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Value of Avoided Soil Erosion and Policy Measures to Encourage Afforestation in New Zealand

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Understanding the economic value of avoided land erosion in New Zealand will help policy makers factor in the costs of erosion to the economy. This report quantifies the area of hill country marginal agricultural land's potential for afforestation to mitigate erosion risks. The soil erosion model NZEEM (New Zealand Empirical Erosion Model) was employed to estimate the mean sediment discharge in response to different land use scenarios. Spatial economic modelling is undertaken to determine the net private and public benefit due to the avoided soil erosion from afforesting these areas. A policy framework based on the relative magnitude of net private and public benefits[1] was used 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 these net benefits to identify policy instruments to encourage future forests activities in New Zealand.

Highest mean value (107 tonnes/ha) of erosion was reported in the Gisborne region, the Nelson region was lowest at 17 tonnes/ha. This study indicates that in some cases forestry is not viable, for example where land prices, transport costs or road construction costs are too high, or are combined with a high discount rate. Thus the public benefit from avoided erosion (and other ecosystem services) will not be forthcoming in these areas.

Afforesting these areas may require novel forest farming systems/technologies or incentive schemes. The policy framework applied in the study is capable of identifying optimum policy instruments, such as the provision of positive incentives where current returns do not provide enough of an incentive to change behaviour towards more sustainable outcomes or where technology development may be required because returns are so low that positive incentives would be ineffective. These aim to encourage afforestation on selected marginal lands while achieving efficient and effective use of public funds.

The provision of a framework for valuing avoided soil erosion from forestry, which separates the impacts into net public and net private benefits, aids industry indirectly by allowing national and regional policy makers to make more meaningful decisions on how to encourage the provision of this valuable ecosystem service. Furthermore this framework has the potential to account for additional ecosystem services, which will further improve sustainable decision making. There is also the potential to apply this framework to current forest systems in order to help promote the non-market value of current forestry which impacts on industry's license to operate.

INTRODUCTION

Soil erosion has been identified as one of the major causes of soil quality deterioration and thus could negatively impact on the main services soil provides whether it be via provisioning, regulating or cultural services[2]. This study focuses on areas of New Zealand that would be suitable for afforestation, termed future forests[3]. These are areas with marginal agricultural value and slight to extreme erosion severity. The key aim of the study is to determine:

(i) The economic value of avoided erosion from afforestation of future forest scenarios.

(ii) The optimal policy instruments to facilitate the land use changes required from marginal pastoral land to planted forests.

METHODS

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 model NZEEM (New Zealand Empirical Erosion Model)[4]. The NZEEM model can be used to predict 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 [4]. From NZEEM we can estimate the incremental soil erosion levels for different land types given in the Land Cover Data Base (LCDB2 Class)[5].

Evaluating Benefit of Avoided Soil Erosion

We used the incremental net private and public cost 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. This demarcation also enabled us to relate our valuation to a policy analysis framework[1]. 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. In this study, public benefits represent the net benefits accruing to every one other than the private land manager.

Two steps are involved in estimating the incremental cost and 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[3]. Two discounting rates were used, eight per cent which is representative of the rate used in forest market valuation[6], 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 the afforestation project. 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 modeled 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

Private Net Benefits

A detailed description for the financial private net benefits can be found in Harrison et al. 2012[7]**.** For a consistent measure of opportunity cost across all land uses we used land value data from a property valuation specialist, Property IQ[8]. In New Zealand, land is typically valued by its highest and best use[9] 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 have employed the Hedonic Price Model (HPM - a model that explains the price of a good based on its characteristics) to evaluate the impact of avoided erosion from a future forest to 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 maybe requested from the authors.

Public Net benefits

Previous literature has estimated erosion levels pertaining to area[10]. 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 tonnes of sediment from afforestation, per year. This assumes full canopy cover and maximum soil protection from a change to woody biomass. However, erosion from forestry may be the same or worse than the current land use during harvesting and early establishment periods. Following from Marden and Rowan (1993)[11] 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. The data collected for avoided soil erosion relates to sediment volume collected for New Zealand. It accounts for avoided flood damage (NZ$ 0.87/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.

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 early growth period
Avoided on site damage	Opportunity cost of land use change	Avoided drinking water quality damage	

[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

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[12, 13] and expands to identify the appropriate policy mechanism for encouraging more sustainable outcomes based on this relationship[1]. 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 allow 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.

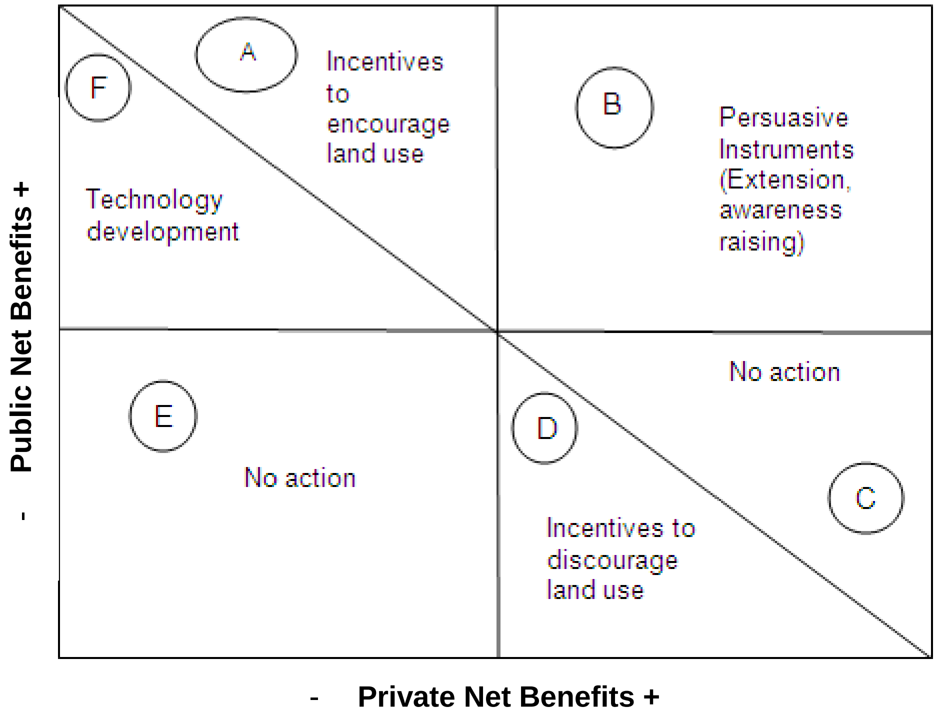

Figure 1: Selection of policy instruments based on public and private net benefits of land use changes (Pannell -2008)

Area A - Private Costs Outweigh Public Benefits

When the public benefits of a land use change is greater than the private costs there are overall social benefits from land management 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.

Area B - Both Public and Private Benefits are Positive

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[1].

Areas C, D and E below are not detailed because erosion is reduced from afforestation and so the public net benefit is positive. Results therefore relate to the top two quadrants of this framework. For a detailed description refer to Pannell (2008).

Area C – Private Benefits Outweigh Public Costs

Land use changes should be accepted if they occur. Because of the negative public benefits, no policies should be introduced to encourage the land use change.

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.

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.

Area F – Public Benefits Outweigh Private Costs

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 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 promote adoption of changed practices over large areas, without the need for incentives (Pannell, 2008).

RESULTS & DISCUSSION

The Nelson region indicated the lowest mean value (17.32 tons/ha) of soil erosion whereas Gisborne region has the highest value (107 tons/ha). Waikato region indicated comparatively moderate level of erosion (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 highly and a moderately erodible region, (ii) the difference in the returns from forestry and the level of erosion between a carbon and a structural forestry regime, (iii) and the effect of a lower discount rate on public and private net benefits.

For this discussion, we have selected to focus on Gisborne and Waikato results (Figures 2-11). These figures plot each individual future forest on a framework representing the top half of the policy framework described in the previous section. Gisborne consists of 1,819 future forests covering a total of 196,011ha with an average forest size of 122ha while Waikato consists of 3,395 future forest covering 179,652ha with an average of 61ha.

The graphs (Figures 2-9) highlight a BCR (Benefit Cost Ratio) 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 BCR3 line would therefore represent a benefit of three dollars for every dollar lost to the private individual on the project. Another way of looking at this would thus be that for a BCR2 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 BCR1 line) would be inefficient and therefore technology development or no action would make more sense (Figure 1: Area F). PES (payments for ecosystem services) may be effective and efficient above the BCR1 line and have a greater priority as the BCR increases. Thus PES1, in figure 2-9 represents a higher priority forest for positive incentives provision because it sit above the BCR3 line.

In both regions analysed, forest programmes managed solely for carbon with $8/NZU revenue are less profitable than the structural forest regimes, this is visible by the greater amount of forests plotted in the right hand quadrant of figures 2-5 (for the structural regimes) compared to the carbon regimes in figures 6-9, indicating a greater number of forest overall with negative net private benefits (not economically viable). . However, carbon forest regimes indicate higher public net benefits than the structural regimes due to causing fewer disturbances to the soil. 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 with a higher NZ$12,900 per hectare for the same region and discount rate for a carbon regime (Figure 6). .

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 current forest valuations of costs and returns use a higher discount rate, usually around eight percent. Also, public net benefit is higher in the Gisborne region compared to the other regions due to the greater level of erosion reduction.

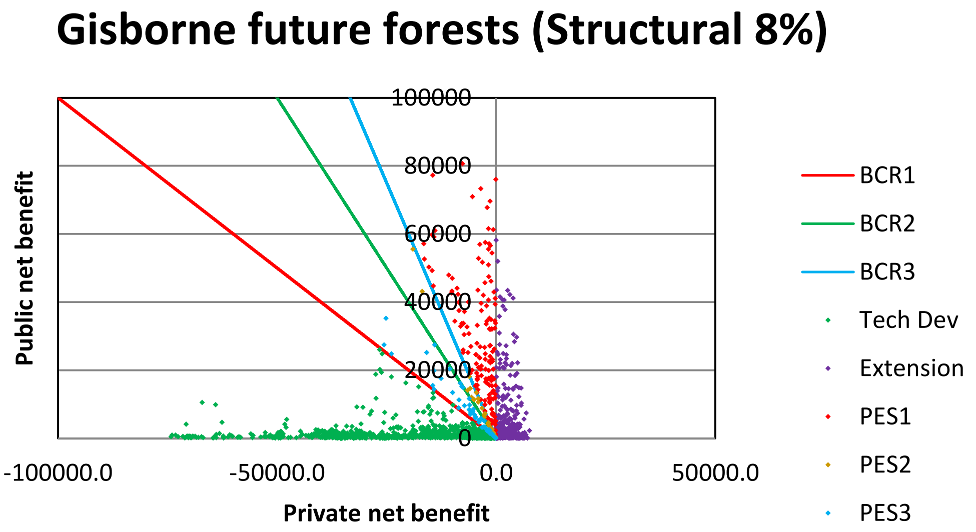

Figure 2: Net public and private benefits/ha (NZ$) for Structural future forest regimes at an 8% discount rate in the Gisborne region, plotted by colour according to appropriate policy mechanism.

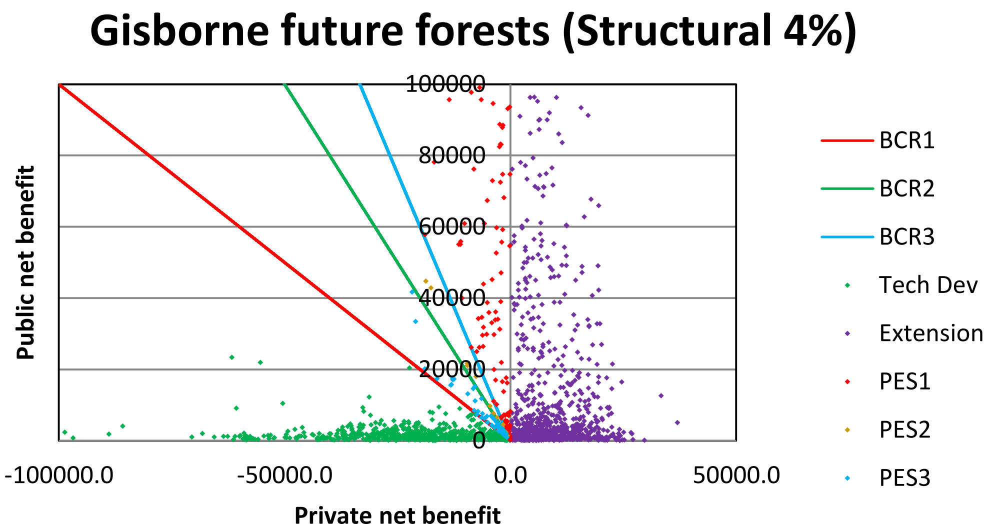

Figure 3: Net public and private benefits/ha (NZ$) for Structural future forest regimes at a 4% discount rate in the Gisborne region, plotted by colour according to appropriate policy mechanism.

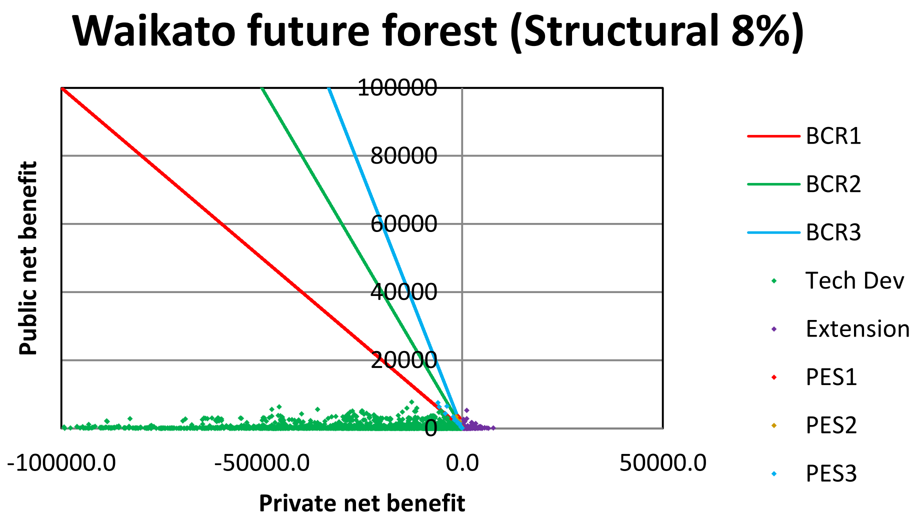

Figure 4: Net public and private benefits/ha (NZ$) for structural future forest regimes at a 8% discount rate in the Waikato region, plotted by colour according to appropriate policy mechanism.

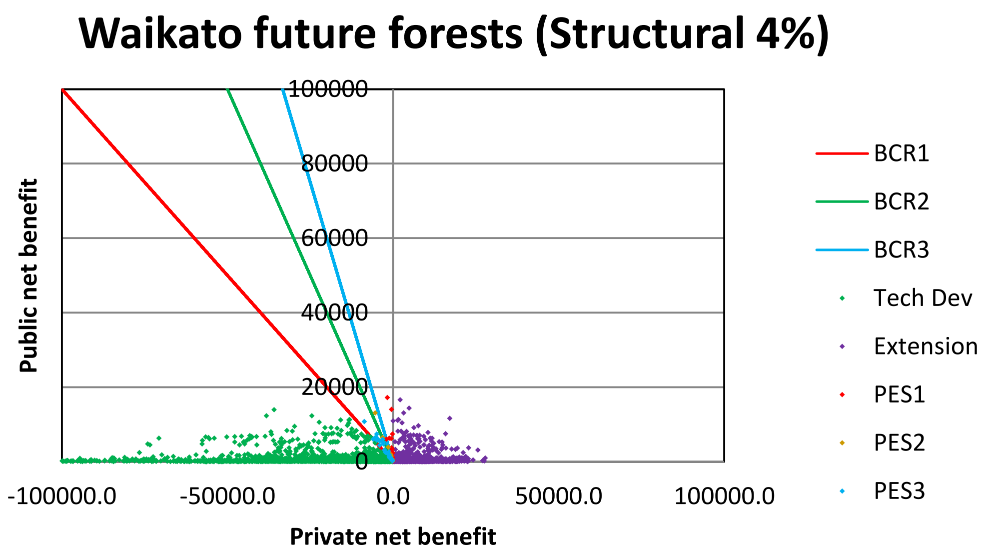

Figure 5: Net public and private benefits/ha (NZ$) for structural future forest regimes at a 4% discount rate in the Waikato region, plotted by colour according to appropriate policy mechanism

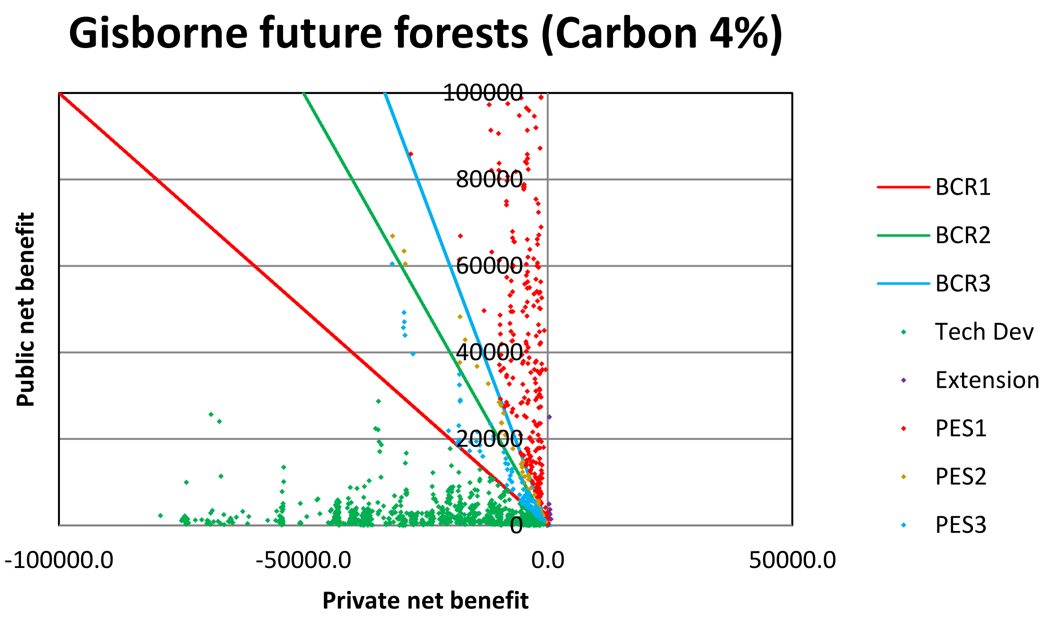

Figure 6: Net public and private benefits/ha (NZ$) for carbon future forest regimes at a 4% discount rate in the Gisborne region, plotted by colour according to appropriate policy mechanism.

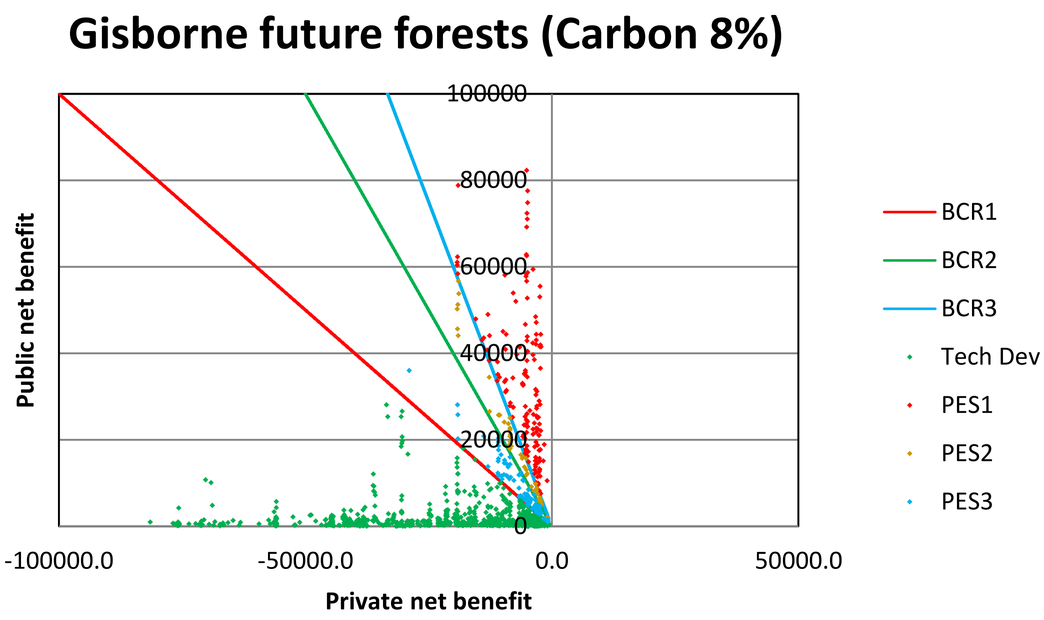

Figure 7: Net public and private benefits/ha (NZ$) for carbon future forest regimes at an 8% discount rate in the Gisborne region, plotted by colour according to appropriate policy mechanism.

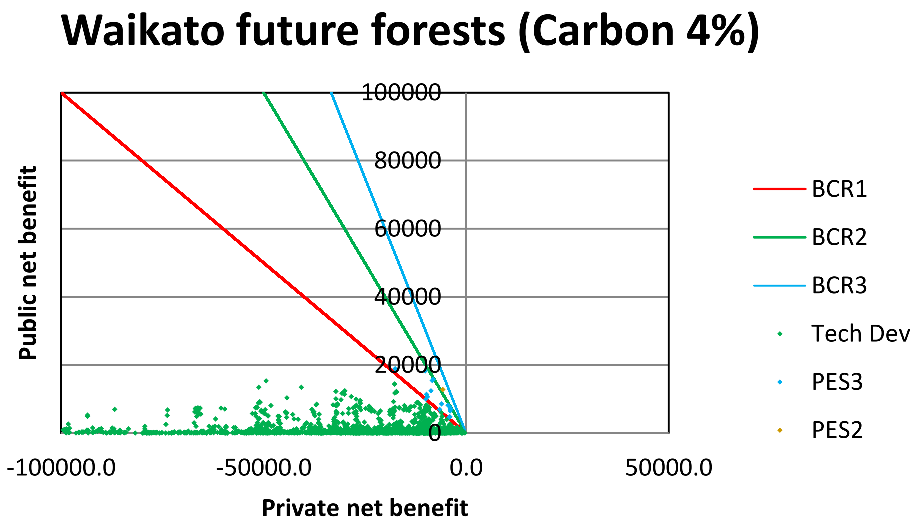

Figure 8: Net public and private benefits/ha (NZ$) for carbon future forest regimes at a 4% discount rate in the Waikato region, plotted by colour according to appropriate policy mechanism.

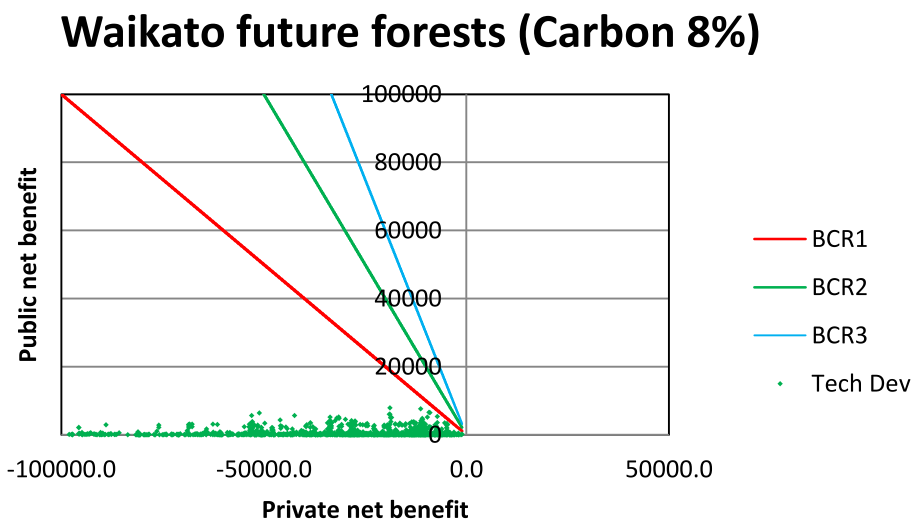

Figure 9: Net public and private benefits/ha (NZ$) for carbon future forest regimes at an 8% discount rate in the Waikato region, plotted by colour according to appropriate policy mechanism.

Most of the future forest areas are not viable in either region i.e. the private net benefit is negative. This is due to higher harvesting costs, road construction and establishment costs on steep areas. Furthermore, the opportunity cost of the land use (land value) further imposes an economic cost on a potential forester.

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 in both regions 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, for instance improving harvesting and 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%) there are quite a few forests which have a positive private net benefit and may 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-13b for New Zealand and the Gisborne region. These maps identify the appropriate policy mechanism to encourage a specific forest regime under two discount rates. A key consideration is further costs which impact on private net benefit, such as social costs which may induce a lag to adoption and therefore although private net benefits are positive forestry may not necessarily go ahead. Although the private net benefits resemble those of a third party investor model, for an investor who purchases the land to afforest, it may also represent a landowner who must switch land use and therefore change identity which imposes a cost or transaction costs from land use change, which are not considered in this analysis.

Table 2: Legend for policy selection on future forests

Extension
PES1
PES2
PES3
Technology Development
No Data

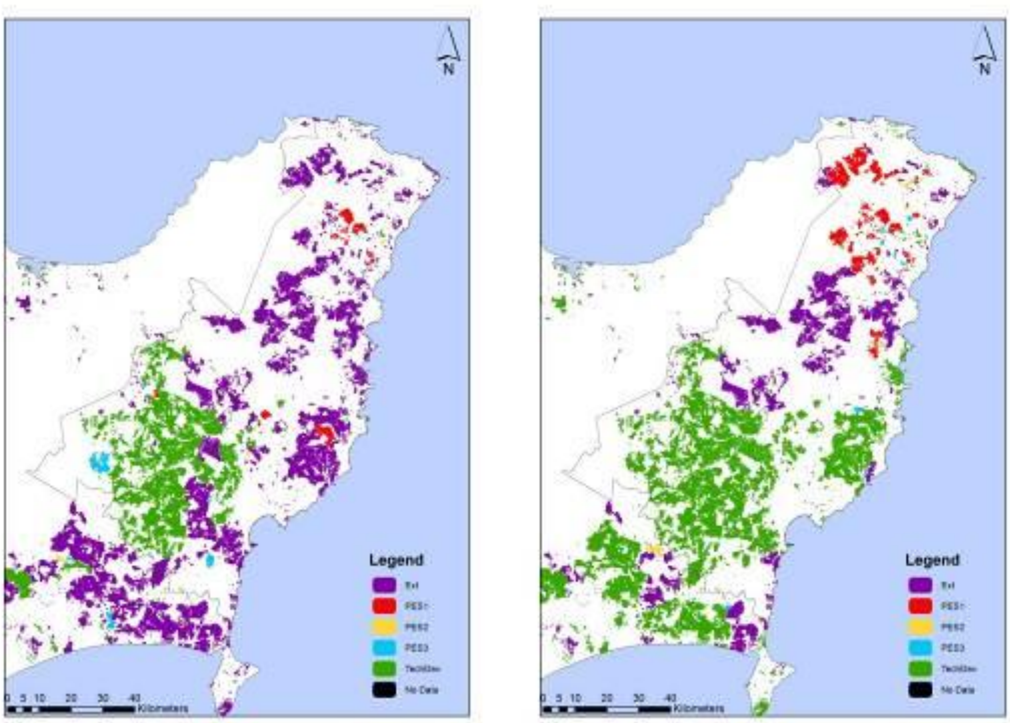

Figure 10a and 10b: Policy mechanism per future forest appropriate to encourage afforestation for a structural regime with a 4% (left) and 8% (right) discount rate for the Gisborne region.

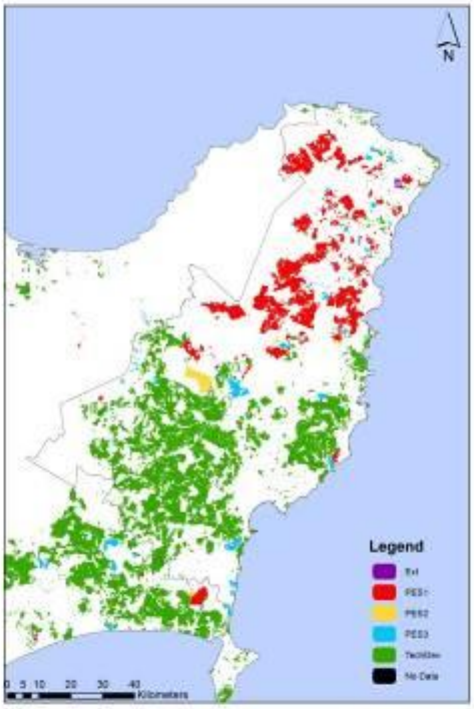

Figure 11a and 11b: Policy mechanism per future forest appropriate to encourage afforestation for a carbon regime with a 4% (left) and 8% (right) discount rate for the Gisborne region.

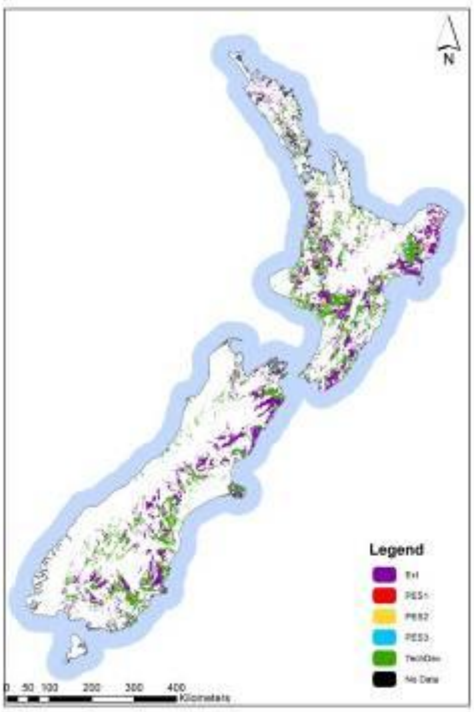

Figure 12a and 12b: Policy mechanism per future forest appropriate to encourage afforestation for a structural regime with a 4% (left) and 8% (right) discount rate for New Zealand.

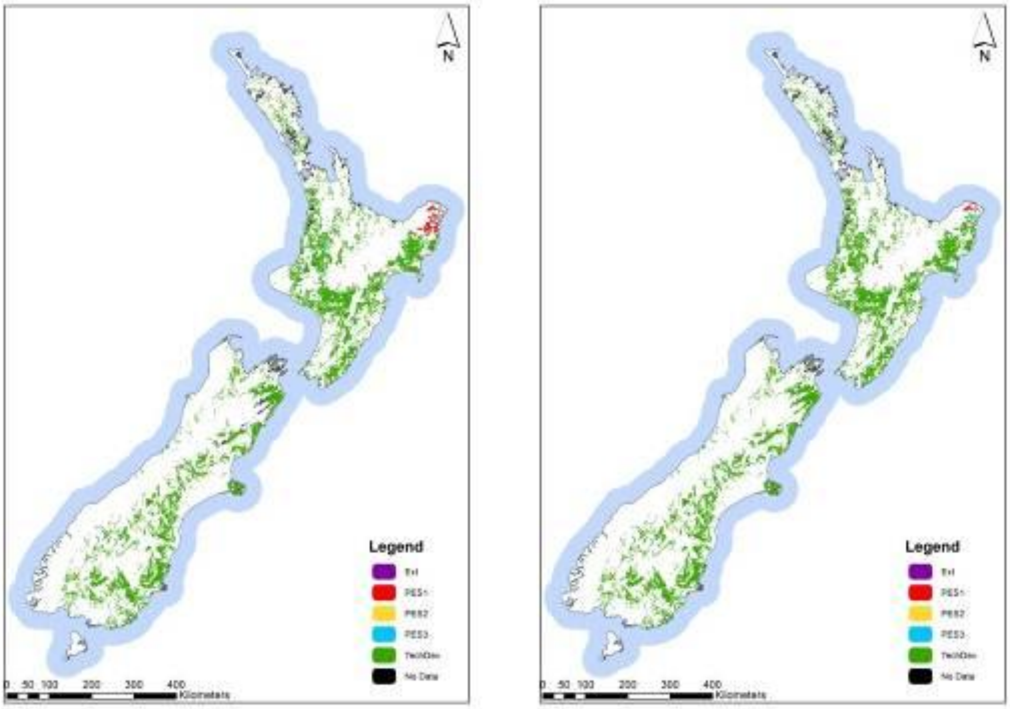

Figure 13a and 13b: Policy mechanism per future forest appropriate to encourage afforestation for a CARBON regime with a 4% (left) and 8% (right) discount rate for New Zealand.

CONCLUSION

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

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 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 R&D or participatory R& D with landholders. Also, it could be achieved by training of landholders to improve their skills at implementing an existing land use.

This modelling of various levels of ecosystem service combined in a policy decision making framework allows consideration of benefits which usually benefits different stakeholders. This provides insights into policies which can be implemented to contribute to successful behaviour change towards more sustainable land uses. This framework applies to future forests as projects which consider the ratio of public and private net benefits and the consequent policies which should be used. It can also be applied to current forests which would have implications for the forest industry’s license to operate. In this case there may be more profitable options for an existing forest plot, but if we account for the net public benefits of these forests, incentives would be needed to encourage this plot to stay in forestry to sustain the public benefit or inhibit public cost from a change in land use, through the loss of ecosystem services (Figure 1: Area D).

It should also be noted that this framework only considers the value of avoided soil erosion (which is even thought to be a conservative estimate) 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 the greatest number of ecosystem services[14]. 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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