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An Ecosystem Services Approach to the Cost of Soil Erosion and Value of Soil Conservation

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An Ecosystem Services Approach to the Cost of Soil Erosion and Value of Soil Conservation

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Abstract

This paper reports on ecosystem services lost from a grazed pasture following a soil erosion event after a heavy rain storm which provoked landslides on hill slopes along a 250km coastal strip in the Hawke's Bay in April 2011. The study also characterises the recovery of the provision of ecosystem services in the years following the erosion event, as well as the influence the introduction of a space planted conservation tree would have on the provision of services from pasture soil. Finally the study explores how an ecosystem services approach can be used to inform a cost-benefit analysis of an ecological infrastructure investment in soil conservation and in decision making by policy. The total value of the ecosystem services provided by a typical sheep and beef farm was, for uneroded land, $5,085/ha/yr for rolling land and $3,717/ha/yr for steep land. The total value of the services provided by the bare ground of steep hills, following an erosion event, dropped by 64%. The recovery of ecosystems services after erosion stabilised after 50 years at approximately 61% (in dollar value) of uneroded levels. The presence of soil conservation trees increased the value of the services provided by 23%, 20 years after planting. The cost benefit analysis of soil conservation showed that planting trees isn't profitable unless the trees are harvested for timber, and low discount rates (<5%) are used. However, when considering the value of the extra provision of ecosystem services, the Net Present Value of the investment is greatly positive regardless of the discount rate (0-10%).This study addresses a real-world conservation issue and shows how an ecosystem services approach can be integrated and used on the ground to advance existing governance frameworks and inform resource management challenges.

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1 Introduction

Hill country erosion is estimated to cost New Zealand between $100 and $150 million per year (Jones et al., 2008). Over the last 50+ years investment in New Zealand on soil conservation to reduce the risk of soil erosion in hill and steepland country and the downstream costs associated with sediment loadings in waterways and the damage to productive farmland and towns due to siltation, runs into many billions of dollars (Krausse et al., 2001). Evaluation of this ecological infrastructure investment has been largely limited to measures of the reduction in physical erosion (Barry et al., 2012), improvements in waterways clarity and the reductions in sediment loads of our rivers. The “value” of the ecosystems services provided by soils retained by reducing erosion has not been included, beyond the provision of food and fibre.

The current approach for quantifying the costs of soil erosion associated with a storm event and by default valuing soil conservation practices is limited, as the assessment is restricted to the cost of the clean up and the reinstatement of built infrastructure. Assessment of the lost soil natural capital stocks, if included, is generally limited to quantifying the area of land affected by slips and debris tails. An example of this is the recent analysis undertaken by GNS Science, where satellite imagery was used to assess the proportion of land affected by landslides following the April 2011 storm in the Hawkes Bay (Jones et al., 2011). That heavy rain storm event impacted on a 10 km wide, 250 km long coastal belt from Mahia to Porangahau. Landslides occurred on hill slopes throughout the affected area, including gullying and reactivated earthflow erosion on older sediments. Overall 43 km^2 of bare ground was classified from a total area of 5900 km^2. When compared to pre-event imagery, 86 % of the bare ground in the RapidEye imagery was recognised as new bare ground. AgResearch then cross-referenced that information with spatial information on the distribution of land use capability classes in the region and identified which LUC were the most affected (Table 1). Of all the land affected by the April 2011 storm, 95% was on LUC Class 6 to 8. Out of the 503 ha of LUC Class 8 identified, 12% was new bare ground. Moreover, 51% of the damage was situated on LUC Class 6 (Table 1).

A few studies have measured the loss in pasture production, associated with erosion as a measure of the lost natural capital (Lambert et al., 1984). Pasture production is just one of fourteen ecosystem services Dominati et al., (2010) identified and described in a framework developed specifically to quantify and value ecosystem services of pasture soils.

In a meeting with Hawke’s Bay Regional Council Staff in December 2011, the feasibility of using Dominati et al., (2010) ecosystem service framework to estimate the loss of services from the land affected in the April storm was raised. Discussion included how the “value of the lost ecosystems services” might compare with the cost of the clean up and reinstatement of built infrastructure following the April 2011 storm event. Placing a value on the soil services lost following an erosion event provides an indication and a basis for assessing the cost-efficiency of an ecological infrastructure investment in soil conservation practices.

Table 1: Area of land and land lost to erosion in the April 2011 storm by Land Use Capability Class.

Land Use Capability Class	1	2	3	4	5	6	7	8	other	Total
Area in Sheep & Beef (ha)	1,661	6,100	39,467	20,026	3,764	207,979	65,588	3,985	1,624	348,569
Area lost to erosion (ha)	4.7	24.4	109.7	54.3	25.5	2,156.7	1,341.3	503.8	2.9	4,220
Bare ground (% of total land in that LUC)	0.3%	0.4%	0.3%	0.3%	0.7%	1.0%	2.0%	12.6%	0.2%	NA
Bare ground (% of total area lost)	0.1%	0.6%	2.6%	1.3%	0.6%	51.1%	31.8%	11.9%	0.1%	100%

94.8%

2 Objectives

Hawke's Bay Regional Council asked AgResearch to investigate a number of elements for the study:

- Quantify and value the provision of ecosystem services from soils for a model East Coast hill land sheep and beef operation using the Dominati et al., (2010) framework.
- Quantify and value the loss in ecosystem services from the land affected by landslides within the 10 km wide, 250 km long coastal belt from Mahia to Porangahau in the Hawke's Bay hill country in April 2011 from the data supplied to the Hawke's Bay Regional Council by GNS Science, using the Dominati et al. (2010) framework.
- Characterise the recovery profile of soil ecosystem services in the years following a landslide event.
- Assess the provision of ecosystem services from a soil under a pasture/wide spaced poplars system.
- Assess, using an ecosystems service approach, the cost-efficiency (cost-benefit analysis) of an ecological infrastructure investment in soil conservation practices on hill pasture land at risk from soil erosion

3 Methodology for the quantification and valuation of the provision of ecosystem services for a typical sheep and beef operation

Below we described the general methodology used to quantify and value the ecosystem services provided by a sheep and beef operation. This methodology forms the basis for the evaluation of the different scenarios.

3.1 Model East Coast hill land sheep and beef operation

A model East Coast hill land sheep and beef operation was selected to assess the provision and value of the ecosystem services for a pastoral farm operating along the coastal belt impacted by the rainstorm in April 2011.

The model was based on the 2012 MAF farm monitoring data for a summer dry hill country breeding and semi-finishing sheep and beef operation for Hawke's Bay and the Wairarapa.

The farm characteristics include a 70: 30 sheep to cattle ratio, 130% lambing, stocking rate of 10 su/ha, pasture grown of 9 tonnes DM/ha/yr, rainfall 1000 mm and a climate described as summer dry (Table 2).

Data provided by Hawke's Bay Regional Council for Te Apiti station was used to choose soil and landscape information (Table 2).

Table 2: Farm and soil characteristics of the sheep and beef operation.

	Block 1	Block 2
LUC Classes	1-5	6-8
Area (ha)	255 (45%)	315 (55%)
Relative productivity	1.6	1
Soil type	Waimarama sandy loam (sedimentary, brown)	Wanstead clay loam (recent, pallic)
Olsen P (µg/ml)	25	16
Anion Storage Capacity	43	21
N fertiliser applied (kg N/ha/yr)	20	0
P fertiliser applied (kg P/ha/yr)	20	15

The Overseer® nutrient budget (version 6.0) was used to estimate pasture production and calculate nitrate (NO_3^-) leaching and phosphorus (P) losses.

3.2 Ecosystem services quantification and valuation

3.2.1 Provision of Forage:

In a sheep and beef system, the provision of food from soils is indirect and embodied by pasture growth and pasture quality, which determine animal growth, health and production. To quantify the provision of food from soils, two aspects of the service need to be considered: the amount of pasture grown, and its quality.

3.2.1.1 Forage quantity

To quantify the provision of food from soils, the distinction needs to be made between the part of pasture yield coming from soil natural capital stocks and the contribution from added capital (i.e. fertilisers).

Pasture yield modelled with Overseer® (version 6.0) was 10,594 kg DM/ha/yr for block#1 and 6,622 kg DM/ha/yr for block#2, with 3,260 and 2,518 livestock units carried respectively, assuming the same sheep to cattle ratio of 70:30. The sale of wool, lambs, cull ewes, breeding cows, rising 2 year old cattle and cull cows generated a net cash income of $1,291/ha for block#1 and $807/ha for block#2

To determine the part of pasture yield sustainable by soil natural capital stocks, the influence of N and P fertilisers were subtracted from the calculated pasture yield. A response to N fertiliser of 20 kg DM/kg N was used. A relative yield of 60% was used to estimate pasture yield with no P fertilisation. The pasture growth provided by the soil natural capital averaged 6,116 kg DM/ha/yr (58% of total pasture yield) for block#1 and 3,973 kg DM/ha/yr (60% of total pasture yield) for block#2, with the corresponding livestock stocking rate (SU/ha) 1,882 SU for block#1 and 1,511 SU for block#2, respectively, assuming the same sheep to cattle ratio of 70: 30. Net cash income was calculated from animal and wool sales, using market prices. The provision of food was worth $745/ha/yr for block#1 and $484/ha/yr for block#2.

3.2.1.2 Forage Quality:

For optimum sheep and beef production animals need in addition to carbohydrate and protein, macro (Calcium, Magnesium, Iron) and micro (Selenium, Cobalt, Copper and Iodine) nutrients. These are provided by the soil to the animal via the plant in the process of grazing. Plants also have trace elements requirements (e.g. Molybdenum). Soils can be deficient in one or several of the trace-elements (e.g. pumice soils are cobalt and selenium deficient) (Grace, 1994).

To measure this service, we identified the level of provision of trace-elements from the soils, and determined the trace element nutrient management to prevent deficiencies, if the soil could not provide the service (avoided cost). The costs of purchase of trace elements and their application to pastures (for Selenium, Cobalt and Copper) and in animal drench (for Selenium, Cobalt, Copper and Iodine) were used to value the service. The soils studied here, Waimarama sandy loam for block#1 and Wanstead clay loam for block#2, present no trace-element deficiencies.

Under a more intensive cattle policy, the Waimarama sandy loam might need inputs of potassium.

A soil with adequate quantities of trace-elements for a sheep and beef farm, that would supply all trace-elements needed by the animals, is worth $29/ha/yr, including provision of Selenium, Cobalt, Copper and Iodine to sheep and cattle.

3.2.2 Provision of Support:

Soils represent the physical base on which plants grow and animals, humans and infrastructures stand. Physical support is important at different scales. At the farm scale, soil's capacity to support animals at the paddock scale depends on the bulk density and compaction of the upper horizon. Support of buildings and farm tracks depend more on the strength of the deeper horizons and the subsoil.

To quantify the provision of support to human infrastructures, soil strength was considered as well as the slope of the landscape. The steeper the terrain is, the most expensive it is to build and maintain infrastructures such as fences and farm tracks. To value the provision of support to human infrastructures, the defensive expenditures method was used (Pearce et al., 2006). The cost of putting up and maintaining fences and tracks was calculated for both blocks of the studied farm. The capital cost of infrastructure was $617,056 for block#1 and $723,457 for block#2. Construction costs were annualised using a discount rate of 10%. Depreciation was calculated over 15 years for block#1 and 10 years for block#2. Annualised costs were $204/ha/yr cheaper for block#1 than for block#2. That value was used as a proxy for the value of the service. The provision of support to human infrastructures was then worth $204/ha/yr for block#1 and $0/ha/yr for block#2 since steep land provides poor support for human infrastructures and therefore serves as reference to value the service.

The provision of support to farm animals depends on soil's sensitivity to treading damage, and water logging. A poorly drained soil stays saturated longer, and therefore is more sensitive to treading. In spring, wet soils are a problem at lambing and calving because they can increase mortality rates of the newborns.

To value the provision of support for farm animals, the defensive expenditures method was used. To simulate the impact of wet soils on the mortality of newborn, lambs loss was increased from 5% to 10% and calves losses was increased to 5%. The income lost was used as a proxy for the value of a well-drained soil for animal support. The provision of support to animals was then worth $53/ha/yr for block#1 and $33/ha/yr for block#2, which represents the income lost if soils are wet and the support service is not provided. The value of the service for block#2 was lower than for block#1 because block#2 usually carries less animals per ha and is less likely to be as wet, due to slope.

3.2.3 Provision of Raw Materials:

In examining soils' capacity to provide raw materials, the distinction needs to be made between renewable and non-renewable goods. Raw materials found within the soil profile include peat and clays. At the farm level, these materials are often absent or not exploited. For this reason, in this study, the provision of raw materials from soils was not included, but it is acknowledge that it could make a contribution in some situations, for example, at a different scale like the region or country.

The ecosystem services examined below are regulating services, which are usually not valued, or included in decision-making processes.

3.2.4 Flood Mitigation:

The ability of soils to store water and buffer excessive rainfall doesn't remove the risk of flooding, but rather reduces its likelihood and the need for manmade flood-protection structures to reduce the risk of downstream flooding. The flood mitigation potential of a soil depends on how much water it can absorb and store before saturation is reached and runoff starts.

To quantify flood mitigation, annual rainfall and runoff were considered. A measure of the service was defined as the difference between rainfall and runoff (calculated with Overseer® version 6.0), the amount of water actually absorbed by the soil. This measure is integrative of factors such as slope, land cover and soil drainage class. Table 3 presents the measure of the service for each of the two blocks.

Table 3: Rainfall, runoff and flood mitigation service (mm/ha/yr) for the modelled sheep and beef operation

Block	Rainfall (RF)	Runoff (RO)	Flood mitigation RF-RO
#1	1000	17	966
#2	1000	224	790

The provision cost method (Pearce et al., 2006) was used to value the flood mitigation service. If the soil had no retention capacity, another way of reducing flood risk at the farm scale would be to build retention dams to store the water otherwise stored by the soil in order to delay the flood peak. It was assumed that a water-retention dam on-farm should be big enough to store, at once, 10% of the total water stored annually by the soil. The cost of building such a dam was used to assess the value of the service. Construction costs were annualised over 20 years using a discount rate of 10%. Flood mitigation was worth $1155/ha/yr for block#1 and $911/ha/yr for block#2.

3.2.5 Filtering of Nutrients and Contaminants:

Soils are the substrate through which water passes before entering water bodies like rivers and lakes. They act as filtering agents. In sheep and beef systems, a number of materials are either returned to pastures such as animal dung and urine and or applied such as fertilisers and pesticides. the soil's ability to filter contaminants such as pathogens (e.g. e-coli), pesticides or endocrine-disrupting chemicals (EDCs) is a critical ecosystem service in limiting human exposure to these contaminants.

Table 4: Nutrients losses and filtering service for a sheep and beep operation

		Block#1	Block#2
N flows (kgN/ha/yr)	N inputs from fertilisers	20	0
	N leaching	18	7
	Max N loss	41	18
	N retained	23	11
P flows (kgP/ha/yr)	P inputs	20	15
	P loss risk	0.4	1.9
	Max P loss risk	2	8
	P retained	1.6	6.1

The filtering of nutrients and contaminants represents the amount of nutrients retained by the soil. The service was defined as the difference between a maximum loss specific to a soil type, depending on soil nutrient status, inputs, management and production intensity, and the actual nutrients loss. Maximum losses for N and P were calculated with Overseer® by setting N immobilisation potential to ‘none’ and Anion Storage Capacity to 1 respectively. In Table 4 the nutrient inputs, actual losses, maximum losses and the measure of the services for each block are summarised.

Since no detailed data was available on the dynamics of the quantities of contaminants such as e-coli and endocrine disrupting chemicals (EDCs) entering and leaving the soil, to quantify the filtering of soil contaminants, the risk of contamination of runoff water by dung pads was considered as a proxy for the service.

The provision cost method was used to value these services. Another way to filter nutrients and contaminants on a sheep and beef farm would be to use an alternative between filtering grass strips (not efficient enough to replace the service provided by the soil) and fully constructed wetlands (used on dairy farms). It was assumed that a semi constructed wetland (not lined) should be big enough to store, at one time, 10% of the water currently filtered by the soil (the volume represented by the annual rainfall minus runoff). This volume was used to calculate the size of the wetland (assumed 30cm deep) that would be required to replace the soil service. The cost of fencing and planting the wetland area were used to assess wetland construction costs and valuing the service. Construction costs were annualised over 20 years with a discount rate of 10%. The wetland volumes needed for block#1 and block#2 respectively are 983 m^3 and 776 m^3. Annual maintenance costs were estimated to be 2% of the construction costs.

The filtering of nutrients and contaminants was worth $2,227/ha/yr for block#1 and $1,800/ha/yr for block#2.

3.2.6 Detoxification and Recycling of Wastes:

The ability of soils to deactivate non-organic contaminants (detoxification) and biologically degrade organic wastes constitutes an ecosystem service in itself independent from the filtering of nutrients and contaminants, or the provision of nutrients to plants.

Because of the complexity surrounding detoxification and the recycling of wastes, this service was quantified indirectly. The abundance and activity of the main agents, invertebrates and micro-organisms, responsible for the detoxification and recycling of wastes are influenced by both the soil water content (SWC) and pore function (macroporosity), two key measures of a soil's natural capital stocks. It was assumed that ideal conditions for optimum decomposition of wastes by soil fauna is when the SWC is between stress point[1] (SP) and field capacity (FC) (SP<SWC<FC). The amount of dung in kg DM/ha/yr deposited in ideal conditions (SP<SWC<FC) was determined to be 40% of the total amount of dung DM deposited in a year for block#1 and 30% for block#2 (Table 5).

The provision cost method was used to value the recycling of wastes. If soil biota didn't decompose and recycle wastes, the alternate solution at the farm scale would be to use an effluent treatment pond to degrade wastes and fert-irrigation to return the wastes nutrients to pasture.

Table 5: Dung deposited and effluent equivalent for the 2 blocks.

	Dung dry matter deposited (kg dung DM/ha/yr)	**% of dung decomposed properly**	**Effluent volume equivalent (m^3/ha/yr)**
Block 1	2131	40%	21.3
Block 2	1079	30%	8.1

The amount of dung currently decomposed and recycled properly by the soils (Table 5) was converted to the volume of effluent that would have to be treated in a treatment pond if the soil wasn't providing the service. On average, the total costs of an effluent pond was \$15.8/m^3, including annualised construction costs (over 20 years with a discount rate of 10%) and annual maintenance costs of the pond and the irrigation system (Trafford, 2011) for effluent application to land (pump, irrigator).

The decomposition of wastes was worth \$336/ha/yr for block#1 and \$127/ha/yr for block#2.

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[1] Stress point is the moisture content for which water is still available to the plant but its extraction becomes more difficult, slowing plant growth.

3.2.7 Carbon storage and Greenhouse Gases Regulation:

3.2.7.1 Net Carbon Flows:

When investigating soil carbon (C) stocks, it's very important to consider net flows of C from soils, because they determine C stock stability. Net C storage in soils is an ecosystem service, whereas net C loss is a degradation process. A measure of the service was defined as the annual net C flow to the soil.

Table 6: Carbon stocks and net C storage in mg/cm^3 for 0-10 cm depth for the two blocks

Block	C stock From Sparling et al. 2003	Change in total C From Schipper et al. 2010
1	54.90	0.30
2	51.10	0.12

For a typical sheep and beef dry hill country, soil C stocks are assumed to be 53.0 ± 1.9 mg/cm^3 (0-10cm) (Sparling et al., 2003). Schipper et al. (2007; 2010) showed that in sheep and beef systems, C is accumulating on average by 0.21 ± 0.09 Mg C/ha/yr. This measure was used to estimate net C accumulation from each block (Table 6). Net C accumulation was converted to CO_2 equivalents and valued using the market price of CO_2 at NZ$ 5.00/t CO_2 (July 2012 price) (MfE, 2013).

Net C storage was worth $6 /ha/yr for block#1 and $2 /ha/yr for block#2. The value of this service is highly dependent on C price, which has been very volatile in the last year, introducing considerable uncertainty around the valuation of this service.

3.2.7.2 Nitrous oxide regulation:

Gaseous nitrogen (N) losses are the product of denitrification (biological or chemical in anaerobic conditions). The method used to quantify nitrous oxide (N_2O) emissions from the studied soil, was taken from the IPCC (Intergovernmental Panel on Climate Change) methodology (Eggleston et al., 2006). However, annual N leaching outputs from Overseer® were used instead of the usual IPCC approximations to calculate indirect N_2O emissions from N leached.

Different emission factors were used for the amounts of wastes deposited on pasture when the soil was dry (standard emission factor EF3PRP= 0.01 kgN_2O-

N/kgN excreted) or wet (greater emission factor of 0.015 kgN_2O-N/kgN excreted) (de Klein et al., 2003).

The service was defined as the difference between the maximum potential N_2O emissions simulated for a soil continuously above Field Capacity and the actual calculated N_2O emissions annually. The measure of the service represents the N_2O that could potentially be emitted from the soil, but wasn't as a consequence of soil water content regulation.

The total potential N_2O emissions from soils were 4.6 and 2.1 kgN_2O/ha/yr for Block#1 and #2, respectively (Giltrap et al., 2008; Saggar et al., 2004). The regulation of N_2O emissions were1.5 kgN_2O/ha/yr for block#1 and 0.7 kgN_2O/ha/yr for block#2. These measures were converted to CO_2 equivalents (using 310 as the global warming potential of N_2O for 100-year time period) and valued using the market price of CO_2 at NZ$ 5.00/t CO_2. This service was worth $2.3 /ha/yr for block#1 and $1.2 /ha/yr for block#2.

3.2.7.3 Methane oxidation:

The degradation of methane (CH_4) a powerful greenhouse gas, by soil biota (methanotrophs) is an ecosystem service. Methane oxidation depends on soil natural capital stocks including soil water organic matter contents.

The service was defined as the total amount of CH_4 oxidised calculated from literature data (Saggar et al., 2008). The amount of CH_4 oxidised by pastoral soils under sheep and beef at the farm scale is between 0.8 and 2.2 g CH_4-C/ha/day (Saggar et al., 2008) or approximately 0.57 kg CH_4/ha/yr or 16 kg CO_2 eq/ha/yr (using the global warming potential of CH_4 as 21 for 100-year time period). CH_4 oxidation was converted to CO_2 equivalents and multiplied by the market price of CO_2. The market price of CO_2 used here was NZ$ 5 /t CO_2. CH_4 oxidation was worth $0.08 /ha/yr for both blocks. This value is negligible compared to other services but was included here for completeness.

3.2.8 Regulation of Pest and Disease Populations:

Pest and disease infestation in sheep and beef systems can cause production losses through the loss of pasture production or have direct impacts on animal health and performance. Soils play a major role in the regulation of many pests and disease of pastoral systems. In this study only two pasture pests were considered, porina caterpillars and grass grubs. They both damage pasture plants, decreasing pasture production and increasing input costs. Eggs and young larvae of porina and grass grubs are very sensitive to moisture extremes. Mature larvae are sensitive to cattle treading and low macroporosity.

For the sheep and beef farm considered, the level of infestation was considered medium for Porina, typically for well established pastures where biological control agents are already present. The level of infestation was considered very low for grass grubs, because of the coarse soil texture. It was assumed that high infestation levels for well-established pastures are at most half of the initial infestation rates on new pastures (Jackson, 1990; Kalmakoff et al., 1993). The service provided by the soil is then the difference between high infestation rates on new pasture and actual average infestation rates, which represents the natural pest regulation provided by established biological control agents.

The provision cost method was used to value this service assuming insecticide application is required to control pests. If the soil fails to regulate pest and disease populations, insecticides can be used. A broad spectrum insecticide was chosen, efficient on porina and grass grubs. Purchase and application costs were considered for high initial infestation rates and average infestation rates. The value of the service was then defined as the difference between the cost of insecticide application for initial infestation rates, and the cost of the insecticide application at the average infestation rate. The value of the regulation of pasture pests was $273/ha/yr for both blocks.

In sheep and beef system, internal parasites such as nematodes are a major health issue. Soil conditions such as temperature and moisture impact on nematode larvae (L3) survival. For the purpose of this study, it was assumed that the soils considered were providing optimal regulation of nematodes. To value the service, the provision cost method was used. The cost of additional feed consumed by the slower growing animals was used as a proxy.

Sheep: Lambs infected with nematodes are slower growing after weaning. Infected lambs were assumed to present a liveweight gain of 125 g LWG/day instead of 200 g LWG/day for healthy lambs (Trafford, 2011). Therefore, finished lambs need 30 additional days and stored lambs need 60 additional days to reach target weight, 35 kg and 45 kg, respectively (PGGWrightson, 2012). Grazed pasture was valued at 14 cents/kg DM. The additional feed consumed by slower growing lambs will cost an extra $5 /lamb for finished lambs and $10/lamb for stored lambs but will provide no additional financial return. This represents an extra cost of $39.5/ha/yr.

Cattle: Production loss due to nematodes is more frequent during autumn, winter and early spring when cattle are 7–12 months (Boom, 2007). Infected animals were assumed to present a liveweight gain of 1 kg LWG/day between 7-12 months instead of 1.5 kg LWG/day for healthy animals (Trafford, 2011). Therefore, infected animals take longer to reach target weight before being sold but provide no additional financial return. The extra cost associated to the additional feed consumed by the slower growing animals was used as a proxy for the value of the service. Extra feed cost between 7-12 months was estimated at $65.4/head, which is $15.7/ha/year.

Overall the value of pest control was worth 273 + 39 + 15 = $327 /ha/yr.

3.3 Summary of the valuation of soil services for a sheep and beef operation:

The value of each of the soil services for the model sheep and beef operation in Hawke's Bay are summarised in Table 7. The filtering of nutrients and contaminants (44-49%) indicate the highest contribution. Flood mitigation (23-25%) and the provision of food (13-14%) show higher contributions compared to the other services. This analysis is revealing on several fronts. At the present time the "value" of grassland systems to both the land owners, as a resource for generating an income and return on the capital invested in land and infrastructure, and to human well being is largely limited to the contribution this agro-ecosystem makes to food supply.

If we add the value of all ecosystem services, the total value of the ecosystem services provided by the typical sheep and beef farm studied equates to $5,085/ha/yr for Block#1 and $3,717/ha/yr for Block#2.

It is not recommended to sum the services, as it hides the contribution of each service. Moreover, while we were very careful when quantifying and valuing each service, the issue of double counting is still a risk, since all services are linked.

Table 7: Economic value ($NZ) of soil services for a typical Hawke's Bay sheep and beef operation.

Soil services	Block#1 $NZ		Block#2 $NZ	
Food -Quantity	745	14%	484	13%
Food -Quality	29	1%	29	1%
Support for human infrastructures	204	4%	0	0%
Support for farm animals	53	1%	33	1%
Flood mitigation	1155	23%	911	25%
Filtering of nutrients and contaminants	2227	44%	1800	49%
Decomposition of wastes	336	7%	127	3%
Net carbon accumulation	6	0%	2	0%
Nitrous oxide regulation	2	0%	1	0%
Methane oxidation	0	0%	0.08	0%
Regulation of pest and disease populations	328	6%	328	9%
Total ($/ha/yr)	5085		3717	

4 April 2011 storm: Loss of soil ecosystem services and recovery

4.1 Loss of soil ecosystem services

The heavy rain storm event in April 2011 in Hawke's Bay impacted on a 10 km wide, 250 km long coastal belt from Mahia to Porangahau. Landslides occurred on hill slopes throughout the affected area, including gullying and reactivated earth flow erosion on older sediments. The proportion of land affected by landslides following the April 2011 storm was estimated by Jones at al. (2011) using satellite imagery. Overall 43 km^2 of bare ground was classified from a total area of 5900 km^2. When compared to pre-event imagery, 86 % of the bare ground in the Rapid Eye imagery was recognised as new bare ground (Jones et al., 2011).

As calculated in Table 1, 95% of all the land affected by landslides during the April 2011 storm was on LUC Classes 6 to 8. For the purpose of this study, the quantification and valuation of soil ecosystem services was recalculated for bare ground on LUC Classes 6-8, assumed to be represented by block#2, just after the erosion event.

Forage quantity and quality: It was assumed that just after the landslides, the first 15cm of topsoil would have been removed; therefore no pasture was left growing on erosion scars. The associated value of the services was then $0/ha/yr (Table 8).

Support for human infrastructures and farm animals: Similarly, bare ground doesn't provide any support to human infrastructures such as farm tracks or fences. Sheep and cattle are known to camp on bare ground but it doesn't provide good conditions, especially for lambing (Table 8).

Flood mitigation: Stavi and Lal (2011) showed that cumulative water infiltration decreased by 77% on eroded land, compared to non eroded. They also showed that cumulative water runoff increased 68% on eroded land. Rosser and Ross (2011) showed that the depth to bedrock was 45 cm at scar sites, half (98 cm) that of the uneroded sites located in the Wairarapa, indicating reduced available water capacity on the eroded site. For this study we assumed that the amount of water stored by the soil profile was 70% lower on erosion scars. This reduces the amount of water stored to 233mm, corresponding to a value of $273/ha/yr for the service (Table 8).

Filtering of nutrients and contaminants: Similarly, it was assumed that capacity of bare ground to filter nutrients and contaminants decreased by 70%. The amount of water filtered was 233 m^3, corresponding to a value of $634/ha/yr (Table 8).

Decomposition of wastes: On bare ground, it was assumed than only 5% (54 kg dung DM/ha/yr) of the dung deposited was decomposed which is worth $21/ha/yr (Table 8).

Net Carbon accumulation and carbon stocks: The C stock in the topsoil is lost after a landslide. It was assumed that the bare ground initially didn't accumulate any C, therefore the value of the service is $0/ha/yr (Table 8). If we assumed that 10 cm of soil was lost as sediments as a result of the erosion event and that sediment contained 51 mgC/cm^3 worth $937/ha. Most of this C is trapped in sediments deposited in river beds and the sea (Dymond, 2010), so only lost from the farm.

Nitrous oxide and methane regulation: Since N_2O and CH_4 regulation is carried out by topsoil, bare ground was not assumed to provide these services (Table 8).

Regulation of pest and disease populations: Since no pasture is growing on bare ground after a slip, the provision of regulation of pest and disease populations was assumed to be maximum and therefore worth $371/ha/yr (Table 8).

The total value of the ecosystem services for eroded land was $1,299/ha/yr, a 64% decline, compared to $3,717/ha/yr for the uneroded land (Table 8. The value of soil ecosystem services lost through erosion was then $2,418/ha/yr.

The April 2011 storm, created 43 km^2 (4300 ha) of bare ground. The corresponding value of lost soil ecosystem services from the loss of soil is estimated to be $10,397,400 ($2418*4300 ha). This lost of value should be included in the analysis of such storm events on the farm and regional economy.

Table 8: Quantification and valuation of soil services for uneroded and eroded land (Block 2) as a consequence of the April 2011 storm.

Soil services	**Uneroded Block 2**		**Eroded Block 2**	
	Quantity	Value ($/ha/yr)	Quantity	Value ($/ha/yr)
Food -Quantity (kgDM/ha/yr)	3973	484	0	0
Food -Quality	No TE deficiencies	29	All TE deficient	0
Support for human infrastructures	Nil	0	Nil	0
Support for farm animals	Normal conditions	33	No support	0
Flood mitigation (mm)	776	911	233 (30%)	273
Filtering of nutrients and contaminants (m^3)	776	1800	233 (30%)	634
Decomposition of wastes (kgDM/ha/yr)	323	127	54 (5%)	21
Net Carbon accumulation (kgC/ha/yr)	120	2	0	0
N_2O regulation (kg N_2O/ha/yr)	0.7	1	0	0
CH_4 oxidation (kg CH_4/ha/yr)	0.77	0	0	0
Regulation of pest and disease populations	Optimal	328	Maximal	371
Total ($/ha/yr)		3717		1299 (-64%)

4.2 Recovery of the soil services after land slides

A number of studies (Lambert et al., 1984; Rosser and Ross, 2011; Sparling et al., 2003) have examined the recovery rates of topsoil properties and pasture growth on land following an erosion event. These data are used to calculate the recovery of the provision of ecosystem services from the eroded soils of the model sheep and beef operation in the Hawke’s Bay (Fig. 1).

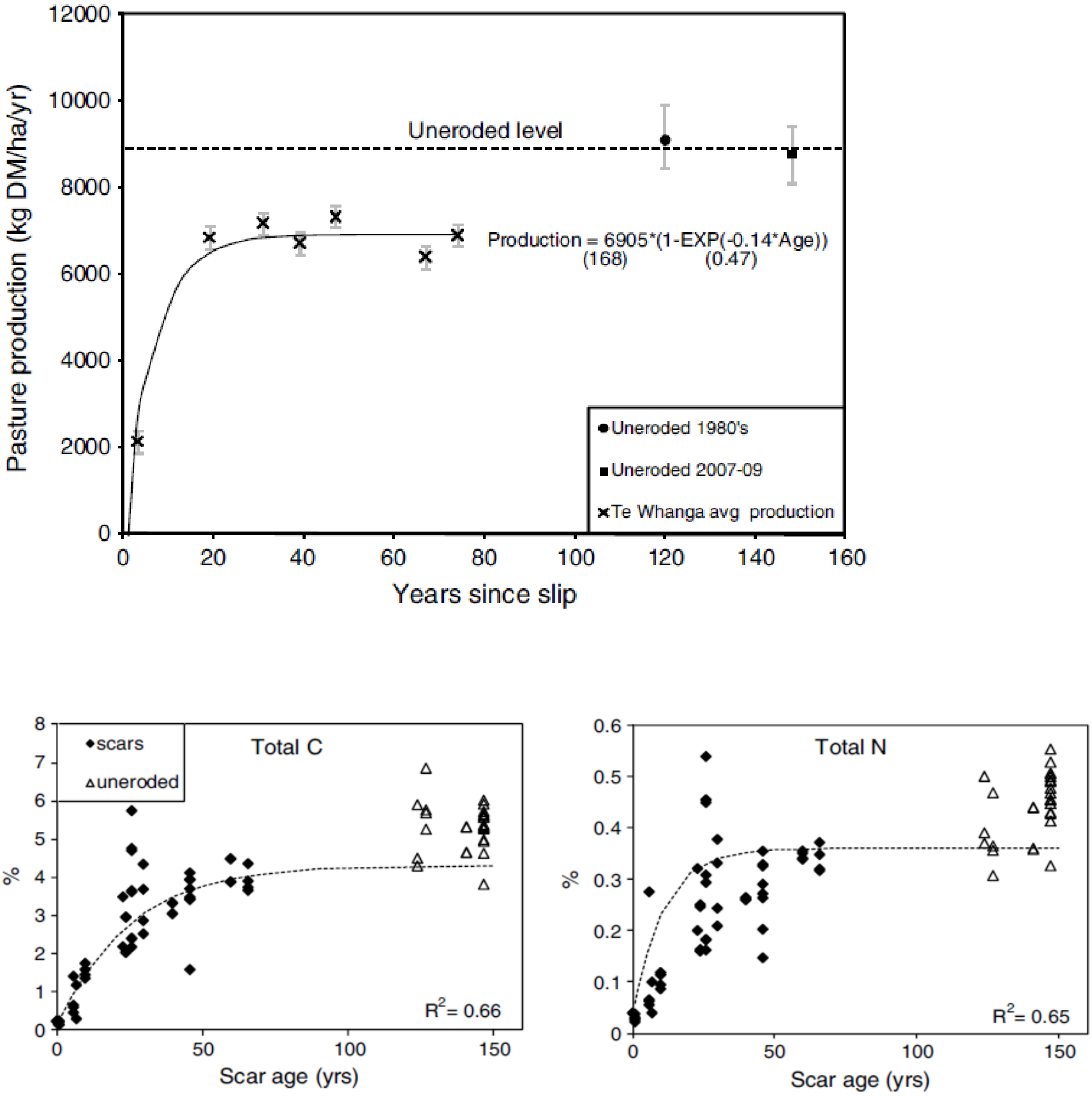

Figure 1: Soil properties recovery (Rosser and Ross, 2011).

Food quantity: Maximum pasture recovery occurs within 20-50 years of the erosion event (Rosser and Ross, 2011). Recovery beyond 80% of uneroded level is unlikely even after 50+ years, reflecting the fact that the soil that was lost was developed in a forest, rather than a grassland ecosystem. Rosser and Ross (2011) showed that after 60+ years of recovery, topsoil pH and C:N ratio had recovered to uneroded values. However, most of the characteristics indicative of soil nutrient status (C, N...) had recovered to only 75–80% of the uneroded values (Fig.1) and may not recover to uneroded soil levels **within human lifetimes**. Rosser and Ross (2011) assumed that reduced nutrients status coupled with reduced water holding capacity, due to the time required for soil development to depth to occur are ultimately limiting recovery in pasture growth at eroded sites. For this study it was therefore assumed that the provision of food quantity, that is pasture growth, would recover to 60% after 20 years, 80% after 50 years and then plateau (Table 9).

Forage quality: Similarly it was assumed from the conclusions of Rosser and Ross (2011) that the provision of trace-elements would recover to 60% after 20 years, 80% after 50 years and then plateau (Table 10).

Support for human infrastructures: it was assumed in this study that this service isn't provided by steep hill country soils of Block 2 (Table 10).

Support for farm animals: The provision of support to farm animals is related to the soil's drainage class and pasture growth. Rosser and Ross (2011) showed that topsoil depths on eroded sites were roughly a third of topsoil depths on uneroded sites, indicating reduced deep drainage and profile retention water capacity on eroded soils. Depth to bedrock was 45 cm at scar sites of different ages and 98 cm at uneroded sites, less than half. This would mean these landscape units are likely to be wetter for extend periods limiting the support service, as subsoil properties are often the determinant of topsoil moisture contents. The use of the pasture growth recovery as a proxy for this service is therefore likely to underestimate the time required for the support for farm animals to recovery. Therefore, it was assumed in this study that the support to animals would recover up to 50% in 20 years on uneroded levels and then plateau, which means lamb losses of 7.5% and calf losses of 3%.

Flood mitigation: Flood mitigation depends on the soil's profile depth and infiltration rates. As indicated, Rosser and Ross (2011) found the depth to bedrock on the eroded site was only half of the uneroded landscape unit. Sparling et al. (2003) in a study on the recovery of topsoil properties on eroded sites reported that bulk density and particle density on the same slip scars decreased with slip age, although they did not find any corresponding trend over time for porosity or available water for individual soil samples. In that study, it was assumed that about half of the soil profile depth was lost in the landslide as showed in Rosser and Ross (2011). Since Rosser and Ross (2011) showed that the average rate of topsoil development on landslide scars was quite slow, approximately 2.2 mm/year, it was assumed that the amount of water stored by an eroded soil could recover to 40% of uneroded levels in 20 years and then plateau at 50% beyond 50 years (Table 10). Recovery beyond that point is dependent on subsoil profile development a pedological process that takes hundreds of years.

Filtering of nutrients and contaminants: The filtering of nutrients and contaminants is highly dependent on the depth of the soil profile and the nutrient status of the topsoil. It was assumed that this service will recover up to 40% in 20 years, then plateau at 50% beyond 50 years (Table 10). Recovery beyond that point is dependent on subsoil development a process taking hundreds of years.

Decomposition of wastes: The decomposition of wastes is highly dependent on the depth of the soil profile, the nutrient status and the soil's biodiversity. Macro-fauna like earthworms are likely to repopulate these areas within a few years of a pasture recovery, while the return of other elements of the soil biological community, mesofauna, nematodes, fungi and bacteria are likely to be slower because of their limited mobility (Schon et al., 2012). Sparling et al. (2003) studied the recovery of biochemical characteristics after landslip erosion, and showed that microbial C and mineralisable N, two indicators of soil's microbiology activity, recovered up to 80% of uneroded land in around 30 years. Considering these factors, to simulate the recovery of the decomposition of wastes service, we used a recovery of 60% after 20 years, and 80% after 50 years (Table 10).

Net Carbon accumulation: The soil remaining after an erosion event accumulates C faster than the uneroded soil (Lambert et al., 1984; Page et al., 2004; Sparling et al., 2003) even though total C levels may not recover to uneroded soil levels within human lifetimes (Rosser and Ross, 2011; Sparling et al., 2003). From the data of Sparling et al. (2003) and Page et al. (2004), it was assumed in this study that eroded soil's total C levels would recover to 80% of uneroded levels in the topsoil (0-10cm) within 45 years. It was assumed that net C accumulation rates were high to start with, around 1.6 mg C/cm^3/yr, which is more than 10 times faster than uneroded levels of 0.12 mg C/cm^3, then decreased overtime (Table 9), and reaching 80% of uneroded levels in 45 years, similarly to total C levels. Following these assumptions the average net C accumulation rate for the first 60 years of recovery would be 0.62 mg C/cm^3/yr, which is similar to the average rate of recovery reported by Page et al. (2004) (Table 10).

N_2O regulation and CH_4 oxidation: The regulation of GHG emissions depends on soil's drainage class and nutrients status. It was therefore assumed that this service will recover up to 50% in 20 years then plateau, similarly to flood mitigation and the filtering of nutrients (Table 10). Until the subsoil develops increasing drainage and total water holding capacity, the topsoil soil moisture content is likely to be higher than the uneroded soil for significant periods during the autumn winter and early spring. It would be possible to explore the influence of soil depth to bedrock in more detail using a water balance model.

Regulation of pest and disease populations: As pasture starts re-growing on erosion scars, and topsoil starts accumulating pests will come back. It was assumed that, as with newly sown pasture, initial infestation rate will be high for about 5 years, before declining to uneroded levels (Table 10).

Table 9: Assumptions for Net C accumulation rate and Total C content depending on slip age for eroded soils (0-10cm) and at greater depths

Slip age	Net C accumulation		Total C	
years	mg/cm^3/yr	% of uneroded level	mg/cm^3	% of uneroded level
0-10	1.6	1333	20	39
10-20	1.2	1000	32	62
20-30	0.5	417	37	72
30-40	0.25	208	40	77
40-50	0.1	83	41	79
50-60	0.1	83	41.5	81
60-120	0.1	83	47.5	93

Table 10: Recovery of soil services following an erosion event as a % of uneroded levels over time (years) for Block#2.

Soil service	**Years following the erosion event**			
	0	20	50	100
Food Quantity	0%	60%	80%	80%
Food -Quality	0%	60%	80%	80%
Support for human infrastructures	Nil	Nil	Nil	Nil
Support for farm animals	0%	50%	50%	50%
Flood mitigation	30%	40%	50%	50%
Filtering of nutrients and contaminants	30%	40%	50%	50%
Decomposition of wastes	5%	60%	80%	80%
Net Carbon accumulation (1-10 cm)	0%	1000%	83%	83%
Nitrous oxide regulation	0%	50%	50%	50%
Methane oxidation	0%	50%	50%	50%
Regulation of pest and disease populations	155%	100%	100%	100%

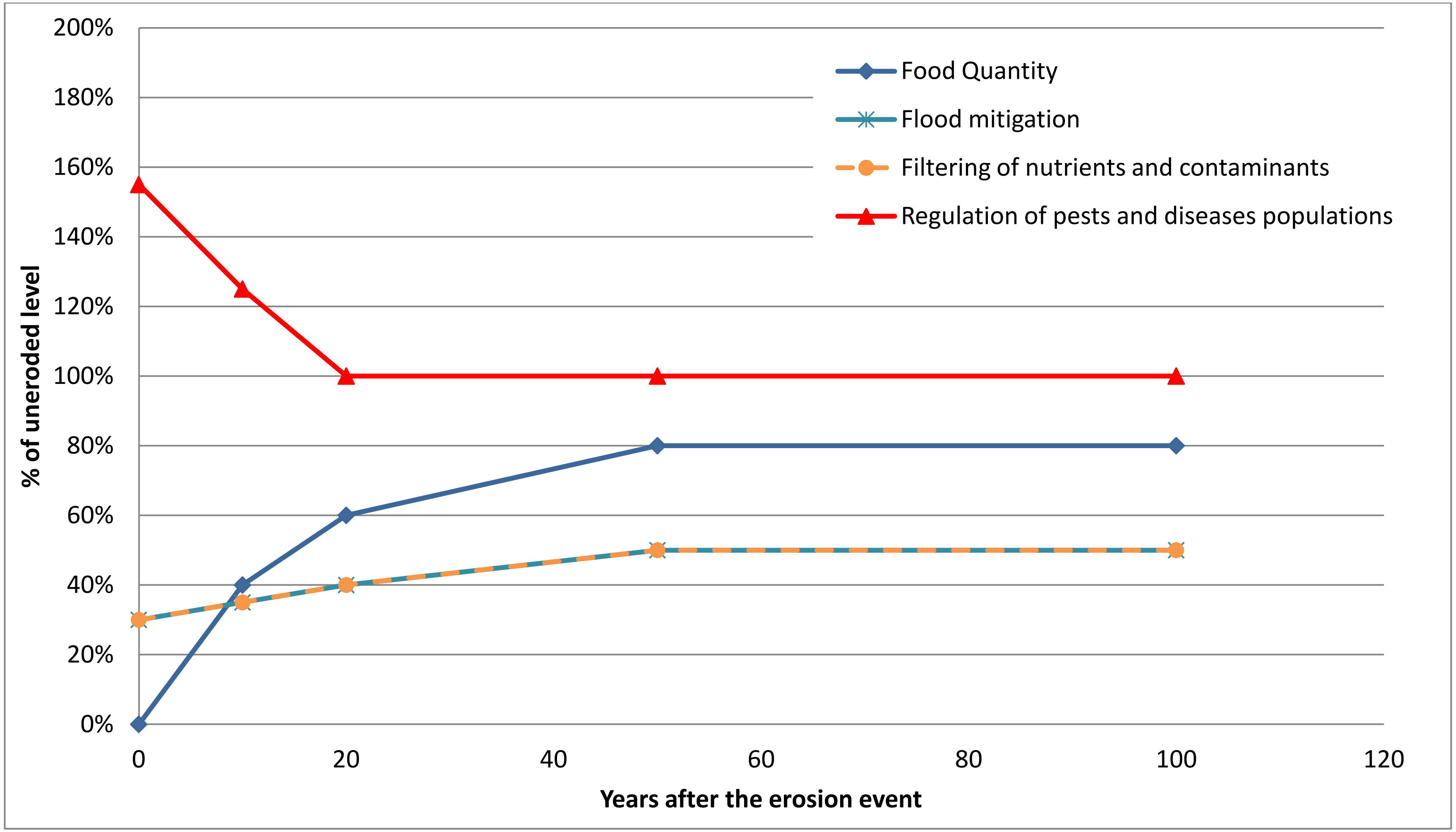

Figure 2: Recovery of soil services following an erosion event as a % of uneroded levels over time (years).

Table 11: Value of soil services since the erosion event over time in $/ha/yr.

Soil service	**Uneroded**	**Eroded** **Slip age**		
		0	20	50
Food Quantity	484	0	290	387
Food Quality	29	0	17	23
Support for human infrastructures	0	0	0	0
Support for farm animals	33	0	17	17
Subtotal for provisioning services	546	0	324	427
% of value of uneroded level		0%	59%	78%
Flood mitigation	911	273	364	456
Filtering of nutrients and contaminants	1800	634	807	978
Decomposition of wastes	127	21	76	102
Net Carbon accumulation (0-10cm)	2	0	22	1.8
N_2O regulation	1	0	0.6	0.6
CH_4 oxidation	0.08	0	0.04	0.04
Regulation of pest and disease populations	328	371	328	328
Subtotal for regulating services	3171	1299	1598	1866
% of value of uneroded level		41%	50%	59%
Total value ($/ha/yr)	3717	1299	1922	2293
% of value of uneroded level		35%	52%	62%

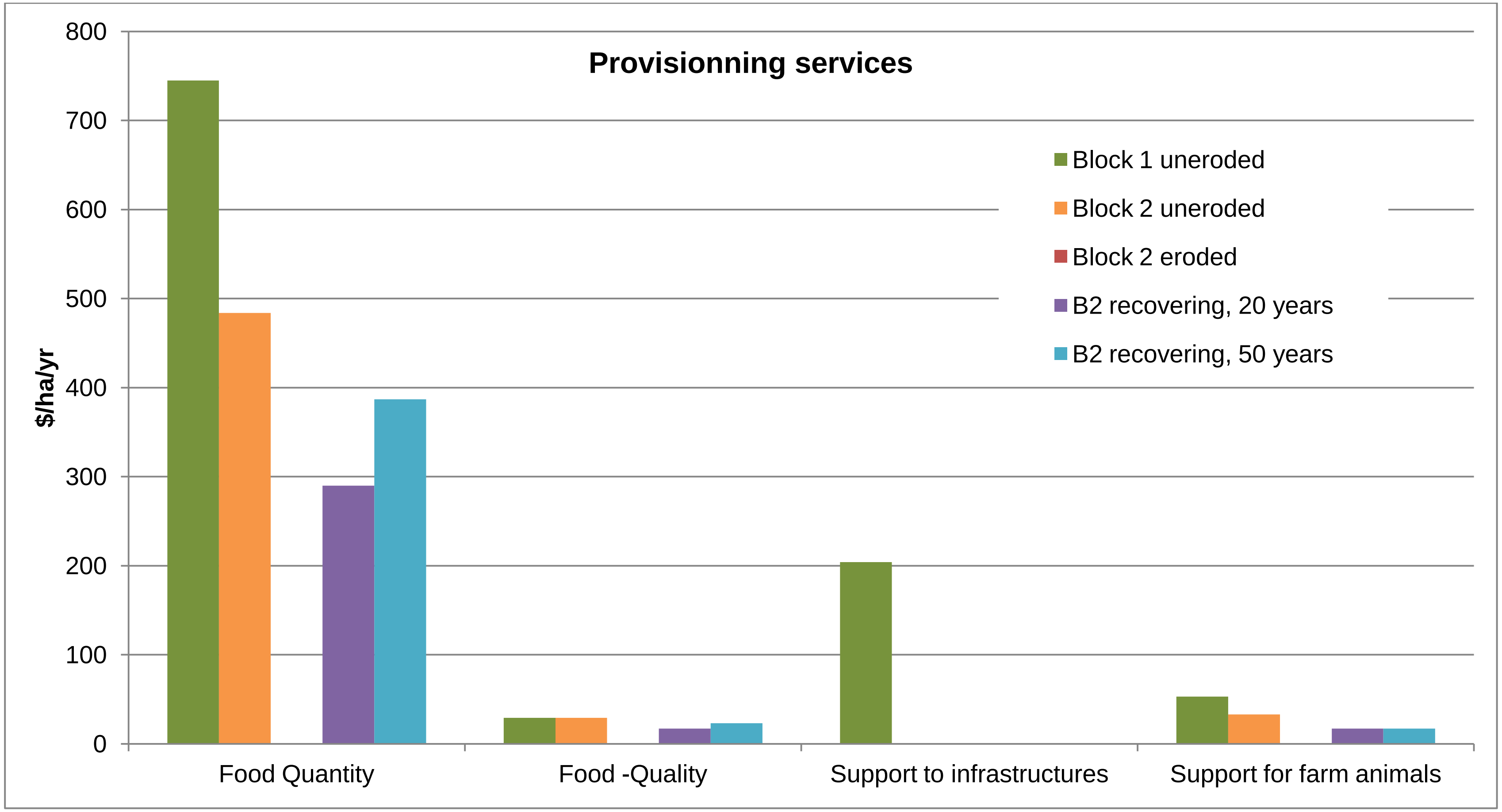

Figure 3a: Value of provisioning services ($NZ/ha/yr) from the uneroded Block #1 and #2, eroded block #2 and 20 and 50 years after the erosion event on block #2.

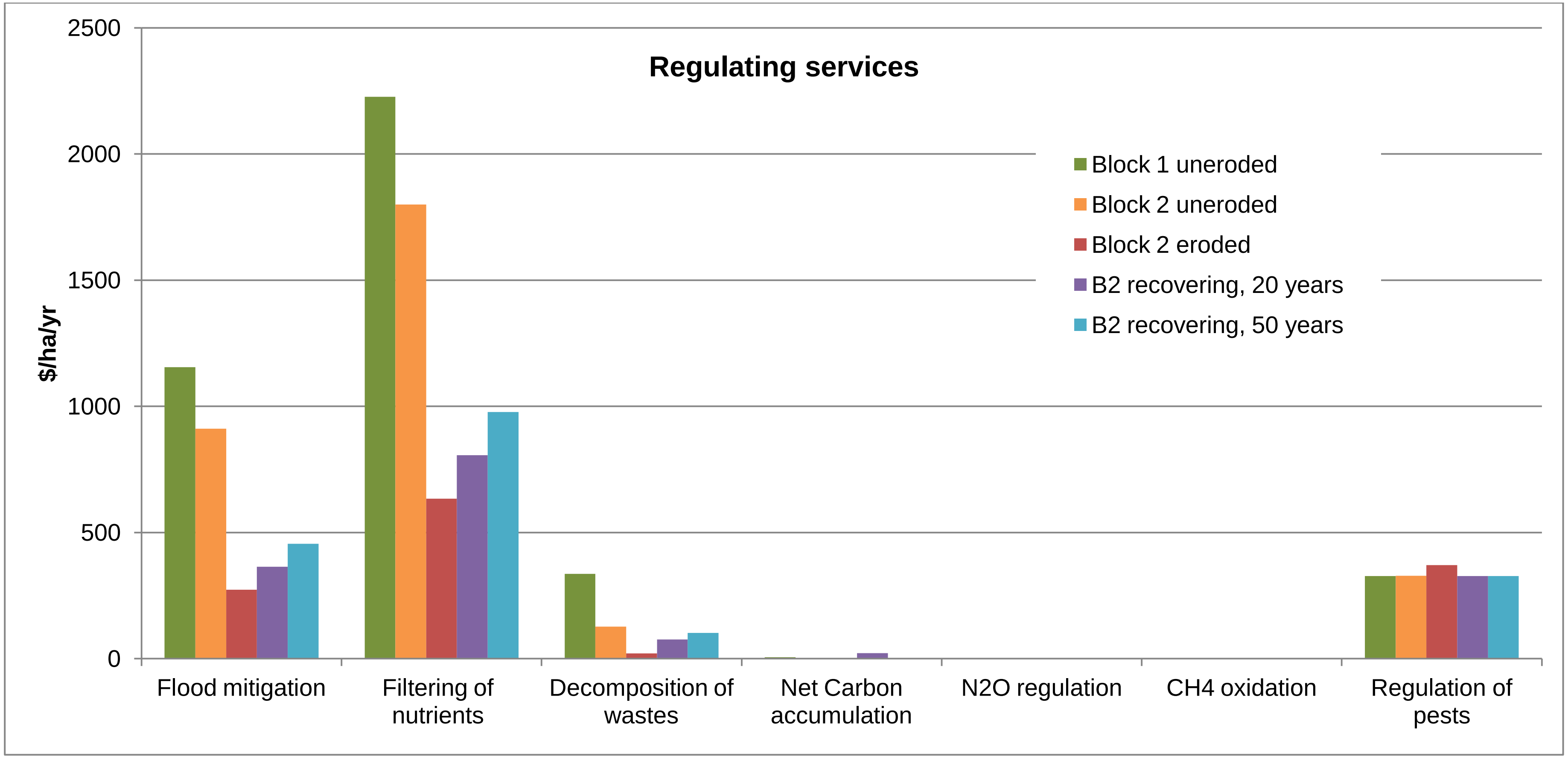

Figure 3b: Value of regulating services ($NZ/ha/yr) from the uneroded Block #1 and #2, eroded block #2 and 20 and 50 years after the erosion event on block #2.

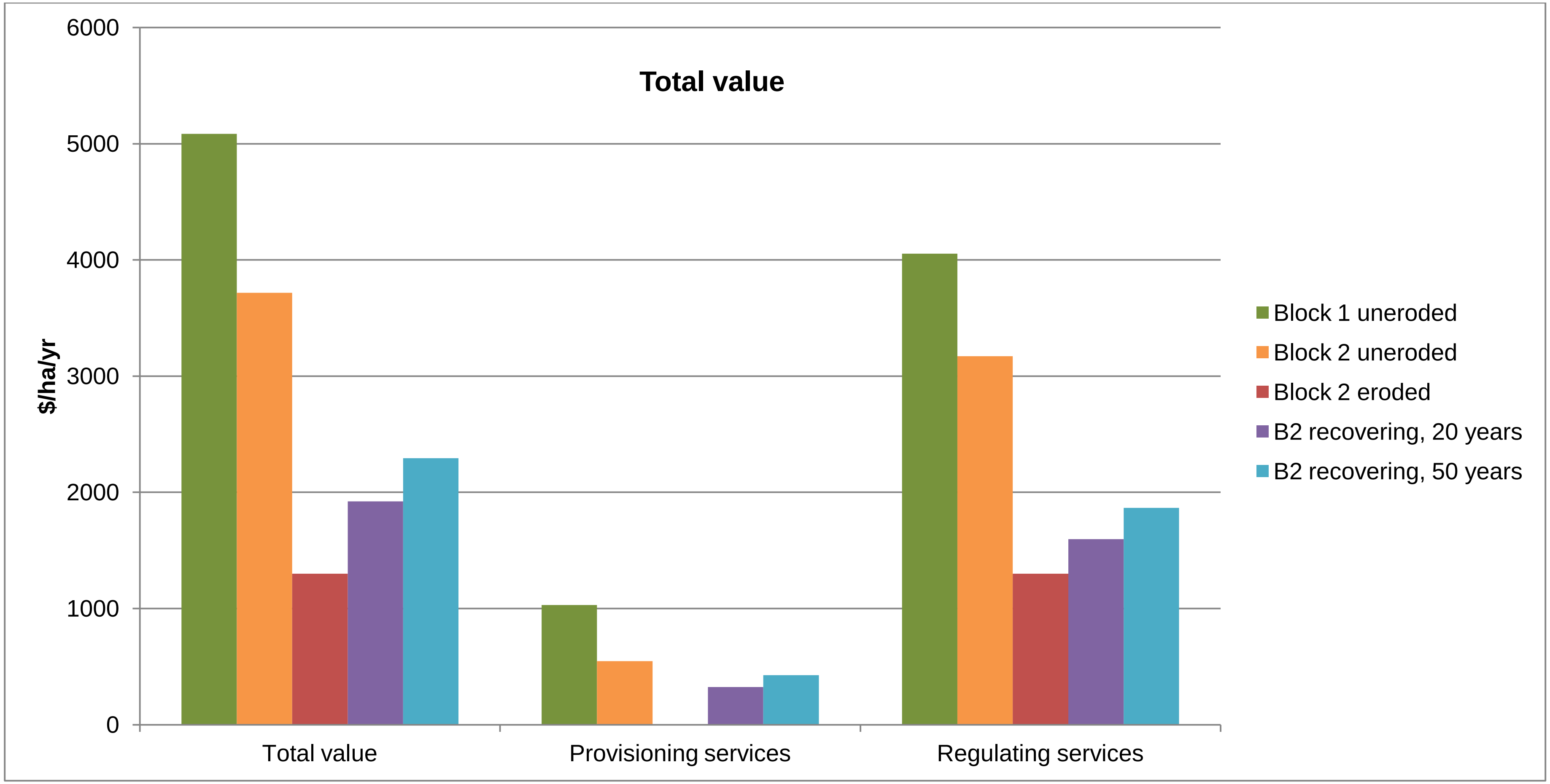

Figure 3c: Value of provisioning and regulating services ($NZ/ha/yr) and total value from the uneroded Block #1 and #2, eroded block #2 and 20 and 50 years after the erosion event on block #2.

Seven of the eleven services were lost as a consequence of the erosion event, with the regulation of pest and disease, flood mitigation and filtering of nutrients services most seriously affected. The provision of ecosystem services recovers to about 62% (in dollar value) of uneroded levels after 50 years (Table 11). The recovery of the regulating services lags behind the provisioning services. Recovery beyond 50% of uneroded level is dependent on subsoil development a pedological process that takes tens of hundreds of years. Until the subsoil develops increasing drainage and total water holding capacity, the soil cannot provide these services to the same degree as the uneroded land.

In the next section we examine the impact of wide-space tree planting on the provision of ecosystem services, via direct effects and potential reduction in loss of ecosystem services.

5 Impact of soil conservation practices on the provision of services from a pasture soil

The analysis undertaken by GNS Science (Jones et al., 2011) identified 43 km^2 (4300ha) of bare ground from a total area of 5900 km^2 in the Hawke's Bay following the April 2011 storm. According to the GIS analysis of the LUC Classes of the region (Table 1), 20% (71,017 ha) of the actual area under sheep and beef pastures (348,569 ha) is rolling hill country (LUC Classes 1-5), and 80% (277,552 ha) is steep hill country (LUC Classes 6-8).The 4300 ha of bare ground represent 1.2% of that effective pastoral area.

The introduction of spaced planted trees into the grazed area is one soil conservation practice used to reduce the risk of soil erosion on LUC Class 6 and 7 land. Following the April 2011 storm, 51.1% of the new bare ground was on LUC Class 6, 31.8% on Class 7 and 11.9% Class 8 (Table 1). The benefits from wide-spaced tree planting are well known for their ability to reduce shallow landslides on LUC Class 6 and some of LUC Class 7. Douglas et al. (2001) verified the large benefit from wide-spaced tree planting on sites susceptible to shallow landslides. They reported that spaced planted conservation trees (32–65 stems per hectare) of various sizes on slopes of mostly 25-30° reduced the extent of soil slipping at 65 sites by an average of 95%, compared with slipping on nearby unprotected pasture control sites. Scars also occurred on fewer sites with space planted trees than pasture (10 vs. 45). There were no significant differences between conservation plant species in their effectiveness in reducing landslide occurrence.

We examined the influence wide-spaced tree planting (e.g. Populus spp.) on the provision of ecosystem services from a steep hill country pasture soil under a sheep and beef operation. In this example the trees are planted at **50 stems per hectare** and achieve 30% canopy cover (McIvor and Douglas, 2012). This canopy cover aligns with the requirements of the emissions trading scheme. Introduction of a tree into a pastoral system provides some additional services that would otherwise not be available in a grasslands system.

5.1 Change to the pasture soil ecosystem services in a spaced planted tree-pasture system

Food quantity: It was assumed that wide-spaced trees will reduce pasture production by 15% when trees are 5-10 years, and 25% when trees are 10-20 years (Benavides et al., 2009; McIvor and Douglas, 2012).

Food quality: Guevara-Escobar et al. (2007) showed that there was no difference in the chemical composition of pasture between the open pasture and the poplar under-storey. Therefore, it was assumed the provision of this service wouldn’t change with the introduction of wide spaced trees.

Support for human infrastructures: it was assumed in this study that this service is not provided by steep hill country soils of Block# 2.

Support for farm animals: The provision of support to farm animals is related to the soil’s drainage class and depends on soil’s sensitivity to treading damage, and water logging. There is a case to argue that a planted tree would improve this service, but in this analysis the provision of support to animal is assumed to be unchanged.

Flood mitigation: Under wide-spaced trees, less rain reaches the ground, with more intercepted by tree canopies and lost by direct evaporation. Rainfall received varies between 5-35% less compared to open pasture, depending on the age of the trees and density (Benavides et al., 2009). It was assumed runoff was decreased by 10% under young trees (<10 years) and 30% under older trees (>20 years).

Filtering of nutrients and contaminants: Increased water uptake by plants (pasture + trees) under trees and plants contribution to higher drainage through improved soil physical characteristics (Benavides et al., 2009) were assumed to improve the soil’s filtering capacity by 10% under young trees (<10 years) and 30% under older trees (>20 years).

Decomposition of wastes: Benavides et al., (2009) reported an increase in carbon (C) and nitrogen (N) mineralization and Guevara-Escobar et al., (2002) an increase in soil pH and exchangeable cations (Ca, K, Mg) under wide-spaced planted trees compared to open pastures. We assumed the decomposition of wastes was 5% greater under young trees (<10 years) and 10% under older trees (>20 years).

Net soil carbon accumulation: It was showed that soil C and N content were greater in open pasture than in a Populus-pasture system (Benavides et al., 2009; Guevara-Escobar et al., 2002); The net C accumulated in soils by tree-pasture systems was assumed to be 60% of open pasture.

Nitrous oxide regulation and methane oxidation: Since pasture under trees are better drained (Benavides et al., 2009) it was assumed that N_2O emissions would be 50% lower and CH_4 oxidation would double.

Regulation of soil pest and disease populations: Improved soil structure and drainage under trees would provide better habitat for soil fauna. Guevara-Escobar et al. (2002) found similar earthworm population in open pastures and under poplar but they noted that other authors found higher invertebrate mass and numbers in a pasture-poplar system. It was assumed here that the level of regulation of soil pest and disease populations would be the same for open pasture or under poplars.

5.2 Additional ecosystem services following the introduction of spaced planted trees to the pasture system

Conservation trees are an ecological infrastructure investment that adds support and resilience to hill country pastoral ecosystem vulnerable to erosion. McGregor et al., (1999) and Parminter et al., (2001) identified several benefits from introducing spaced planted trees into a pasture system, beyond improved soil stabilisation to include shelter from extreme events, shade throughout the year, vista, food source for native birds, wood fibre and an alternate forage source for grazing animals during drought periods, providing insurance against decline in ovulation rates (Barry et al., 2012; Orsborn et al., 2003). To the list of soil services described by Dominati et al., (2010) the following services need to be added to capture the influence the introduction of a spaced planted tree has on the agro-ecosystem.

Extra Forage source for livestock: Coppicing willow and poplar in the summer months to provide a food source in summer dry hill country is a common practice. The quality of the forage is comparable to pasture and has the added benefit at that time of year of being free of toxins and is not contaminated with L_3 larvae. Feeding poplar foliage to ewes during mating can help to sustain lambing percentage as a drought management options. Increase in reproduction performance of up to 30% have been achieved from feeding fresh tree foliage at up to 1.5 kg/ewe/day (Orsborn et al., 2003). The quantity of available forage fed as a supplementary stock feed increases with tree age. It was assumed that trees could be used for forage from 5 years old on, with one cut between 5-10 years and 2 cuts between 10-20 years. The amount of forage produced was calculated and valued using pasture dry matter price.

<u>Wood production</u>: Silviculture is another service that trees provide as they can be harvested for their wood. It was assumed that the value of the wood net of harvest and transport cost, at 20 years would be $2800/ha (50 sph) and $5600/ha (100sph) (Parminter et al., 2001). The net present value of a net revenue of $2,800/ha in year 20 corresponds to an annuity of $104/ha/yr for 20 years, using a discount rate of 3%. The value of the annuity was used as a proxy for the value of the service.

<u>Shade and shelter for livestock:</u> The provision of shelter and shade for animals is another emerging reason for greater tree planting on pastoral farms. This is given additional momentum due to animal welfare issues. Trees are an option for reducing the risk of stock losses from extreme climatic events and moderating extended weather extremes (e.g. temperature) to protect capital stock and sustain animal growth rates. With the focus on increasing per head performance by the sheep and beef sector providing a kinder environment for animals becomes increasingly important factor in being able to capture the potential of the genetic gains possible.

- **Shade:** The observation has been made by producers that when shade is provided throughout the landscape, livestock are more settled and roam less. Betteridge et al. (2012) found animals with access to shade, grazed longer each day than animals without shade, despite spending time under shade during the day. To value the provision of shade for this study, it was assumed that dry matter utilisation was increased from 70% to 75% for trees older than 5 years.
- **Shelter:** Shelter has the potential to make a significant difference in lamb survival rates and initial growth rates in the spring months, by lowering wind speed and reducing the risk of hypothermia (Parminter et al., 2001). Soils under trees are drier than open pasture, from the combined effect of less effective rainfall from canopy interception and the higher evapo-transpiration rate of a tree-pasture system (Guevara-Escobar et al., 1998, Guevara-Escobar et al., 2002). To value the provision of shelter for this study, it was assumed that lamb

and calves losses between scanning and weaning were reduced by 25% (Parminter et al., 2001) for trees older than 5 years and 50% for trees older than 10 years.

Carbon accumulation in trees: Established soil conservation plantings of both poplars and willows provide an opportunity to claim C credits under the Emissions Trading Scheme. In addition to net soil C accumulation, the net C accumulated in poplar trees was assumed to be linear and equal to 0.82 tC/ha/yr (based on a stock of 18.1 tC/ha for a 30 year old tree at 37sph (Guevara-Escobar et al., 2002)).

Nitrous oxide regulation and methane oxidation: Ramirez-Restrepo et al. (2010) found that willow fodder influences the methane production of livestock. Such effects on the animal's environment and performance must have implications for GHG emissions, but to our knowledge there are no data on the influence of a tree-pasture system on the GHG balance of a farm system. A SLMACC project initiated this year might throw some light on this subject.

Regulation of above ground pest and disease populations: the presence of trees on the pasture most certainly has an impact on the regulation of pest and disease above ground but no information was available on the subject. This service can then be added when data becomes available.

5.3 Value of the ecosystem services following the introduction of a space planted tree to the pasture system

The introduction of trees into a pasture system for soil conservation increases the value of existing services including flood mitigation, filtering of nutrients and contaminants and decomposition of wastes (Table 12). The additional attributes which included forage, wood, shade and shelter and net carbon accumulation in the tree, show the biggest impact on the overall value of services. This translated into a small overall increase in the provision of services from the 20 years old space planted trees, despite the provision of food from the open pasture compromised by the introduction of space planted trees.

A comparison of the provision of ecosystem services from the 20 year space planted tree pasture system with the open pasture recovering from an erosion event 50 years previous, serves to highlights the key role the tree plays in protecting the soils natural capital stocks and in particular the preservation of key regulating services (Table 13).

Table 12: Economic value of ecosystem services from a pasture soil (Block #2) and from a spaced planted tree-pasture system, 5-10 and 10-20 years after the introduction of the tree in $/ha/yr.

Soil service	**Uneroded pasture**	**Wide space tree planted** 5-10 years	**Wide space tree planted** 10-20 years
Food Quantity Pasture	484	411 (-)	363
Food Quantity Tree	NA	105 (+)	210
Food Quality-Pasture	29	29 (=)	29
Wood- Fibre	NA	104 (+)	104
Provision of support for human infrastructures	0	0 (=)	0
Provision of support for farm animals	33	33 (=)	33
Provision of shade to animals	NA	58 (+)	58
Provision of shelter to animals	NA	9 (+)	19
Flood mitigation	911	938 (+)	990
Filtering of nutrients and contaminants	1800	1873 (+)	1960
Decomposition of wastes	127	149 (+)	170
Net carbon accumulation (soil)	2.2	1.3 (-)	1.3
Net carbon accumulation (tree)	NA	150 (+)	300
Nitrous oxide regulation	1.2	2.7 (+)	2.7
Methane oxidation	0.08	0.16 (+)	0.16
Regulation of pest and disease populations	328	327 (=)	327
Total value ($/ha/yr)	3717	4191 (+13%)	4568 (+23%)

Table 13: Summary of the economic value ($/ha/yr) of ecosystem services from uneroded pasture soil on block #1 and #2, on block #2 immediately (0), 20 and 50 years after an erosion event, and from a spaced planted tree-pasture system 5-10 and 10-20 years after the introduction of the tree.

Soil service	Uneroded pasture	Uneroded pasture	Eroded Block #2	Eroded Block #2	Eroded Block #2	Block #2 with trees	Block #2 with trees
	Block #1	Block #2	0 years	20 years	50 years	5-10 years	10-20 years
Food Quantity Pasture	745	484	0	290	387	411	363
Food Quantity Tree		NA				105	210
Food Quality-Pasture	29	29	0	17	23	29	29
Wood- Fibre		NA				104	104
Provision of support for human infrastructures	204	0	0	0	0	0	0
Provision of support for farm animals	53	33	0	17	17	33	33
Provision of shade		NA				58	58
Provision of shelter		NA				9	19
Flood mitigation	1155	911	273	364	456	938	990
Filtering of nutrients and contaminants	2227	1800	634	807	978	1873	1960
Decomposition of wastes	336	127	21	76	102	149	170
Net carbon accumulation (soil)	6	2.2	0	22	1.8	1.3	1.3
Net carbon accumulation (tree)		NA				150	300
Nitrous oxide regulation	2	1.2	0	0.6	0.6	2.7	2.7
Methane oxidation	0.08	0.08	0	0.04	0.04	0.16	0.16
Regulation of pest and disease populations	328	328	371	328	328	327	327
Total value ($/ha/yr)	5085	3717	1299	1922	2293	4191	4568

6 Benefit Cost Analysis for soil conservation:

The last element investigated is an assessment, using an ecosystems service approach, of the cost-efficiency (cost-benefit analysis) of an ecological infrastructure investment in soil conservation on hill pasture land at risk from soil erosion.

6.1 Net present value of the flow of ecosystem services

To assess the investment in soil conservation three scenarios were considered over 20 years:

- Business as usual: provision of ecosystem services from a sheep and beef farm for the 2 blocks with no erosion event and no addition of conservation trees
- Erosion event on block #2 and recovery of soil and ecosystem services
- Planting or conservation trees at 50 sph on block #2

For each of these scenarios the Net Present Value (NPV) of the flow of ecosystem services was calculated. The NPV of the cash flow represents the time value of money. Future cash flows need to be discounted to their present value using a discount rate, to be able to compare the value of different scenarios in the present. The NPV of a cash flow informs trade-offs between money to be received at different points in time. First the NPV of the flow of services from the 3 scenarios was considered over 20 years to assess the difference in value between them.

Several discount rates were used to investigate the sensitivity of the NPV to the discount rate, for different scenarios. Small discount rates capture long-term net benefits- from the public point of view, whereas higher discount rates such as 10% put more weight on short-term benefits- from the private point of view.

When considering the recovery of the land (Block #2) after a land slide, it was assumed that the value of the ecosystem services provided was $1299/ha/yr for the first year, increasing linearly to $1922/ha/yr over the following 20 years.

When considering the provision of ecosystem services from block #2 under wide-space planted trees, it was assumed that the provision of ecosystem services was similar to pasture only for the first 5 years, $3717/ha/yr, $4191/ha/yr between years 6-10, and $4568/ha/yr between years 10-20.

Storm effects on the NPV of ecosystem services

After a single erosion event the value of the ecosystem services provided by the pasture soils of a sheep and beef farm dropped by 75% from $3717/ha/yr to $1299/ha/yr.

This represents a loss of NPV of $33,984/ha over 20 years, using a 3% discount rate (Figure 4). Scaled up to 4300ha of land in the Hawke's Bay affected in the April 2011 storm the NPV lost amounts to $146 million. This represents the "value" of the ecosystem services permanently lost from this single erosion event.

This lost value is in addition to the material cost of the storm, which was put at $39 million for infrastructure, land and personal and commercial damage claims. That includes $10 million damage to local roads, $2.5 million to state highways, $60,000 in benefits and allowances and $500,000 in labour assistance for farms. Insurance council of NZ figures show $6.45 million was paid out, with EQC paying $17.45 million to 339 claimants (pers. com. Nathan Heath).

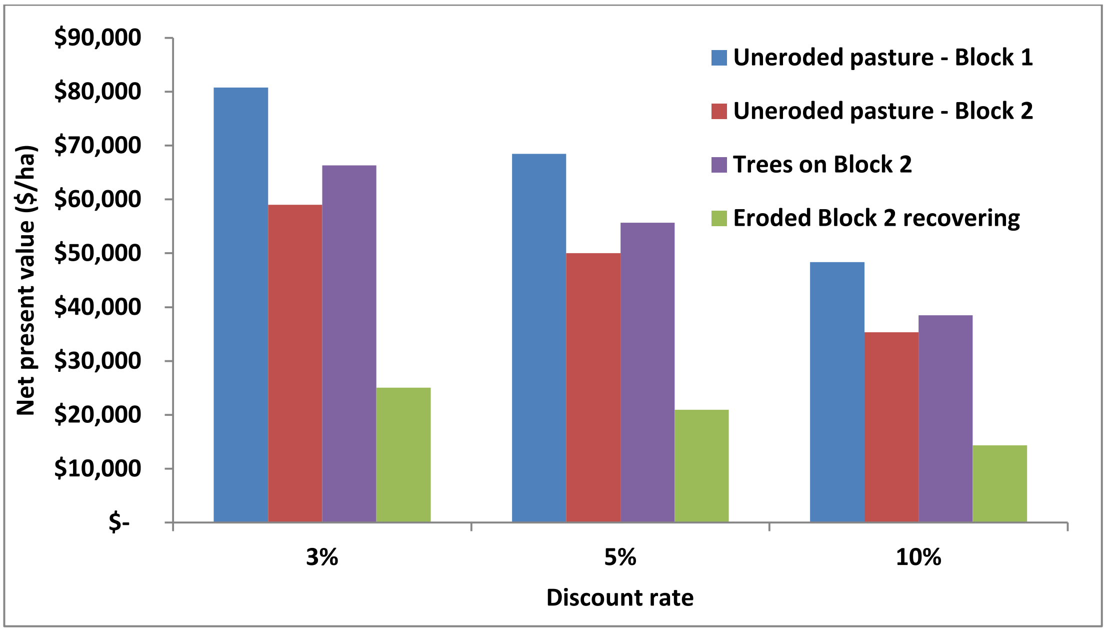

Figure 4: Net present value of the uneroded pasture on block #1 and #2, eroded block #2 recovering, and block #2 planted with spaced trees, over 20 years, depending on discount rate.

6.2 Benefit Cost Analysis of Soil conservation

Soil conservation trees not only reduce the risk of erosion which conserves the equivalent of $33,984/ha of NPV, but also added an extra $7,274/ha (or $31,278,200 for 4,300 ha) to the net present value of the ecosystem services provided by the land over 20 years, when a discount rate of 3% was employed (Figure 4).

If we apply these numbers to the land affected by the April 2011 storm, and assume that 50% of the affected land would benefit from space planted trees, having soil conservation trees on 2150ha of the affected area could potentially represent a value of $108 million ($73 million of ecosystem services not lost, $15.6 million of potential extra ecosystem services from trees, and $20 million in costs that could have been avoided, assuming the actual costs would be halved for 2150ha), for an original investment of $ 1.6 million in planting 2150 ha. This means that for every $1 spent on soil conservation trees is worth $68 of NPV of avoided infrastructure costs and avoided ecosystem services loss.

When realising a benefit-cost analysis of an investment in soil conservation, the costs associated with planting poplars, including planting, pruning, pollarding and harvesting if needed, were considered. The additional values of the ecosystem services provided by a tree-pasture system were considered as benefits (net marginal differences between pasture only and tree-pasture system). The value of ecosystem services is rarely considered in classical Benefit Cost Analysis (BCA), but it was done here to show the difference it makes to decision-making. The option of selling the trees for timber after 20 years was also considered as a benefit.

The costs associated with tree planting were assumed to be $736/ha (for 50sph) at planting and $200/ha in year 7 and 17 for pruning and pollarding. The cost of harvesting and transport was deduced of the net revenue of selling the trees. Figure 5 presents the NPV of different option combinations.

The BCA analysis considered the cash flows between trees planting and harvesting, if it is the case, but not beyond, e.g. not the replanting after harvesting.

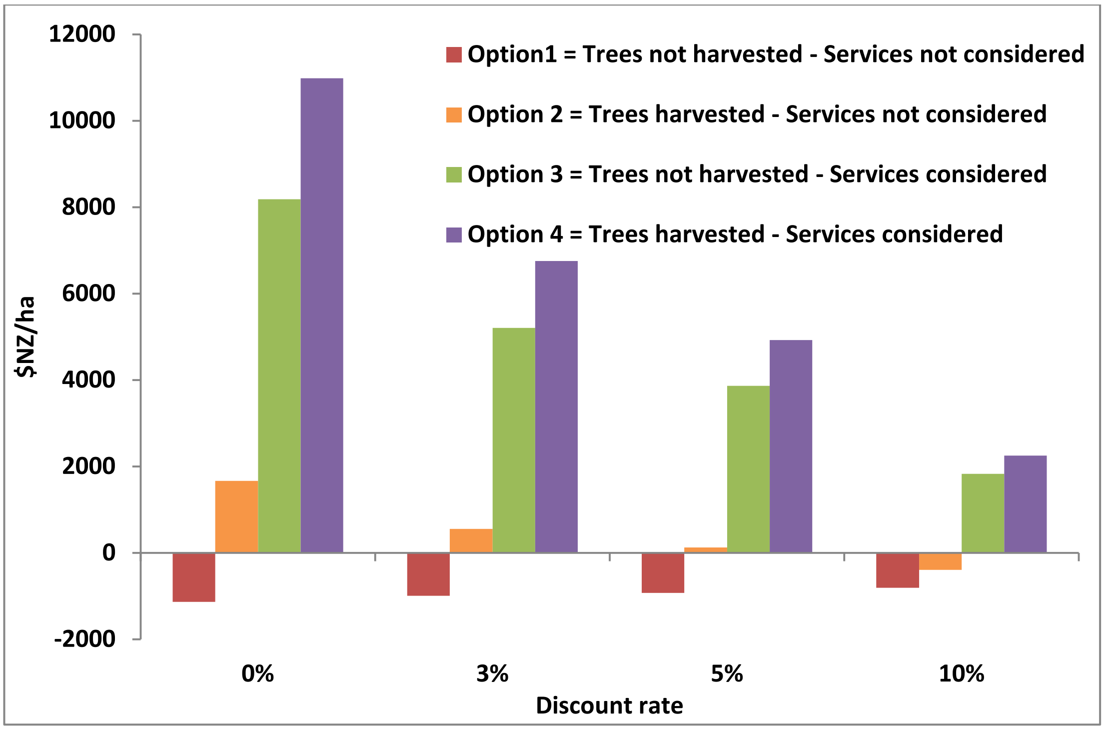

Figure 5: Benefit cost analysis of an investment in spaced planted conservation trees for options that include trees harvested or not and ecosystem services considered or not, at four discount rates.

Planting soil conservation trees without harvesting them (option 1) isn't profitable if the extra-provision of ecosystem services (Table 13) is not considered (NPV = -$998 at 3%). However, if the extra-provision of ecosystem services is considered (option 3) the NPV of the investment is positive regardless of the discount rate used.

If the trees are harvested for timber after 20 years (option 2), the investment is only profitable for low discount rates less than 5%. Again, if considering the value of the extra provision of ecosystem services from trees as well as timber sale (option 4), the NPV of the investment is positive regardless of the discount rate.

Even if the value of the ecosystem services is halved, considering it in a cost-benefit analysis makes a great difference to the NPV of the investment. Depending on if ecosystem services are considered or not, the decision made to invest in soil conservation can have very different outcomes.

This study shows that inclusion of the provision of all the ecosystem services in the cost benefit analysis provides a different picture of the "value" of an investment in space planted conservation trees. An ecosystem services framework offers a more holistic approach to resource management option and enables policy makers to step beyond a consideration of the soil conservation value of tree planting to inclusion of all the ecosystem functions influenced by tree planting that provide benefits to the land owner and to community.

7 Study limitations

A limitation of the study is that the cultural services associated with a sheep and beef operation were not considered. However, it would be relevant to do so in any future investigation. For example the presence of conservation trees on farm will impact on the provision of cultural services such as vista and landscape aesthetics values, land prices and sense of stewardship of the land. Conservation trees will also have an impact on the provision of habitat for biodiversity, e.g. poplars are known to be a food source for native bird species.

The grouping of Land Use Capability Classes in 2 blocks gives an idea of differences in ecosystem services provision between landscape units. The study could be improved by looking in greater details at combinations between LUC land units and soil types when quantifying and valuing the provision of ecosystem services. Doing so will be data hungry.

The quantification of the recovery of soils after a landslides and how that translates into the recovery of the provision of ecosystem service could be improved through modelling and through specific data collection. Similarly, a number of assumptions were made about the properties of a tree-pasture system and how these properties change over time. Again this could be improved when data becomes available.

Finally, the cost-benefit analysis of an investment in soil conservation could also be improved using more extensive data regarding the on-farm costs and benefits of tree-pasture systems, e.g. pruning, pollarding and harvesting poplar trees are practices which are not very common so the costs associated are not well documented.

The authors recommend caution in using the data presented here because of limitations in data sets describing the impact of wide-spaced trees on the provision of ecosystem services, and numerous assumptions made.

We also recommend caution in the use of the economic valuation of ecosystem services. Converting each service into dollar values was more about creating the opportunity to examine how services change with a change in the natural capital stocks, than placing a monetary value on the services. The use of “dollars” provides a common currency in which to compare services and compare services from different soils under the same and different managements.

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