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ASSESSING THE VIABILITY OF FUTURE AND RECENTLY ESTABLISHED EXOTIC FORESTS IN NEW ZEALAND

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SUMMARY

This study examined the benefits of establishing exotic *Pinus radiata* forests in New Zealand. In the first part of the study, a sensitivity analysis was carried out by using an existing afforestation data set to identify the factors affecting the private benefit of establishing exotic forests on marginal land. In the second part, a spatial economic framework was used to examine the private and public benefits from forests that were established between 1996 and 2009. Results indicate that recently established forests in less productive land provide lower private benefit but higher public benefit than forests established in more productive land.

Keywords: exotic forests, spatial analysis, ecosystem services, private benefits, public benefits

INTRODUCTION

Ecosystem services are defined as the benefits derived by the society from an ecosystem (UKNEA, 2011). The 10 key ecosystems in the world are categorised into cultivated, dryland, forest, urban, inland water, coastal, marine, polar, mountain and island ecosystems (MEA, 2005). Of these 10, the forest ecosystem provides the highest number of ecosystem services (MEA, 2005). The forest ecosystem includes New Zealand's exotic planted forest ecosystem, which provides provisioning (forest products), regulating (carbon sequestration, avoided erosion), cultural (recreation) and supporting (soil formation, nutrient cycling) services (Yao et al., In press; Quine et al., 2011). Of these services, only forest products (e.g. dollars per cubic metre of wood) and credits from carbon sequestration (e.g. dollars per tonne of carbon dioxide sequestered) have market prices. The values of other forest ecosystem services such as avoided erosion and recreation, although very valuable to society, do not have market prices. Consequently, such services are overlooked so are not accounted for (or less visible) in policy decision making. The invisibility of ecosystem services in policy can be described by this short quote "We use nature because she is valuable, we lose nature because she is free" (Sukdev, 2013). In addition to lack of representation of key ecosystem services in policy and planning, the values of these services tend to vary across the landscape. Timber yield from forestry would likely be low in areas with poor soil and low rainfall, while in areas with more suitable soil and sufficient rainfall would get higher yield. On the other hand, soil erosion rate would likely be higher in steeply sloping area with sandy soil while lower in areas with levelled land and clayey soil. To account for the variation in the provisioning and regulating services values across the landscape, it is important to have a methodological framework that accounts for the variation in yield of forest products, variation in soil erosion and other factors. A spatial-economic framework that could account for variations in the services provided by the establishment of new planted forests across the landscape is the Forest Investment Finder plus (hereby called FIF+).

The FIF+ framework puts together various models and spatial data to enable the identification of areas where new planted forests would likely be economically viable (or unviable). FIF+ uses the New Zealand Empirical Erosion Model (NZEEM) to calculate the change in sedimentation rates of affected water bodies and water ways due to afforestation Dymond et al. (2010). Therefore, FIF+ provides an estimate of the net private benefits (profit) and public benefits (reduction in sedimentation) of land use change (e.g., scrub to forest). Once these two groups net benefits have been estimated, appropriate policy instruments can be identified that encourage afforestation by employing the policy framework developed by Pannell (2008). Policy options include technology development, positive incentives, extension and no action.

It is important for forest investors, landowners, concerned community groups and government institutions to identify those areas in the country where new forests could be grown profitably whilst also provide valuable ecosystem services. Watt et al. (2011) identified possible areas for future forests in New Zealand. Barry et al. (2012) applied FIF+ to examine the net private and public benefits of afforestation which are located mainly in marginal lands with moderate to very severe erosion problems. Barry et al. (2012) found that the establishment of new forests in future forest areas would mostly be unprofitable in all of the country's 16 regions. However, positive public benefits from avoided erosion were possible mostly in all regions. The highest benefits were available in Gisborne, which experiences the highest erosion rates in the country. The public benefit of avoided erosion in that region ($10,170 per hectare per year) is more than eight times the national average of $1,240 per hectare per year. Barry et al. (2012) applied FIF+ in future forests but not in existing forests. They assumed that profitability is the main driver for establishing new forests. Consequently, they used different private cost and benefit items such as cost of establishment, pruning, road construction, harvesting and revenue from sale of timber. However, given that the costs of forest operations and prices of wood vary over time, they were not able to show which factors would have the most significant impact on profit. Barry et al. (2012) also pointed out that, in areas where afforestation provides the most significant public benefit, afforestation should be encouraged by providing positive incentives. However, there could be many other reasons why new forests are established. This study aims to extend the Barry et al. (2012) study by answering the following research questions:

1. When investing in afforestation of future forest areas, which factors provide the greatest impact on profitability?
2. Whereabouts in New Zealand are exotic forests established between 1996 and 2009?
3. What factors are likely to have influenced the establishment of these recent forests?

To answer the first research question above, the data described in Barry et al. (2012) was used and a sensitivity analysis was carried out by varying different costs of forestry operations and prices timber and carbon. This allowed the identification of the factors that significantly affect the area of profitability of forests in future forest areas, which consist mainly of severely eroded land. To answer the second question, planted forests established in New Zealand between 1996 and 2009 were identified using New Zealand land cover databases (i.e. LCDBs 2 and 3). To answer the third question, the factors that would influence the establishment of recent forests were identified using a pairwise correlation analysis (Snedecor & Cochran, 1989). It is envisioned that answers to the above questions would help forest investors, land managers, policy makers and planners to discuss issues about investing in a productive land use (i.e. planted forest) that provides multiple ecosystem services.

DESCRIPTION OF THE FIF+ FRAMEWORK

FIF+ consists of three components: private benefits, public benefits and identification of appropriate policies.

The first component is mainly spatial that allows the accounting of a wide range of factors to predict the volume of different log grades that can be produced from establishing new forests across the landscape. This timber yield prediction component uses several spatial layers which include *forest productivity* (300 Index and Site Index), and *biophysical* (temperature, soil, land cover and impedances) (see Barry et al., 2012). Different cost items can be adjusted based on steepness of the land and size of the forests using spatial layers which include slope and impedances. Economies of scale can be achieved by purchasing more efficient and large machines for large forests, while it can be difficult to attain economies of scale in smaller forests. A spatial algorithm was also developed to identify the sites for the road construction to operate the future forests. The predicted length of the road, the slopes and other factors allow the estimation of the cost of the construction of logging roads for future forests. Further details of this component can be found in Harrison et al. (2012).

Revenue from sale of timber is calculated by multiplying the log grades predicted from above with price data. The price data used here was the 12-quarter average log prices published by the Ministry for Primary Industries (MPI 2013). Revenue from sale of carbon credits is calculated by multiplying the predicted amount of carbon dioxide sequestered by the carbon prices reported in by CommTrade (2013). These estimates of costs and revenues were used to estimate the profit of each future forest. This component helps identify where in New Zealand's future forest areas where an investor could get a profitable return on their forest investment. Barry et al. (2012) suggested that the country has created a spatial-economic data set of New Zealand's future forests with Watt et al. (2011) as one of the bases.

These future forest areas represent the marginal land area with moderate to severe erosion where *Pinus radiata* forest can successfully grow. A sensitivity analysis was conducted to identify the factors affecting the profitability future forests assuming a 28-year rotation under structural regime and a carbon price of $4 per tonne of carbon.[1]

The second component of the framework accounts for the public benefit from afforestation. This is the value of avoided erosion, which is a regulating service that has no market value. Planting of forest trees especially on steep slopes would likely stabilise the soil and reduce erosion (Fahey & Marden, 2006). This consequently leads to a reduction in sedimentation in water ways and water bodies. The value of avoided erosion was estimated using the New Zealand Empirical Erosion Model (NZEEM). The NZEEM provides an estimate of the amount of sedimentation in water ways based on the type of land use above the catchment (Dymond et al. 2010). An avoided-cost approach was employed to value the reduction in sedimentation. Under this approach, the value of the benefit can be calculated based on the avoided costs of preventing an ecosystem to reduce the services that it provides (Kim & Dixon, 1986; Badola & Hussain, 2005). Using the avoided cost of filtration of sediment to produce drinking water ($5.50 per tonne) and avoided flood damage ($0.90 per tonne) as proxies of the benefits, the value of reducing one tonne of sediment in water ways was calculated to be approximately $6.50. This can be considered as a conservative estimate of off-site public benefits because there could potentially be other benefits from reducing sedimentation or improving water quality. For example, water quality improvement can also enhance biodiversity and recreational activities. For simplicity, this study only accounted for the above two items of avoided public costs (water filtration and flood damage) from afforestation.

The third component of the FIF framework puts together the results of the first two components into the Public: Private Benefits Framework proposed by Pannell (2008). The PPBF determines the magnitudes of both private and public net benefits of alternative land uses compared to the current land use. The PPBF framework identifies the appropriate class of policy mechanism for a particular case depending on the magnitude of net private and public benefits, relative to current land use. This component of FIF+ is described in more detail in Barry et al. (2012) and Pannell (2008). For this study, the PPBF framework was not applied because PPBF is about the identification of appropriate policies to encourage land use change. This present study is focused more on the identification of factors affecting the viability of future forests and what possible factors contributed to the establishment of recently established forests.

DATA CONSTRUCTION AND DESCRIPTION

This study used two sets of spatial economic data. The first data set consisted of spatial and economic details of the proposed New Zealand's future forest areas. This was constructed by Barry et al. (2012) based on the criteria described in Watt et al. (2011). The first data set includes a digital layer of future forest areas where the forest tress species *Pinus radiata* would grow successfully (Figure 1). The second data set was constructed specifically for this study and contains data about exotic planted forests that were established between 1996 and 2009.

[1] Twenty-eight years is the most common growing period of *Pinus radiata* in New Zealand (Barry et al. 2012).

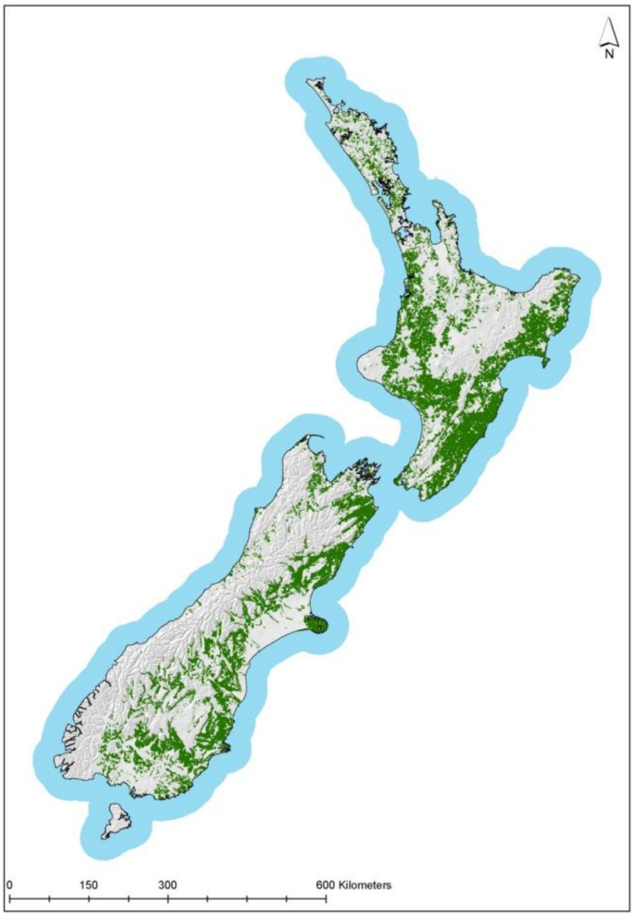


Figure 1: Map of New Zealand showing the 2.47 million hectares of future forest areas

The first data set on future forests was used for the sensitivity analysis to answer the first research question. Cost items included land purchase, establishment, harvesting and road construction, while revenue items included the prices of timber and carbon (Table 1) (see Barry et al., 2012). To conduct the sensitivity analysis, cost and price items were adjusted by plus or minus 10% from the status quo. By varying the cost and price items, the area of profitable forests changed with varying magnitudes which are reported in the results and discussion section.

Table 1: Data used to assess profitability for a 28-year rotation of *Pinus radiata*

Costs	Revenues
Land purchase ($ per 625 m^2)	Carbon credits ($ per New Zealand Unit)
Establishment ($ per 625 m^2)	Timber ($ per tonne)
Silviculture ($ per 625 m^2)	
External road construction ($ per km)	
Internal landing construction ($ per 625 m^2)	
Internal road construction ($ per km)	
Harvesting ($ per tonne)	
Transport ($ per tonne/km)	
Emissions Trading Scheme compliance[2] ($ per 625 m^2)	

[2] This cost was assumed to be a constant value per hectare and was included after the spatial modelling.

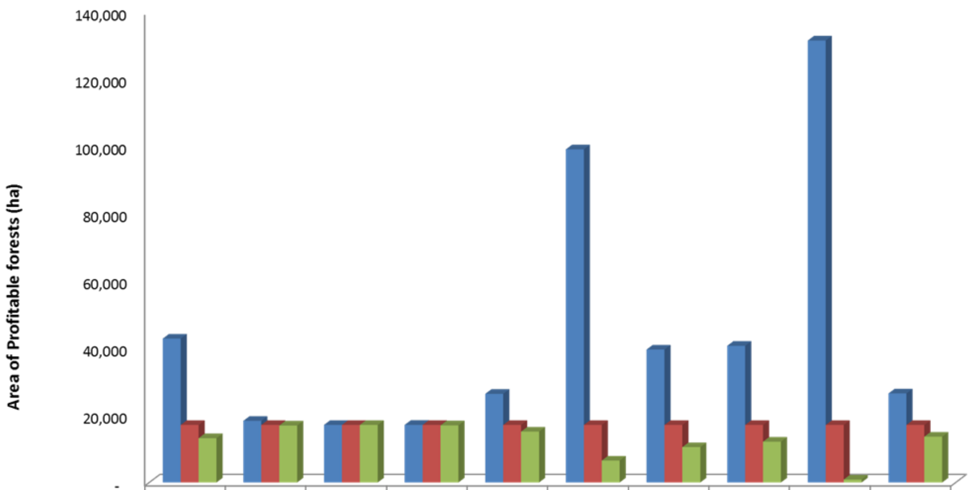
The second data set was constructed and analysed to answer the second and third research questions. To construct this data set, exotic planted forests (both commercial and non-commercial) planted between 1996 and 2009 were identified using digital maps of New Zealand's land surface. Two key maps used were the New Zealand Land Cover Database (LCDB) versions 2 and 3. LCDB-2 is a spatial layer that provides a thematic classification of land cover and land use classes in New Zealand. It was released in July 2004 and used satellite imagery that was captured in the summers of 2001/2002 and 1996/97. LCDB-3 is a thematic map that adds a new time period derived from the satellite imagery taken during the summer of 2008/09. This updated map was released in March 2013 and can be accessed at http://lris.scinfo.org.nz/layer/304-lcdb-v30-land-cover-database-version-3/.

The exotic forests that were identified to be planted between 1996 and 2009 were grouped into two and are referred to as: **R**ecent **F**orests in **F**uture Forest Areas (RF_F) and **R**ecent **F**orests in **O**ther Areas (RF_O). This is to compare the two groups based on land productivity. As mentioned earlier, future forest areas have moderate to very severe erosion therefore would likely be on steep slopes and less productive. While land in other areas can have a combination of both marginal and more productive land areas.

It is important to use the best currently available data to limit errors associated with the construction when extracting data from any spatial layer. The 15-metre national Digital Elevation Model (DEM) produced by University of Otago was used to identify elevation data, a full description can be found in Columbus et al (2011). Erosion data was extracted from the data set described in Dymond et al. (2010). Both spatial layers for elevation and erosion were downloaded for free at http://lris.scinfo.org.nz/ and http://koordinates.com/ .

RESULTS AND DISCUSSION

The sensitivity analysis of 2.47 million hectares proposed future forest area showed that the main factor impacting on the area of profitable forests (i.e. NPV > 0) are harvesting cost and timber price. On average, a 10% reduction in harvesting cost would result in a five-fold increase in the area of profitable forests (Figure 2). While a 10% increase in timber prices would increase viable future forest areas by up to seven-fold. Other key factors identified were establishment, transport and land costs, where a 10% decrease of each of these costs could result in the doubling of viable areas. On the other hand, a 10% change in landing or external road costs would likely have no impact on the total area of future forests.



	Establishment costs	Thinning costs	Landing costs	External road costs	Internal road costs	Harvesting costs	Transport costs	Land costs	Timber price	Carbon price
10% decrease in costs (ha)	42,784	18,337	17,113	17,125	26,372	99,085	39,534	40,646	131,459	26,470
Status Quo (ha)	17,110	17,110	17,110	17,110	17,110	17,110	17,110	17,110	17,110	17,110
10% increase in costs (ha)	13,169	16,942	17,110	16,985	15,139	6,514	10,508	12,137	856	13,620

Figure 2: Area of profitable forests and the factors that can affect profitability of future forests

ArcGIS 10 software was used to identify the forests that were established between 1996 and 2009 based on LCDBs 2 and 3. About 34,043 hectares of these recently forests were established in North Island during this period.[3] A total of 1,417 forest units were identified with size ranging from 2 ha to 1,025 ha. About 46% of these were in future forest areas which are marginal, sloping agricultural lands with moderate to severe rates of erosion (Land Use Capability classes 6,7 and 8). The rest of the forests were in areas outside the future forest areas with varying ranges of soil productivity (i.e. LUC classes 1 to 8). As mentioned earlier, the recently established forests are classified into two groups: RF_F (**R**ecent **F**orests in **F**uture Forest Areas) and RF_O (**R**ecent **F**orests in **O**ther Areas). The total area of RF_F (25,044 ha) is more than twice as RF_O (8,999 ha) (Table 2). In terms of size, on average, RF_F is at least three times larger than RF_O (Table 2). The distribution of RF_F and RF_O across the North Island is patchy with RF_F mainly located in Wellington, Gisborne and Manawatu (Figures 3 and 4). Of the 9 regions in the North Island, Auckland has the smallest proportion of RF_F with less than one percent. A large proportion of RF_O are located in Wellington, Northland and Waikato. Taranaki represents the region with the smallest RF_O proportion of two percent.

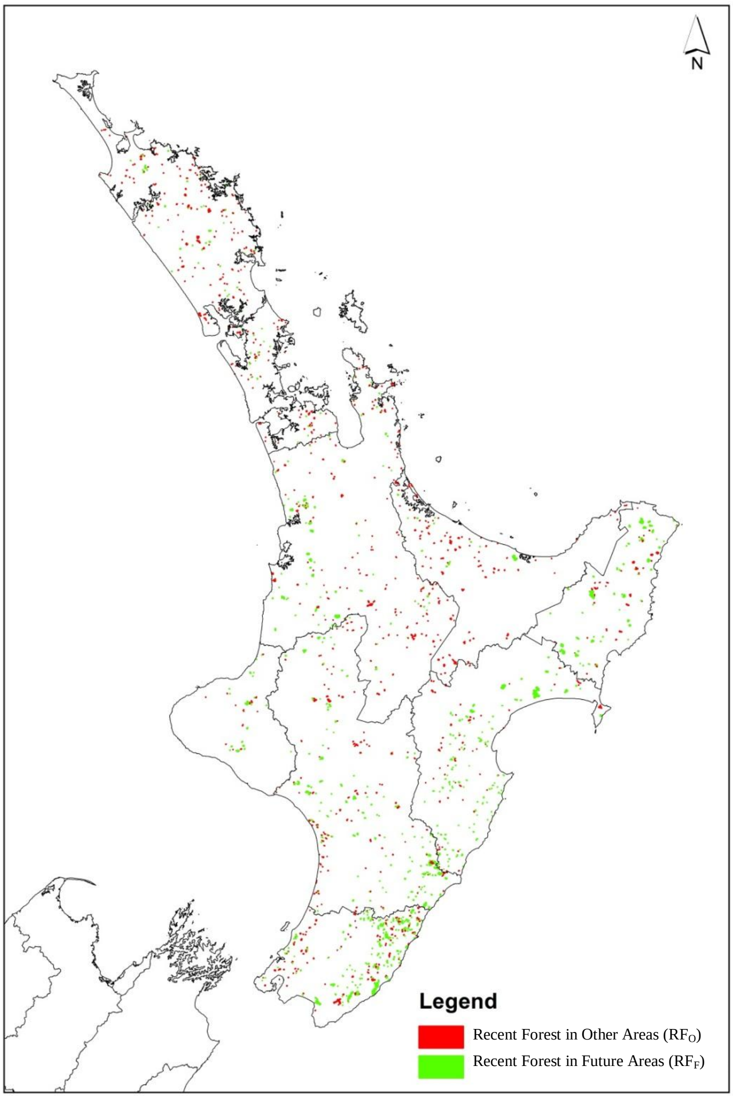
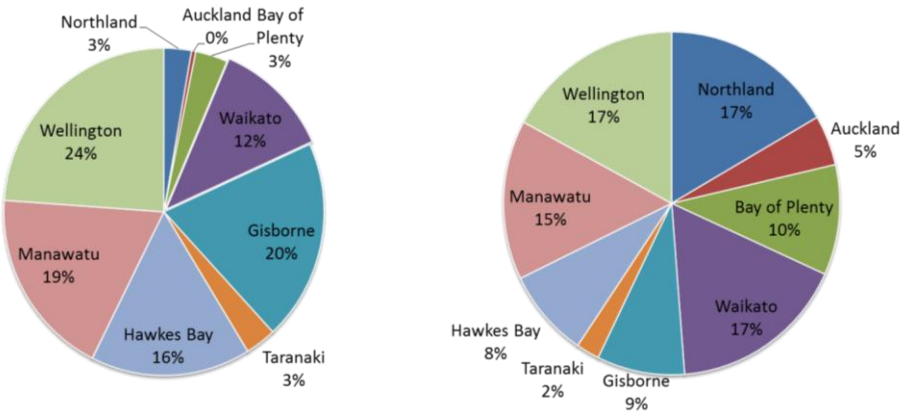


Figure 3: Map of North Island showing the location of **R**ecent **F**orests in **O**ther Areas (RF_O) and **R**ecent **F**orests in **F**uture Areas (RF_F).

[3] New forests in South Island were also identified. However, an extremely large area of recently established forests was predicted for the Canterbury and Southland regions. Based on discussions with an experienced forest manager and the developers of the LCDB maps, this area may have included the areas with wildling pines. Therefore, this data was excluded.



RF_F RF_O

Figure 4: Distribution of recently established forests in North Island by region

About 72% of all the recently established forests identified are within 100 metres from existing forests. This pattern might indicate that many new forests are extensions of existing forests. A larger proportion of RF_O (76%) can be found adjacent to existing forests compared with RF_F with 67% (Table 2). All forests in RF_F belong to the least productive LUC classes 6, 7 and 8 while 20% of RF_O belong to the more productive LUC classes 1 to 5 (with 80% belonging to LUC classes 6, 7 and 8).[4] The relatively higher land productivity in RF_O might explain why the average cost of the land is 45% higher than RF_F areas. In terms of elevation, on average, RF_O is about 13% higher in altitude which can be because most of these recent forests are located further inland (Figure 3).

On average, RF_F land gets about six times the erosion rate as RF_O land (Table 2). The proportions of the areas of viable forests areas are virtually the same between RF_F (14%) and RF_O (15%). A possible reason for this is that RF_F have larger forest areas, which might contribute to the attainment of economies of scale (i.e. lower marginal cost or cheaper cost of production per unit). In terms of profitability, RF_O on average has a slightly higher profit per hectare which can be because a fifth of the area is in a more productive land. Conversely, as RF_F areas have moderate to very severe erosion, the public benefit (value of avoided erosion) is almost twice as RF_O (Table 2).

[4] Land Use Classification (LUC) classes 1 to 5 are the more productive land classes (arable land) with erosion severity ranging from minimal to slight. LUC classes 6, 7 and 8 are considered as non-arable with erosion severity of moderate, severe and very severe, respectively (Lynn et al., 2009).

Table 2: Characteristics of the land areas defined as RF_F and RF_O

Parameter	RF_F	RF_O
Total area (ha)	25,044	8,999
Percentage of area within 100 m from existing forest	67	76
Average area per forest (ha)	38	12
Percentage of area in LUC classes 1, 2 and 3	0	8
Percentage of area in LUC classes 4 and 5	0	12
Percentage of area in LUC classes 6,7 and 8	100	80
Cost of land ($/ha)	6,843	9,920
Elevation (masl)	179	202
Erosion rate in 2008 (t/km²/yr)	578,173	94,272
Percentage of viable forests (with land cost)	14	15
Percentage of viable forests (without land cost)	95	94
Private benefit ($/ha)	2,460	2,730
	(1,430)	(1,690)
Public benefit ($/ha)	2,900	1,540
	(11,020)	(7,660)

Note: Figures in parentheses represent standard deviation.

Results of the pairwise correlation analysis shows a significantly positive correlation between the area of forest established and being adjacent to existing forests (i.e., situated within 100 meters) for both RF_F and RF_O (Tables 3a and 3b).[5] This relationship might indicate that the presence of a forest would likely influence the location of recently established forests. Elevation also has a significant relationship for both groups, indicating that forests have been planted at higher elevations over the last few years. Assuming that higher elevation equals steeper less fertile land, then this corresponds with agricultural trends that have seen perceived higher-value practices, such as dairy expanding in areas with more productive soil. Consequently, the cost of land is significantly negatively correlated to the area of recent forests for both RF_F and RF_O , which might indicate that new forests were established in land with lower prices as the more expensive land (or more productive land) are used for other types of land use (e.g., dairy).

Private benefit or profitability is significantly positively correlated with new forests a-reas in both RF_F and RF_F. This might indicate that new forests were established in areas which could provide investors with good economic returns. In RF_F, recent forest areas are highly correlated with erosion and public benefit, which seems to make sense as future forest areas were found to be in areas of higher erosion. The opposite is true for RF_O where public benefit is not significantly correlated to recently established forest areas. As a result of the relatively lower erosion rates, the value of avoided erosion is significantly lower in RF_O.

[5] The *p*-values of correlation coefficients for both RF_F and RF_O are both less than 0.05 which indicate statistical significance at the 95% confidence level.

Table 3a: Correlation matrix for RF_F showing the correlation coefficients and *p*-values.

	Area	Within 100 meters to existing forests	Elevation	Cost of land	Private benefit	Public benefit	Erosion rate
Area	1.000						
Within 100 meters to existing forests	0.149	1.000					
	(<0.001)						
Elevation	0.093	0.006	1.000				
	(0.017)	(0.889)					
Cost of land	-0.115	0.021	-0.103	1.000			
	(0.003)	(0.589)	(0.008)				
Private benefit	0.128	-0.008	0.105	-0.978	1.000		
	(0.001)	(0.834)	(0.007)	(<0.001)			
Public benefit	0.129	0.023	0.138	-0.137	0.114	1.000	
	(0.001)	(0.551)	(<0.001)	(<0.001)	(0.004)		
Erosion rate	0.121	0.031	0.117	-0.147	0.125	0.968	1.000
	(0.002)	(0.430)	(0.003)	(<0.001)	(0.001)	(<0.001)	

Note: Figures in parentheses are *p*-values.

Table 3b: Correlation matrix for RF_O showing the correlation coefficients and *p*-values.

	Area	Within 100 meters to existing forests	Elevation	Cost of land	Private benefit	Public benefit	Erosion rate
Area	1.000						
Within 100 m to existing forests	0.080	1.000					
	(0.027)						
Elevation	0.086	0.052	1.000				
	(0.017)	(0.151)					
Cost of land	-0.155	-0.098	-0.151	1.000			
	(<0.001)	(0.007)	(<0.001)				
Private benefit	0.101	0.045	0.138	-0.731	1.000		
	(0.005)	(0.217)	(<0.001)	(<0.001)			
Public benefit	0.052	-0.009	0.081	-0.131	0.095	1.000	
	(0.151)	(0.812)	(0.025)	(<0.001)	(0.008)		
Erosion rate	0.040	0.047	0.080	-0.165	0.119	0.755	1.000
	(0.265)	(0.196)	(0.027)	(<0.001)	(0.001)	(<0.001)	

Note: Figures in parentheses are *p*-values.

Based on the results of correlation analysis discussed above, it can be summarised that:

- RF_F would likely occur where:
    - forests are already present
    - high elevation – greater than 180 metres above sea level
    - low cost land
    - high potential return
    - public benefit is provided
    - high erosion rate
- RF_O would likely occur where:
    - forests are already present
    - high elevation – greater than 200 metres above sea level
    - low cost land
    - high potential return

This study also has some limitations. The analytical results of this study might be biased due to regional variation. For example, the Gisborne region has erosion rates that are many times that of any other region in New Zealand. This region has the East Coast Forestry Project which is a targeted and subsidised afforestation scheme that focuses in areas with extremely high erosion (MAF, 2011). This situation could bias the results towards erosion.

While the data used to create the FIF+ model is robust, the spatial economics component of FIF+ has yet to be compared to real profit and loss data from a commercial forestry company. It would be therefore be extremely useful to apply the framework to an existing commercial planted forest. The resulting data could then be tested against real profit and loss accounts and test the validity of the FIF+ model.

In terms of the construction of spatial data set used in this study, it was found that when using any spatial data, errors can be associated with that data. To minimise the impact of these errors and improve the validity of the study, ground truth could be carried out. A first step to achieving this would be to review the forests identified by using LCDB2 and LCDB3. Selecting a random sample of those forests and comparing with aerial photographs associated from the time period that the forest were planted, would identify true new planted forests. Further ground truth would require field visits to sites to measure and test the attributes that have been allocated to specific forests.

CONCLUSIONS, POLICY IMPLICATIONS AND FUTURE DIRECTIONS

This study has found that a reduction in the cost of harvesting is the most important factor for improving the viability of afforestation in future forests. Therefore, developing technologies and other measures that reduce the cost of harvesting in forests on steep lands will be essential for enhancing or improving forest viability. Alternatively, planted forests on steep slopes may not need to be harvested by simply leaving trees to grow permanently or employ continuous cover forestry (Häusler & Scherer-Lorenzen, 2001; Pommerening & Murphy, 2004). However, for those options to remain financially viable, it would be important to recognise the value of avoided erosion that forests provide, perhaps a payment scheme for the provision of forest ecosystem services may be developed (Mercer et al., 2011).

The study further extends Barry et al. (2012) by identifying the factors that influence the establishment of new forests. In future forest areas, the top three factors identified are being adjacent to existing forests, private and public benefits. For investment purposes, it would make sense to establish a forest adjacent to an existing forest and this forest should be profitable or viable. Findings of the study suggest that new forests in future forest areas would likely be planted in areas with high erosion rate and those forests provide about twice the public benefits than new forests in more productive areas. On top of the provision of avoided erosion values, it is important that other ecosystem services provided by new forest be accounted for in policy decision making to recognise those important benefits. This study has not yet accounted for other valuable forest ecosystem services such as biodiversity, recreation and water quality improvement (Dhakal et al., 2012; Yao et al., forthcoming; Rivas-Palma, 2008). Further research in this area should investigate these other values to highlight the benefits of forestry to the general public as well as tourists. With regards to the spatial data that has been constructed in this study, there has been no study yet that examines the accuracy of this method in identifying recently established forests using LCDB 2 and 3. It would be very useful to verify the accuracy of using LCDB layers for identifying new forests or any other types of land use change. That could be a very interesting future study.

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