Factsheet 1: Cost-effectiveness of riparian native planting for improving water quality, greenhouse gas mitigation and biodiversity. Whatawhata case study.

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Background

In 2001, a number of land management changes were implemented within the 260 ha Mangaotama catchment on the then Whatawhata Research Centre. These changes were made under the direction of a multi-stakeholder advisory group, for the purpose of investigating ways of improving the economic and environmental performance of a hill country mixed livestock farm (Dodd et al. 2008).

One of the changes implemented was within a small sub-catchment block with a first-order stream (15 ha) which previously consisted of a mix of steep and rolling pasture with a forest remnant riparian area of ~ 3 ha and a 1 ha pine/eucalypt forest block at the head of the gully (Fig. 1a). This forest fragment was unfenced and severely damaged by livestock and pest browsing. The existing vegetation structure in 2000 consisted of a kahikatea (*Dacrycarpus dacrydioides*) emergent canopy with a subcanopy of broadleaf trees (kohekohe, *Dysoxylum spectabile*; mahoe, *Melicytus ramiflorus*) and tree ferns (silver fern, *Cyathea dealbata*; wheki, *Dicksonia squarrosa*) and very little regeneration at ground level.

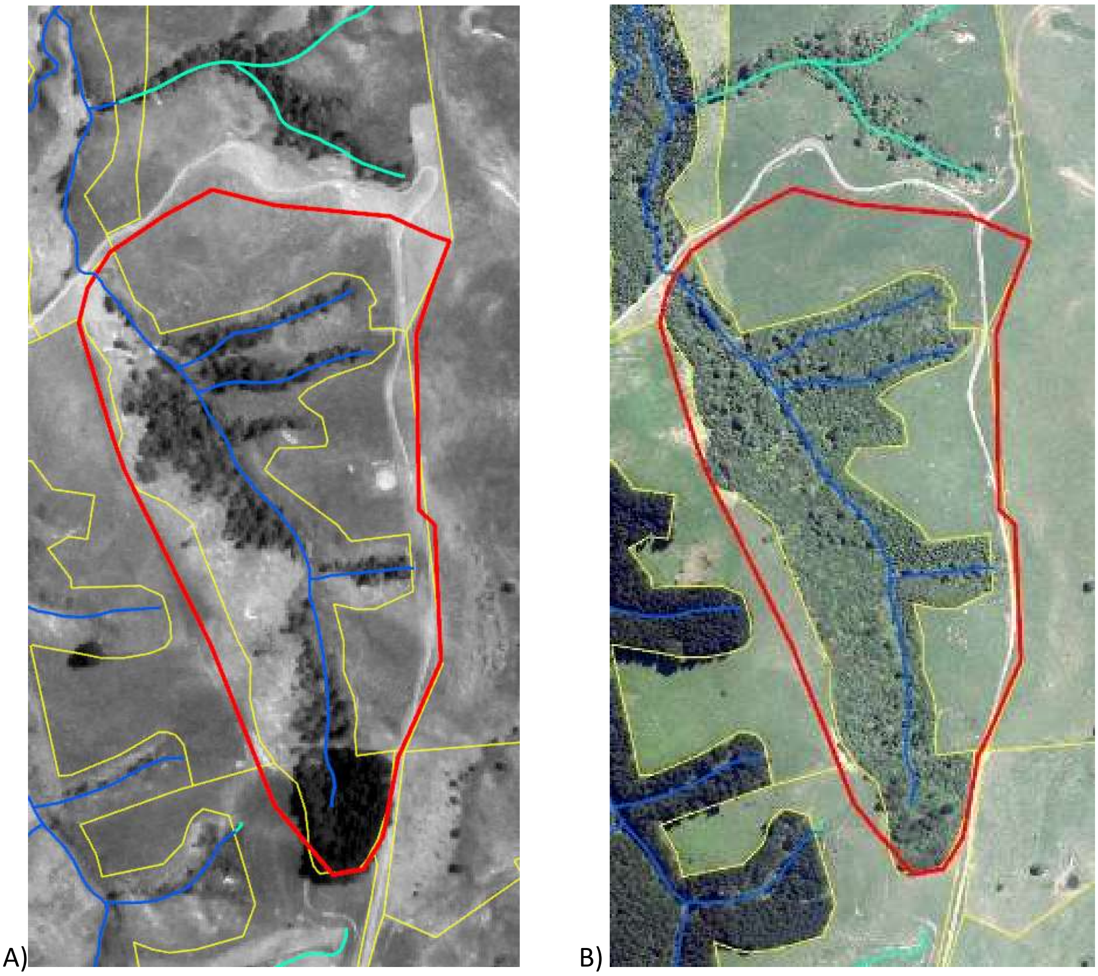

Figure 1. Block layout in a) 1995 showing forest remnant and pine/eucalypt block, and b) 2012 showing new native planting, with current fences (yellow) and stream (blue).

In 2001 the pine trees were harvested, and the remnant fenced to exclude livestock. The new fence line was located at the transition between rolling and steep terrain and included an additional 5.5 ha of the steeper pasture areas around the forest fragment. The pine and pasture areas were planted in native trees and shrubs at a density of 2500 stems/ha. There were two small blocks of kauri (0.2 ha) and totara (0.1 ha), with most of the area planted in mixed native shrubs, including 30 species (Fig. 1b). Possum control was initiated for the following 3 years to protect the young plants.

Measurements

NIWA established a stream monitoring site (PR2) downstream of the plantings in 2000. Monthly water quality measurements and biannual macroinvertebrate survey were carried out at PR2 (Hughes & Quinn 2014, Graham & Quinn 2020).

In 2000, 17 permanent vegetation sample plots (each 50 m^2) were established in the forest remnant (Smale et al. 2008). Measurements included plant species identification, vegetation cover across five height tiers, sapling and seedling numbers, tree stems and heights, and woody debris on the forest floor. In 2002 a further 19 permanent vegetation sample plots (each 50 m^2) were established around the remnant in the planted areas. Measurements included tree survival, root collar diameters, heights and canopy widths. Published allometric relationships between shrub and tree measurements of stem diameter and height were used to calculate tree biomass and carbon stocks (Beets et al. 2012).

Twenty-four soil sampling sites were established in the planted areas in 2002. Measurements included bulk density, soil carbon and nitrogen content at three depths (0-75 mm, 75-150 mm and 150-300 mm).

Costs

The costs associated with establishment and management of the restoration area over 18 years are shown in Table 1. Almost 60% of these related to the actual tree purchase and planting, with the initial costs in Y1-3 approx. $32 000 per ha planted.

Table 1: Actual costs of restoration of 5.5 ha of gully at Whatawhata

Item	Detail	Period (Years)	Cost ($)
Planning	Ecological consultant	Y1	5600
Fencing	2400 m 7-wire post and batten	Y1	18400
Planting, blanking	15400 plants	Y1-2	124200
Releasing	Weed spraying	Y1-3	15600
Pest control	Shooting, trapping	Y1-3	3700
Weed control	Gorse spraying	Y1, 5, 10	22700
Lost grazing	Livestock GM $200 ha^{-1}	Y1-18	19800
Total		Y1-18	**211000**

NB. Not included are the costs of measuring the changes in water quality and vegetation.

Benefits: water quality

The changes in water quality in the first-order stream draining the 15 ha are shown in Table 2.

Table 2: Changes in median measures of stream water quality at PR2, below the riparian planted area, before fencing and planting (2000-2001) vs. after fencing and planting (2002-2020). National Objectives Framework (NOF) bands and national bottom lines (NBL) for rivers are noted where relevant (MfE 2023).

Item	Detail	NBL	2000-2001	NOF band	2002-2020	NOF band
Visual clarity	Black disc (m)	0.61[1]	0.94	B	0.82	B
Dissolved reactive P	µg L^{-1}	n.a.	11	C	14	C
Total P	µg L^{-1}	n.a.	32		39	
Nitrate-N	µg L^{-1}	2400	101	A	273	A
Ammonium-N	µg L^{-1}	240	9	A	8	A
Total-N	µg L^{-1}	n.a.	264		404	
Temperature	°C	n.a.	15.1		12.9	
Macroinvertebrates	QMCI	4.5	4.0	D	5.0	C

[1]Suspended sediment class 2 for river environment classification group Warm Wet Hill

None of the before vs after differences in clarity and nutrient concentrations were statistically significant at this site when analysed after 12 years (Hughes & Quinn 2014). However, re-analysis shows that nitrate-N, total N, DRP and total P concentrations have significantly increased. Temperature has decreased to levels closer to that of the native forest sites (~12.2°C), which provides more suitable conditions for sensitive aquatic invertebrates, which appear to have responded positively.

Benefits: biodiversity

The third major category of benefit is the improvement in forest remnant condition as a result of fencing, pest control and planting the surrounding area. Table 3 shows selected forest structure parameters measured prior to restoration (2000) and 18 years after, along with a comparison against similar riparian gully areas in the nearby Karakariki Scenic Reserve/Whakakai catchment (Table 3).

Table 3: Comparison of native bush fragment structure between 2000 and 2019 following fencing and pest control in 2001.

Item	**Detail**	**2000**	**2019**	**Reserve forest**
Species richness	native species count	65	71	87
Sapling regeneration	stems ha^{-1}	35	10 500	6400
Foliage cover 0.3-2.0 m	%	7	32	48
Foliage cover 2.0-5.0 m	%	39	45	47
Bare ground cover	%	14	2	3
Litter ground cover	%	51	76	62
Tree basal area	m^2 ha^{-1}	55	61	62
Woody debris	m^3 ha^{-1}	65	106	42

While native plant species richness in this fragment has increased slightly over 19 years, other indicators of structure have improved towards and beyond the levels seen in the Whakakai forest. These include a reduction in bare ground cover in favour of litter cover and an increase in vegetation cover in the browsable tier <2 m, both an indication of less livestock disturbance. In addition, an increase in tree biomass was reflected in an increase in basal area and the carbon stock change of 1.0 tC $ha^{-1}y^{-1}$ noted in Table 2. By comparison, the carbon stock change in nearby grazed bush fragments over this period was much lower, at 0.74 tC $ha^{-1}y^{-1}$. Most striking is the increase in sapling regeneration, to levels well beyond the Whakakai forest.

Benefits: greenhouse gas mitigation

Survival of shrubs and trees in the planted areas was approx. 75% after 18 years. While most plants established well in the first 3 years, the increase in canopy cover has suppressed some, along with natural death of short-lived shrub species. Increases in carbon stocks of the forest remnant and planted area over 18 years are shown in Table 4 (Dodd et al. 2020). Additional GHG mitigation benefits accrue from the reduction in livestock and soil emissions associated with the area now excluded from grazing.

Table 4: Measured carbon stock changes and modelled emissions reductions from restoration of 5.5 ha of gully surrounding 3 ha of remnant forest in the Mangaotama catchment.

Item	**Detail**	**Net CO_2-e (t) 2001-2019**
Forest remnant carbon	+1.0 tC $ha^{-1}y^{-1}$	198
Planted native shrubs carbon	+4.8 tC $ha^{-1}y^{-1}$	1647
Planted kauri/totara carbon	+2.1 tC $ha^{-1}y^{-1}$	42
Livestock CH_4 emissions	-3.2 tCO^2_e $ha^{-1}y^{-1}$	317
Soil N_2O emissions	-0.7 tCO^2_e $ha^{-1}y^{-1}$	69
Total	Y1-18	**2273**

Considering the GHG mitigations accumulation alone, the cost:benefit of the forest restoration and planting works out to $93 per tonne of CO_2-e. For comparison, the vegetation carbon accumulation predicted for 18 years from other generic tools is shown in Table 5. Growth at this site appears to have been about 30-50% greater than the MPI lookup table estimates for native forest.

Table 5: Comparative CO_2-e sequestration rates over 18 years

Item	**Source**	**CO_2-e (t ha^{-1}) @18y**
Native forest carbon	MPI lookup tables (national)	155
Native shrub carbon	Tane's Tree Trust (mixed species)	155
Whatawhata native shrub carbon	Measured	317
Native tree carbon	Tane's Tree Trust (native trees)	105
Whatawhata native tree carbon	Measured	139
Pine carbon	MPI lookup tables (Waikato region)	428

Sources: MPI https://www.mpi.govt.nz/dmsdocument/4762/direct ; Tane's Tree Trust https://www.tanestrees.org.nz/resources/carbon-calculator/

Carbon is also stored in soil and stocks potentially change with land use change. Table 6 shows the changes in soil carbon stocks which included variation in slope and aspect. The data indicate that soil carbon stocks are declining over time at this site, regardless of slope or vegetation cover, but the rates of soil carbon loss in planted native shrub areas were less than under permanent pasture.

Table 6: Soil carbon stocks (0-300 mm) under areas of permanent pasture and native shrub planted into pasture.

Vegetation	**Initial (tC ha^{-1})**	**Final (tC ha^{-1})**	**Rate of change (tC ha^{-1} y^{-1})**
Pasture	121.9	94.1	-1.46
Planted shrub	116.6	104.9	-0.62

References

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Images


A)


B)

Figure 2. Looking north from the top of the restoration area in a) 2002; b) 2022.