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Where and how can policy encourage afforestation to avoid soil erosion?

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Where and how can policy encourage afforestation to avoid soil erosion?

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Summary

Understanding the economic value of avoided soil erosion in New Zealand is an important factor in policy decision making enabling the acknowledgement of the costs of erosion to the economy. This paper focuses on potential for afforestation to mitigate erosion risks on marginal agricultural hill country lands. Spatial economic modelling is undertaken to determine the net private and public benefit due to the avoided soil erosion from afforesting these areas. The study indicates that in some cases forestry is not viable and thus the public benefit from avoided erosion (and other ecosystem services) will not be forthcoming in these areas. Afforestation of these areas may therefore require positive incentives or improvements in forest and farm systems and technologies, depending on the relative weight of the public and private net benefits.

Keywords: Spatial economic modelling, ecosystem services, soil erosion, public policy.

1. Introduction

Soils perform many essential services that contribute to the very survival of life on earth. These services can be categorised into three broad groups of services: cultural, regulating, and provisioning. Cultural services include aesthetic experience, spiritual enrichment and recreation (Dominati, Patterson et al. 2010). Regulatory services include flood mitigation, filtering of nutrients, biological control of pests and disease, recycling of wastes and detoxification, and regulation of N_2O and CH_4 emissions. Provision of food, wood and fibre, and raw materials and physical supports are the main provisioning services.

The population in New Zealand is expected to increase to over five million by 2050 from the current level of 4.4 million (Statistics New Zealand 2009). Thus, the demand for agricultural activities would significantly increase and place more pressure on the country's soils potentially leading to increased soil erosion. Understanding the economic value of avoided erosion in New Zealand is therefore an important factor in policy making to optimise soil related activities in the economy.

This study focuses on areas of New Zealand that would be suitable for afforestation, henceforth known as future forests (Watt et al. 2011). These are areas with marginal agricultural value and slight to extreme erosion severity. The key aim of this study is to determine the value of avoiding soil erosion on these areas through afforestation, furthermore to determine the appropriate policy mechanism for encouraging afforestation. A policy framework based on the relative magnitude of net private and public benefits (Pannell 2008) is useful to identify policy instruments to encourage afforestation of marginal agricultural land. In essence, the framework separates the private and public net benefits of avoided soil erosion due to afforestation, and compares relative magnitudes of these net benefits to identify policy instruments to encourage future forests activities in New Zealand.

2. Methods

2.1 Evaluation of Erosion and Sedimentation for Different Land-use Scenarios

To gather data to evaluate erosion and sedimentation for different land-use scenarios we have employed the estimates from the New Zealand Empirical Erosion Model (NZEEM) (Dymond, Betts et al. 2010). NZEEM can be used to estimate the mean sediment discharge in response to different land-cover/land-use scenarios. The model uses input data readily available in GIS layers in New Zealand. This makes it suitable for widespread management applications, in contrast to physical based models which are presently only suitable for research catchments (Dymond, Betts et al. 2010). From NZEEM we can estimate the incremental soil erosion levels for different land types given in the Land Cover Data Base (LCDB2) (Thompson, Grüner et al. 2003). We focused this study on the Waikato, Gisborne, and Nelson regions

2.2 Evaluating Benefit of Avoided Soil Erosion

We used the incremental net private and public benefit analysis measures to evaluate the economic value of avoided erosion. The demarcation of the benefits into two categories namely net private and public benefits helped to avoid possible double counting effects which has been identified as a major problem in valuing impact of soil erosion in the literature. This demarcation also enabled us to relate our valuation to a policy analysis framework (Pannell 2008). In this study, private net benefits refer to the net benefits accruing to the private land manager as the results of the proposed changes in land management whereas public benefits represent the net benefits accruing to everyone other than the private land manager.

Two steps are involved in estimating the incremental net benefits of any given land use changes. First, we estimated the changes in erosion level due to changes in the land use from current to the new practices. Then we estimated the corresponding incremental changes in private and public costs and benefits due to the change in erosion levels for the future forest scenarios developed by Scion (Watt, Palmer et al. 2010). Two discounting rates were used, eight per cent which is representative of the rate used in forest market valuation (Manley 2012), and a more conservative four percent, which is closer to a rate for public investment projects.

As forestry and livestock are perennial activities, we compare these scenarios into perpetuity, i.e. afforestation into perpetuity or the status quo land use into perpetuity. This allows a meaningful comparison of land use options that differ in rotation length. The benefits and costs will vary depending on the forestry regime selected. For instance a typical pruned regime may be less than 30 years and this will receive timber revenue at harvest time along with carbon revenue and will face many costs throughout this regime, from establishment to harvesting. A regime which plants solely for carbon revenue will thus face fewer costs and lower erosion impact than a timber regime because of the lack of harvesting. We modelled both a timber regime and a carbon regime:

1. Structural (framing) regime (thinned to 600 stem ha^{-1} from initial planting of 900 stem ha^{-1}), 28-year rotation
2. Carbon regime (1020 stem ha^{-1}), 90-year rotation

2.2.1 Private Net Benefits

Detailed modeling was carried out on the costs and benefits of a forest regime according to spatial impedances (e.g. heavy vegetation increasing silvicultural costs), or site productivity (a high site index indicating good growth and carbon sequestration). Harrison et al. (2012) provides a detailed description of the spatial modelling of the financial private net benefits (Harrison, Barry et al. 2012). For a consistent measure of opportunity cost across all land uses we used land value data from a property valuation specialist, Property IQ (PropertyIQ 2008). In New Zealand, land is typically valued by its highest and best use (New Zealand Insitute of Chartered Accountants 2004). If the land value is greater than the expected value from the new land use, into perpetuity, then it represents a negative net private benefit.

We also employed the Hedonic Price Model (HPM) which explains the price of a good based on its characteristics to evaluate the impact of avoided erosion from a future forest on rural property values. This essentially highlights the avoided loss to the value of the property as a result of afforestation. Our estimates show that a 1% change in erosion rate corresponds to a 0.11% change in property value, holding all other factors the same. This means that a one hectare land parcel in a future forest area with a property value of $20,000 would likely increase its value by $220 if soil erosion rate decreased by 10%. We used this relationship to account for the private benefit from avoided erosion. More details of the HPM analysis may be requested from the authors.

2.2.2 Public Net benefits

Previous literature has estimated erosion levels pertaining to area (Costanza, d'Arge et al. 1997). Using these figures in valuing avoided soil erosion does not take into account the spatial variability of erosion, for example, areas with less stable soil or steeper slopes will have more erosion risk.

NZEEM shows the erosion under the current land use and the reduced erosion in annual tonnes of sediment from afforestation. This assumes full canopy cover and maximum soil protection from a change to woody vegetation. However, erosion from forestry may be the same or worse than the current land use during harvesting and early establishment periods (approximately 5-7 years). Following from Marden and Rowan (1993) and communication with industry professionals, an estimate of the increased or decreased level of erosion by forest age was used to estimate the erosion avoided over one forest rotation compared to the current land cover for the same time period (Marden and Rowan 1993). The data collected for avoided soil erosion relates to sediment volume collected for New Zealand. It accounts for avoided flood damage (NZ$ 0.90/tonne) and avoided water treatment costs to consumptive water (NZ$ 5.60/tonne). Therefore, approximately NZ$6.50/tonne was applied to the NZEEM results to determine the net public benefit as a result of afforestation.

Pimentel et al (1995) estimated the off-site cost which refers to the public cost of soil erosion to be approximately US$3/tonne (Pimentel, Harvey et al. 1995). The historical exchange rate for this period, adjusted for inflation meant that this was approximately NZ$6.60/tonne (OANDA 2012; Reserve Bank of New Zealand 2012). In another study, Dymond et al. (2011) used a top down approach to estimate the value per tonne, whereby they considered Krausse's estimate of NZ$127million for the cost of erosion annually in New Zealand and translated that into current dollars (c.NZ$200m) and divided this by the annual amount of soil exported to the sea each year. This equates to a cost of approximately $1/tonne of sediment eroded (Dymond, Ausseil et al. 2011). Neither estimate can therefore claim to be correct, for example Krausse (2001) points out that his estimate does not account for a number of costs related to soil erosion (e.g. recreational damage), however they are in a similar order of magnitude as the estimate above.

Table 1: Public-private benefits and costs from avoided soil erosion via afforestation[1]

Private Benefits	**Private Costs**	**Public Benefits**	**Public Costs**
Revenue from land use change	Costs from land use change	Avoided cost of sediment removal	Increased soil vulnerability during establishment and harvest
Avoided on site damage	Opportunity cost of land use change	Avoided drinking water quality damage	

2.3 Policy Framework

The framework below underpins the interpretation of the results that follow. It describes the common approach for interpreting the relationship between public and private benefits (Pagiola and Platais 2007; Engel, Pagiola et al. 2008) and expands to identify the appropriate policy mechanism for encouraging more sustainable outcomes based on this relationship (Pannell 2008). Policy choice is made through a consideration of the likely net public and private benefits that may arise from land use changes. The current practice is indicated at the zero-zero point of the framework (Figure 1). This is because the framework is designed to evaluate projects that seek to move people away from the current practice. In fact, by setting the zero-zero point to current practice, the framework allows us to analyse whether the individuals involved will be made better or worse off by the project, and whether the rest of the community will be made better or worse off. The various combinations of public and private benefits generate a number of situations that lend themselves to specific policy instruments as described below. In this project the net public benefits from avoided erosion are always positive and therefore we are concerned with the top half of Figure 1.

[1] There would likely be more costs and benefits associated with avoided soil erosion, however, there is currently little data available on incremental costs relating to sediment volume and thus the table above refers to costs and benefits for which incremental data could be estimated. For a more detailed list of the potential values relating to soil erosion, see Krausse et al, 2001

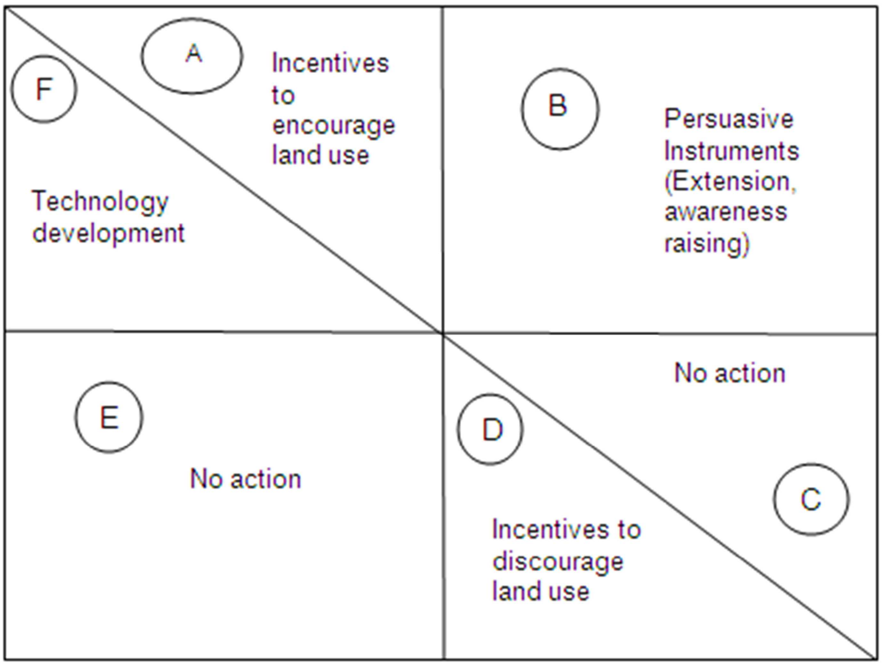


Figure 1: Selection of policy instruments based on public and private net benefits of land use changes (Pannell 2008)

2.3.1 Area A - Private Costs Outweigh Public Benefits[2]

When the public benefits of a land use change are greater than the private costs there are overall social benefits from land use change. However, as private benefits are negative in this process, direct regulation or market-based incentives would be needed to encourage land use changes. The incentive offered must be at least equal to the net private costs faced. However Pannell (2008) indicates that, in reality, the incentive required might need to be greater to get landholders over the 'learning hump' and to promote more rapid adoption.

2.3.2 Area B - Both Public and Private Benefits are Positive[3]

In these circumstances where land use change is profitable, one could expect that change will occur as long as landholders are aware of the pertinent practices. As this may not always be the case, persuasive instruments such as education and training, extension and community programmes would be suitable policy instruments to overcome the informational barrier. The investment in extension should be limited to only the amount necessary to promote the behavioral changes sought and less than the public benefits realised. This ensures that public funds are targeted to where payoffs are greatest and most needed, as incentives should only be provided when public net benefits are high and private net benefits are positive but low (Pannell 2008).

[2] Plotted as PES1, 2 and 3 in Figure keys – PES 1 represents forests with highest Benefit Cost Ratio, PES 3 lowest but all fit within Area A on the Pannell diagram.
[3] Plotted as 'Extension' in Figure keys

2.3.3 Area C – Private Benefits Outweigh Public Costs

Land use changes should be accepted if they occur as the net private benefit is greater than the net public costs. Because of the negative public benefits in this area, no policies should be introduced to encourage the land use change.

2.3.4 Area D - Public Costs Outweigh Private Benefits

Direct regulation or market-based incentives would be appropriate to stop land use change. Indeed as the land use change would deliver private net benefits, landholders are likely to adopt the practices unless prevented from doing so.

2.3.5 Area E - Public and Private Costs Occur

In these circumstances, both public and private benefits of land use change are negative, and neither party should be interested in promoting change.

2.3.6 Area F – Public Benefits Outweigh Private Costs[4]

When private costs outweigh public benefits, the cost of the available technology or practices for land use change would leave society worse off despite the soil conservation benefits that could be delivered, and so regulation, market-based incentives or extension approaches are inappropriate. The obvious policy option in these circumstances is to promote research and development that can deliver more cost effective change through increasing private and/or public benefits. Ideally, technology development programs should target to prompt adoption of changed practices over large areas, without the need for incentives (Pannell, 2008).

3. Results and Discussion

Future forest locations for New Zealand are outlined in Figures 10a and 10b for 4% and 8% discount rates. Baseline erosion rates calculated for this study indicated the Nelson region had the lowest mean erosion rate of 17.32 tonnes/ha, Gisborne region has the highest erosion rate (107 tonnes/ha), while the Waikato region has a moderate mean erosion rate (47 tonnes/ha). Considering the framework described previously we now look at results for the future forests scenarios. These scenarios highlight (i) the difference in the returns from forestry (net private benefit) and the level of erosion (net public benefit) between a carbon and a structural forestry regime, (ii) and the effect of a lower discount rate on public and private net benefits.

For this discussion, we have elected to focus on Gisborne where erosion rates are highest. Plotting each individual future forest on a framework representing the top half of the policy framework described in the previous section shows Gisborne consists of 1,819 future forests covering a total of 196,011ha with an average forest size of 122ha (Figures 11a and 11b).

Figures 2, 3 and 4 highlight a Benefit Cost Ratio (BCR) line for different ratios of public benefits to private costs, for example if a forest plot rested directly on the BCR1 line then for every dollar the potential forest grower would lose from the project the public would gain a dollar in avoided soil erosion benefits. A BCR-3 line would therefore represent a benefit of three dollars for every dollar lost to the

[4] Plotted as ‘Tech Dev’ in Figure keys

private individual on the project. Another way of looking at this would thus be that for a BCR-2 line for every dollar that the government or some other stakeholder would provide to the forest owner the public would gain two dollars as long as the project was made viable from this provision.

This demonstrates the case for providing positive incentives, as a positive incentive should only be provided where benefits to the public outweigh costs to the private individual so providing an incentive where the return would not equal the investment (below the BCR-1 line) would be inefficient. Areas where the BCR is below 1 indicate that private costs (or investment required to implement the project) are much higher than the public net gain. In this situation, policy makers should consider the investment on novel forest farming systems-technologies to improve private net benefits of afforestation schemes (Figure 1: Area F). Payments for erosion control may be effective and efficient above the BCR-1 line and have a greater priority as the BCR increases. Thus, PES1, in Figures 2-4 represents a higher priority forest for positive incentives provision because it sits above the BCR3 line.

In general, forest programmes managed solely for carbon with $8 per unit of New Zealand carbon (NZU) revenue are less profitable than the structural forest regimes, this is demonstrated by the greater amount of forests plotted in the right hand quadrant of Figure 3 compared to Figure 4, indicating a greater number of forests overall with negative net private benefits (not economically viable). However, carbon forest regimes indicate higher public net benefits than the structural regimes due to lower soil erosion caused by longer rotations. For instance the structural regime with a 4% discount rate in Gisborne (Figure 3) has an average public net benefit per hectare of NZ$11,700 per hectare whereas in the same region at the similar discount rate for a carbon regime indicates the public net benefit of NZ$12,900 per hectare (Figure 4).

Figure 2: Net public and private benefits/ha (NZ$) for structural future forest regimes at an 8% discount rate in the Gisborne region, plotted by colour according to appropriate policy mechanism.

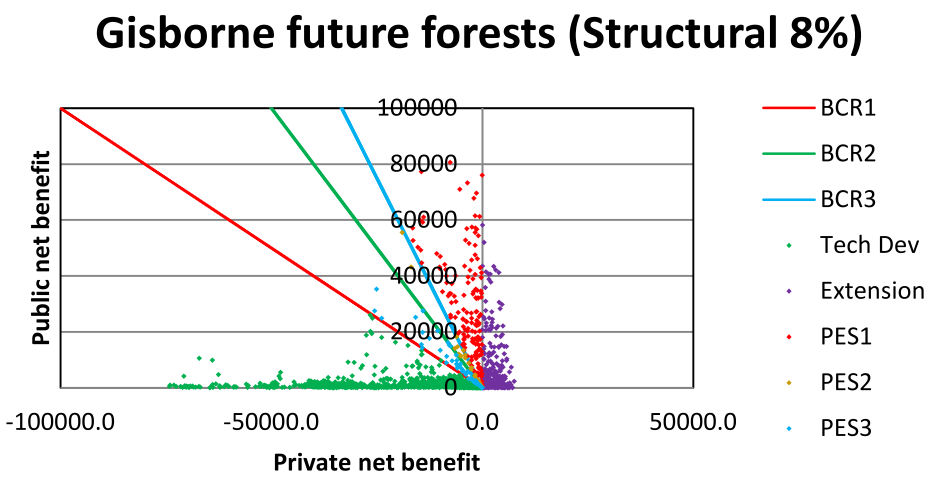


Figure 3: Net public and private benefits/ha (NZ$) for structural future forest regimes at a 4% discount rate in the Gisborne region, plotted by colour according to appropriate policy mechanism.

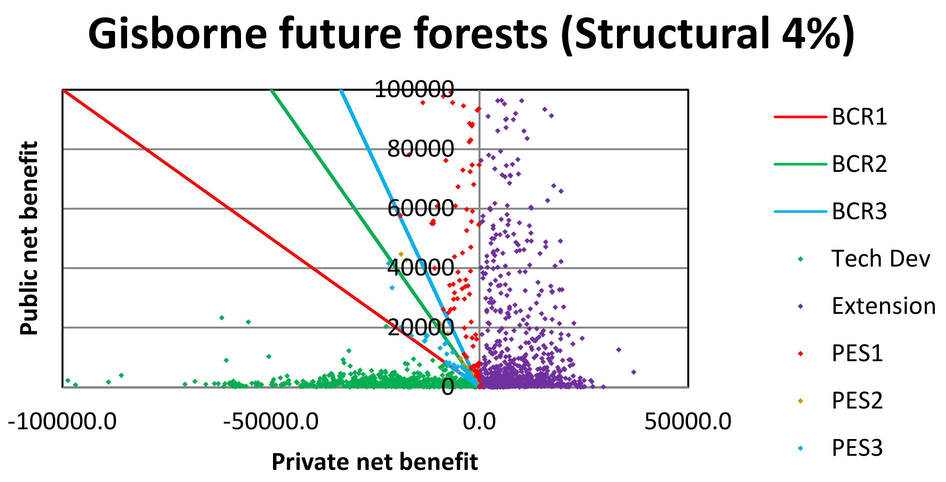
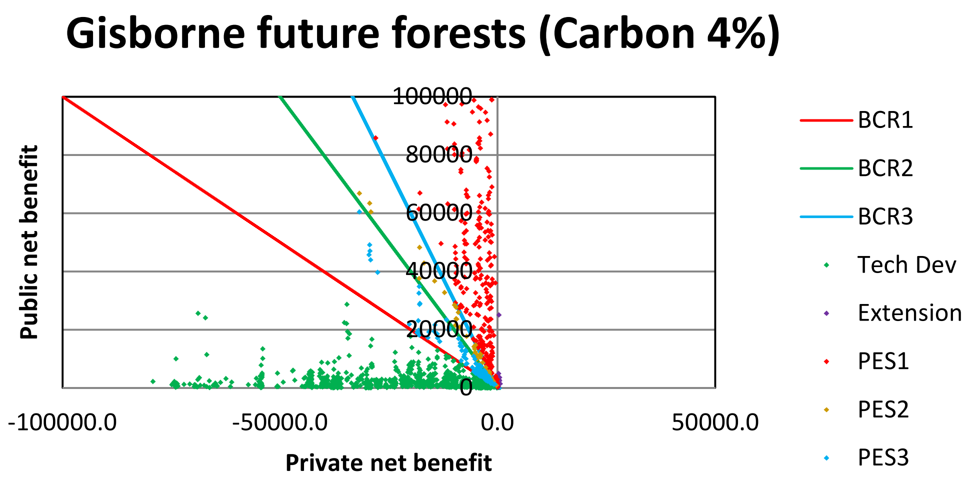


Figure 4: Net public and private benefits/ha (NZ$) for carbon future forest regimes at a 4% discount rate in the Gisborne region, plotted by colour according to appropriate policy mechanism.



The public benefit is higher with a lower discount rate (4%) as it allows capturing long term benefits properly. This is an important consideration as the valuations of forest establishment costs and returns commonly use a high discount rate, usually around eight percent. Also, public net benefit is high in the Gisborne region due to the high level of erosion reduction.

As per the Pannell (2008) policy analysis framework, future forest areas with very high net public benefits and moderately negative or positive net private benefits deserve some assistance through positive incentives schemes. However, many future forest schemes indicate high negative net private benefits and thus it would be very costly to provide assistance through incentives using public funds. Therefore, serious consideration should be given to technology improvement in these types of future forest areas, through measures such as improving harvesting technologies and technologies to enhance road construction efficiency to reduce forest costs.

Finally there are some areas which, under the right conditions, (Figures 2 and 3: Gisborne structural regime, 4% and 8%) provide a positive private net benefit and may thus require low cost policy mechanisms, such as extension (information provision, community support etc.) to encourage sustainable land use change. These can be visualised in Figures 10a -11b for New Zealand and the Gisborne region respectively. These maps identify the appropriate policy mechanism to encourage a specific forest regime under two discount rates.

In this study we have not considered some other potential costs for an afforestation program. An important cost component is the learning costs of new agricultural technologies and systems which can lead to adoption lags. In addition, when a landowner has to switch land use practice, a cost can be incurred due to change of identity in the community as a particular type of farmer. Therefore although private net benefits are positive, forestry may not necessarily be a viable option in practice.

Figure 10a and 10b: Policy mechanism per future forest appropriate to encourage afforestation for a structural regime with a 4% (left) and 8% (right) discount rate for New Zealand.

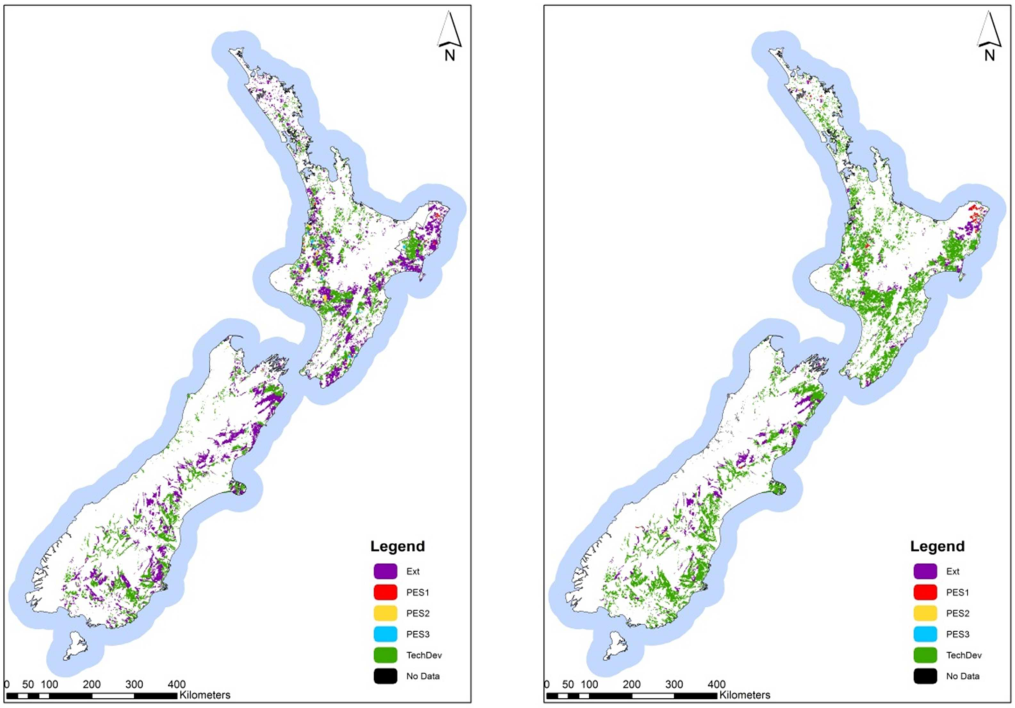
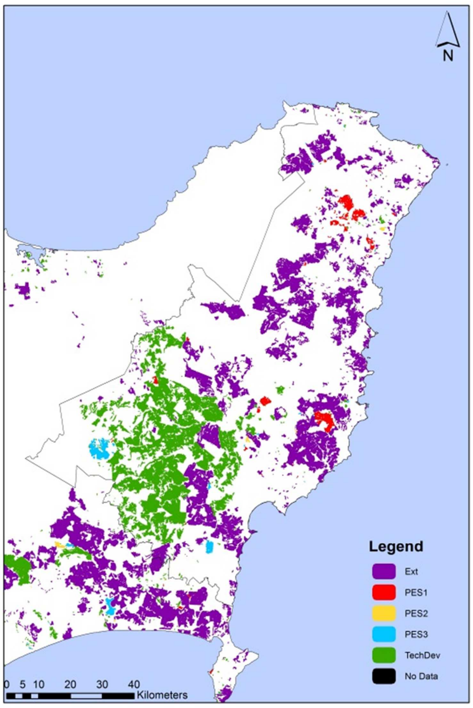
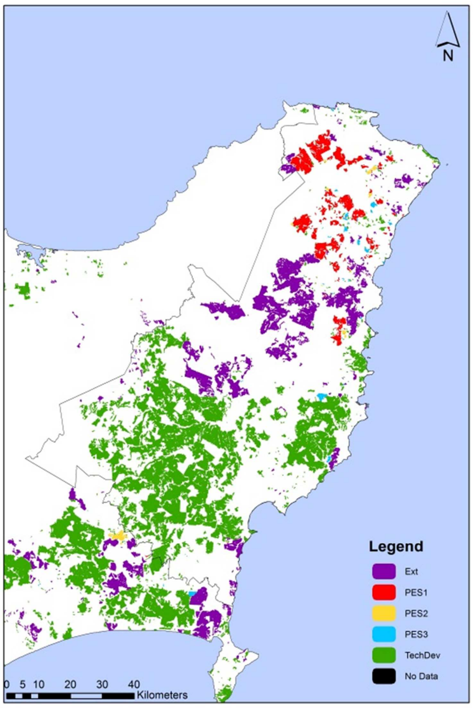


Figure 11a and 11b: Policy mechanism per future forest appropriate to encourage afforestation for a structural regime with a 4% (left) and 8% (right) discount rate for the Gisborne region. (note on the keys: PES1-PES3 are equivalent to area A on the Pannell diagram in Figure 1, Ext is equivalent to area B, and Tech Dev to area F)





4. Conclusion

Regions with very high erosion rates have correspondingly high levels of net public benefits of future forest schemes. When the net private benefits of such schemes are moderately negative or positive it would be worthwhile to encourage afforestation by providing positive incentives. Here, forests that provide a higher public net benefit, with a given private net benefit, receive greater priority because of the increased ratio of public benefit to private cost.

Where the future forests schemes indicate moderate levels of public benefits and very high negative private benefits providing incentives would be very costly and thus technology improvement should be considered as the main policy mechanism to encourage afforestation. As indicated by Pannell (2008), technology change here refers to any intervention that improves the net benefits of the available land management options. This could mean development of improved land management options, such as through strategic participatory research and development activities with landholders. It could also be achieved by training of landholders to improve their skills at implementing an existing land use.

It should be noted that this framework only considers the value of avoided soil erosion and so further definition and valuation of other ecosystem services relative to the status quo land use would change the potential policy mechanism to encourage change. Among the ten key ecosystems in the world, the forest ecosystem (which include the planted forest ecosystem) offers all 11 major ecosystem services (Millennium Ecosystem Assessment 2003). We could therefore assume changing land use to forestry would have a positive impact on ecosystem services provided. Thus, further accounting of ecosystem services in this framework would most likely enhance the rationale for positive incentives to encourage future forests as the ratio of public net benefits would increase relative to the private net costs of these forests.

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