This figure can be interpreted as the environmental value provided over and above the profit from log production. Figure 3 also shows that a significant proportion of the highly erodible land identified as suitable for afforestation would have provided ecosystem services to log ratios of 1.5 or greater.

In areas where significant non-market ecosystem services values can be potentially realised, it is recommended a potential afforestation programme should offer landowners the incentive to afforest (e.g. subsidised establishment cost), as long as the value of the benefits from cleaner water (through avoided erosion and nutrient mitigation) and climate regulation outweigh the costs of the incentive package.

Increased biodiversity

Increased afforestation will extend the habitat available for native flora and fauna. Plantation forests are home to a surprising number of different species, including more than 118 threatened native species (Pawson et al., 2010), such as kiwi, karearea (bush falcon), native orchids, kākābeak, frogs, lizards and insects.

A significant population of brown kiwi are already found in the region (see www.kiwisforkiwi.org). Afforestation (with predator control) would potentially allow them to extend their range. Karearea also thrive in planted forests, with Kaingaroa Forest supporting the largest population in this country. New Zealanders value their native plants and animals and would be prepared to financially support conservation initiatives on both private and public land, even in exotic plantation forests (Yao & Kaval, 2010; Yao et al., 2019b).

Conclusions

Afforestation of the highly erodible sites identified will provide multiple benefits to society such as logs, carbon sequestration, improved water quality through

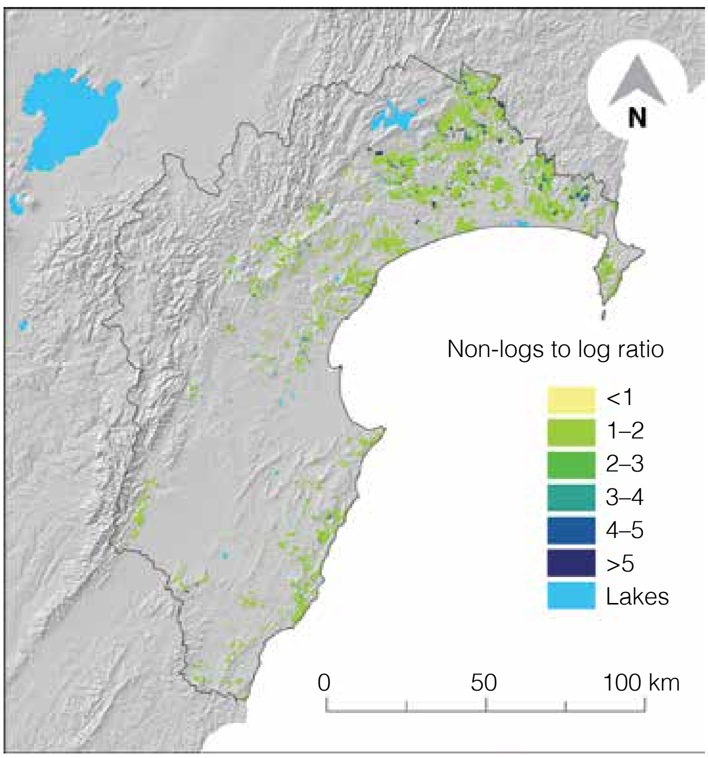


Figure 3: Ratio between non-log ecosystem service values and log values

a reduction in nutrients and avoided erosion, and conservation of iconic species. On most of the land the value of the ecosystem services benefits would likely be at least one-and-a-half times, and in some places up to six times, greater than the log value.

This work has focused on radiata pine, but input parameters for modelling market returns for other species are needed. It is likely that other species with longer rotations and different growth and carbon uptake rates could provide even greater ecosystems service benefits. Data on permanent and selectively harvested native forest is also needed.

This work allows us to recognise and understand how afforestation affects non-log ecosystem services across the Hawke's Bay region and how these might affect its economy, environment and society. Communities that would benefit from a future biodiversity enhancement would be likely to financially support such initiatives. It is advantageous to consider both the private and public benefits from potential afforestation programmes in policy and investment decision-making. Using a spatially explicit framework such as the FIF to evaluate the costs and benefits of expensive afforestation programmes enables decision-makers to be more targeted and cost-effective.

It is important to note that plantation forests have additional environmental and social values other than those studied here, including water flow regulation, flood mitigation, water filtration, recreation, educational values and human health benefits. Due to the limited scope of the project, these benefits have not been accounted for. We recommend that future assessment of ecosystem services for afforestation should quantify these other important services to represent a fuller suite of benefits of forestry.

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