Identifying Complementarities for the Dairy and Forestry Industries in the Central North Island

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REPORT INFORMATION SHEET

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Executive summary

Report Title: Identifying Complementarities for the Dairy and Forestry Industries in the Central North Island
Authors: Juan J. Monge, Sandra J. Velarde, Richard T. Yao, Stefania Pizzirani and Warren J. Parker

Background and objectives

This study was commissioned by Oji Fibre Solutions (OjiFS)[1] and the Waikato Regional Council to provide sound evidence about the effects of land use in New Zealand using the dairy and forestry industries in the Central North Island (CNI) as a case study. The study was independently reviewed by the New Zealand Institute of Economic Research (NZIER) to confirm its validity. The aim of the study is to provoke and promote constructive discussion on how complementarity opportunities can be generated at a land enterprise (farm or forest) and catchment level to create beneficial scenarios for both industries. In that regard the study is deliberately simple in its approach: other sectors of the economy are excluded to keep the scenarios easy to understand and focused. Such a discussion will help stakeholders: comply with current national environmental policies such as the National Policy Statement for Freshwater Management (NPS-FM) and the Emissions Trading Scheme (ETS); inform pathways for achieving regional economic growth within environmental limits; and indicate how the integration of land-uses at different scales can be achieved more effectively than in the past.

Initially motivated by the interest created by Warren Parker's "back of the envelope" contrast of dairy and forestry value chains (Appendix 1), this study has reinforced such calculations through a more extensive economic assessment. The "back of the envelope" comparison was developed with the objective of expanding the "narrow enterprise-only" perspective of land-use change to a wider conversation about environmental and social dimensions as well as financial returns. This study backs-up this analysis through a comprehensive literature review on the environmental externalities and ecosystem services generated by both industries, policies addressing them, and the market and non-market values assigned to them; a regional analysis of the relative profitability and value-added created by both industries; and upstream and downstream complementarity examples.

The following table summarises the main findings from the study applied to the 28,000 hectares initially used in the "back of the envelope" contrast. It incorporates local yield figures at the land-use and manufacturing levels.

Review of environmental externalities and ecosystem services

Relevant literature concerning national and local environmental policies addressing the externalities generated by both land uses (positive and negative) provided a range of prices and limits used as regulation avenues.

The Emissions Trading Scheme (ETS) was established to provide an economic incentive to reduce greenhouse gas emissions including forest-based carbon sequestration. However, modifications to the ETS, such as the exclusion of emitting sectors (e.g. farming) and allowance of international units in the domestic market, have reduced the barrier for land-use change from forestry (such as in the CNI and Canterbury), resulting in high rates of deforestation to establish dairy farms in particular.

The National Policy Statement for Freshwater Management (NPS-FM), introduced in 2011 and updated in 2014, has created an opportunity to internalise the externalities caused by excessive

[1] *Previously known as Carter Holt Harvey (CHH) Pulp and Paper.*

nutrient leaching from intensive land-use systems (e.g. high input dairy farms) and, potentially, to reach a regional development outcome where land use is within environmental limits and the economy is diversified and resilient.

Comparative economic and environmental indicators for a representative forest and dairy farm in the Central North Island

	Forestry		Dairy	
Hectares	28,000		26,600	Grazable
Stocking	550	trees/ha	2.50	cows/ha
Yield/unit	678	m^3/ha	380	kg milk solids/cow
Rotation	28	Years	1	Season
Total yield	678,000	m^3/yr	25,270,000	kg milk solids/yr
10-year average price	98.15	$/$m^3$	6.42	$/kg milk solids
Min. price in 10 years	88.94	$/$m^3$	4.60	$/kg milk solids
Max. price in 10 years	102.31	$/$m^3$	8.64	$/kg milk solids
Average surplus	28,686,180	$ to forest owner	39,673,900	$ to farmer for milk
Minimum surplus (loss)	22,441,787	$	-6,317,500	$
Maximum surplus	31,503,709	$	95,773,300	$
Probabilities of loss	0	%	13	%
Manufactured Product	67,550	t pulp	37,522,559	kg whole milk powder
	275,268	m^3 of lumber	3,035,393	kg cull cow and veal*
10-year avg. export price	737	$/t pulp	7.07	$/kg milk solids
	404	$/$m^3$ of lumber	4.76	$/kg whole milk powder
			4.90	$/kg meat
Values of manuf. products**	160,992,373	$/forest	193,527,714	$/land area to dairy
Land value***	6,000	$/ha	36,100	$/ha
Jobs (farm/forest)	84	emp/forest/yr	415	emp/farm/yr
Jobs (plant/mill)	280	emp/mill/yr	175	emp/plant/yr
Nitrogen discharge****	3	kg/ha/yr	54	kg/ha/yr
Red./Inc. from allow.*****	-32	kg/ha/yr	19	kg/ha/yr
Indicative payment	1,024	$/ha/yr	-608	$/ha/yr
Carbon emitted/stored******	11	t CO_2e/ha/yr seq	-10	t CO_2e/ha/yr emitted
Price assumed	7	$/t CO_2e	7	$/t CO_2e
Indicative payment	77	$/ha/yr	-70	$/ha/yr
Indicative env. payment	1.62	$/$m^3$	-0.71	$/kg MS
Indicative env. payment	30,828,000	$/forest	-18,034,800	$/land area to dairy

***** 18% herd culled at 197 kg avg. carcass weight, 22% replacement rate, 97% of calves that survive, 70% bobbied at 15 kg carcass weight (refer to text for data sources).
****** Valued at export prices and assuming that all raw-product supply is manufactured domestically to show full potentials. Actual production values in the CNI are listed in the main body of the text.
*** Sources: Dairy NZ (2015a), Evison (2008) and McCarthy (2004).
**** All nitrogen figures are based on the benchmarks estimated for Lake Rotorua using Overseer v5, a nitrogen price of $400/kg (or perpetual annuity of $32/kg), and a dairy discharge allowance of 35 kg/ha.
***** Indicative figures to show the externalities generated by forestry (avoided leaching below allowance) and dairy (leaching above allowance). The actual policy implementation is described in the text.
****** Considers average annual seq. rates (35 t CO2e/ha/yr) and emissions (647 t CO2e/ha) for forestry.

Using representative prices and limits created by the NPS-FM for nitrogen and the ETS for carbon in the Lake Rotorua catchment, the last two rows of the table show the “indicative” monetary payments by which market-based profits should be adjusted to reflect the externalities produced by both land uses. Although carbon emissions from dairy are not currently covered by the ETS, they have been included to fully account for externalities. It is of utmost importance to mention that although the table lists specific monetary values; these are “indicative”, rather than definitive, and support the proposition that the value of externalities should, ultimately, be reflected in land values. The actual policy implementations are detailed in the report.

The lack of policies creating economic incentives for other forest ecosystem services (e.g. biodiversity, recreation, flood mitigation and avoided erosion) have precluded these being internalised to forestry in this study. However, as a starting point to such an internalisation process, the large literature on non-market valuation techniques could be drawn-on to assign values to these positive ecosystem services. Estimates of their value have been listed in the main body of the text to show why they also should be considered in determining the optimum mix (and intensity) of land use in a catchment or region.

Economic indicators for primary industries

An economic analysis was undertaken to assess the profitability of a representative dairy farm and a representative steady-state forest in the Central North Island. Considering pure market drivers, a hectare of dairy generated on average about 50% higher returns than a hectare of steady-state forest under a structural timber regime.[2]

Heavy dependence on international commodity markets exposes the dairy industry to large milk solids price fluctuations and associated volatility in the payout to farmers. Based on milk prices in the last decade, this volatility could result in losses for farmers (a 13% probability), affecting their ability to plan long term and acquire the lowest cost credit to stay operationally efficient. Although forestry generated lower returns, product price data from the same 10-year period, indicates it is more resilient than dairy (no loss probabilities) due to: (1) the combination of domestic and export markets; and (2) the relatively stability of prices in the domestic market.

Supply chain economic and environmental indicators

Value-added economic indicators, such as employment, volume and value of manufactured products were estimated for both value chains. The CNI contains 13 dairy manufacturing plants, employing approximately 3,790 people, and 41 wood product mills employing 5,870 people. The majority of dairy products are exported offshore, while just over half of the manufactured wood products are exported offshore. The total values of value-added products manufactured in the region are estimated to be $5 billion and $2 billion for dairy and forestry processing, respectively. In addition, Port of Tauranga data indicates raw log exports account for $1 billion of the forestry products.

Using a bottom-up approach (applied to the “back of the envelope” comparison in Appendix 1), and assuming that all raw log supply is domestically manufactured, the gap between forestry and dairy’s production values would narrow. Thus, in this case the full value of forestry and dairy is broadly similar, with dairy slightly higher when environmental externalities are ignored, as shown in the table above.

Manufacturing sites in both sectors also contribute to environmental burden, although this is substantially less than the associated land-use activities.

Synergies and complementarities

The lower return volatility experienced in the forestry industry coupled with the potential for payment for some ecosystem services (e.g. nitrogen and carbon due to the existence of the

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[2] The aim of comparing average profits is not to identify the best use of a hectare of land but to give the reader an idea of the relative profitability of well-established enterprises. To keep the objectivity of the comparison, no adjustment was made for the fact that dairy generally occurs on higher quality land than forestry. If the objective were to identify the best use of a hectare of land then a marginal analysis comparing potential yields (adjusted for land quality) and profits from both land uses would be more adequate than a comparison of average profits.

NPS-FM and ETS), confirm the economic and environmental complementarities offered by forestry. It is worth emphasising that the objective of this study is not to create debate about the relative merits of both industries, but rather to encourage readers to think more about how dairy and forestry can spatially co-exist to optimise environmental, land productivity, economic growth and community outcomes. A complementarity example at the land-use level in the Lake Rotorua catchment is reported to highlight the scope of this outcome.

Land-use complementarity was assessed through a cash flow approach where the net present values (NPV) from dairy and afforestation (with environmental payments) over a period of 28 years were compared (i.e. a typical CNI radiata pine rotation). As expected, payments for ecosystem services improve the profitability of afforestation, are environmentally sound and would help farmers cope with price uncertainty and production limits under new freshwater and greenhouse gas environmental policies. The afforestation option with financial reward for ecosystem services could appeal to Maori landowners due to their environmental, cultural and long-term perspective towards land ownership. Such potential is critical to the CNI since 37% of national Maori freehold land is located in the Bay of Plenty and Waikato regions and, of this, 80% is non-arable (i.e. Land Use Categories 6 to 8).

Recommendations for further studies

The complementarities identified could be exploited at the farm, catchment or regional level to achieve resilient economic growth under the environmental limits established by the ETS and NPS-FM. More detailed economic regional analysis could be performed to assess the complementarity opportunities of a wider range of land uses – both in terms of sustainable land-use and along supply chains – by utilising regional modelling frameworks such as input-output or computable general equilibrium models. Such models would allow the assessment of "what if" scenarios such as the impact of internalising environmental externalities on value added by capital and labour along the respective supply chains. An example of these "what if" scenarios would be to identify the marginal value of externalities (e.g. nitrogen and carbon) to regional economic growth from different allowance schemes.

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Background

Dairy is New Zealand's largest export earner, followed by meat and forestry (MPI 2015a). Agricultural export revenues are expected to reach $29.7 billion in 2015, with the dairy sector contributing $15.8 billion (MPI, 2015a). The export revenue for forestry in 2015 is expected to be around $4.7 billion (MPI, 2015a).

Milk solids productivity increased by 60% (from 653 to 1,028 kg/ha) between 1990 and 2010 (Parliamentary Commissioner for the Environment, 2013). These productivity gains were achieved through increased stocking rates and increased use of inputs such as water, fertiliser and supplementary feed (Parliamentary Commissioner for the Environment, 2013; DairyNZ, 2015a, 2015b). Unfortunately, this production intensification has precipitated an array of negative environmental impacts including: a reduction in water quality; higher methane gas emissions; higher demands for surface and groundwater for irrigation; and reduced variety in pastoral landscapes (Baskaran et al., 2009). However, these environmental costs are largely not currently factored in to the prices charged for dairy products or internalised to dairy farm businesses. The corollary: the economic contribution of dairying to the New Zealand economy is overstated.

In contrast, a number of positive benefits are associated with forestry other than the economic value of wood and wood-fibre products. For example, forestry sequesters more carbon than other grazing and tillage management techniques (Lewandrowski et al., 2004; Murray et al., 2005). Also, a recent review of water quality in New Zealand by Baillie & Neary (2015) showed that planted forests produce high water quality for a large proportion of the forestry-growing cycle. They also found that planting forests could rapidly improve water quality from land previously in pasture highlighting the potential of changing land use to remediate degraded waterways.

Forestry in New Zealand also provides other important benefits such as avoided erosion, reduced sedimentation, conservation of indigenous wildlife, recreation and tourism (e.g. Yao et al., 2013; Yao and Velarde, 2014; Barry et al., 2014). Thus, the low environmental impacts of forestry can be combined with the high economic returns from dairy farming to achieve greater sustainability of land-use at both the farm and catchment level.

Notwithstanding these positive effects, the negative impacts of forestry such as the spread of wildings, pollen; increased sediment entering waterways in the first 2-3 years after harvesting; and the potential for the residues from harvesting to enter waterways during heavy rainfall events need to be acknowledged. As with dairy farming, best practice management can mitigate the negative and enhance the positive externalities of forestry.

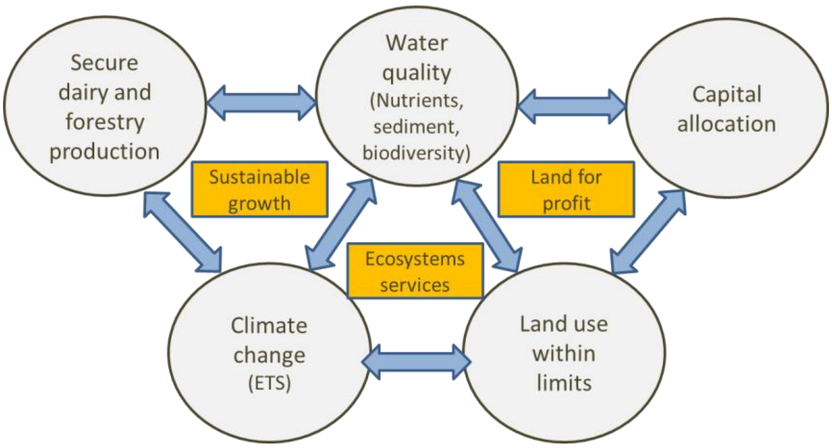

Figure 1. Policy connections – co-benefits/trade-offs (From Parker, Scion 2015-2020 SCI).

Central and local governments are currently confronting the challenge of increasing regional economic growth and social well-being while also reducing the impact of other environmental impacts (externalities or ecosystem services[3]) through the implementation of national environmental policies. These include the National Policy Statement for Freshwater Management (NPS-FM), which is designed to improve freshwater water quality and the Emissions Trading Scheme (ETS), which is designed to reduce greenhouse gas (GHG) emissions (Ministry for the Environment, 2007; 2014). The implementation of the NPS-FM and the ETS has created opportunities to exploit the complementary economic aspects of dairy and forestry as land-use alternatives within environmental limits (Figure 1).

Limited research has been carried out on the valuation of the externalities generated by dairy and forestry, and on the economic value generated by their associated supply chains when these are taken into account. Undertaking such research would demonstrate:

1) the opportunity for realising the complementary benefits of different land-uses to achieve target environmental outcomes (such as offsetting carbon emissions and nitrogen leaching),
2) the downstream impacts of land-use change on an industry's economic contributions and particularly its capacity to sustainably grow export earnings to the equivalent of 40% GDP by 2025[4], and
3) how compliance with regional and district environmental policy requirements can be viably achieved by landowners.

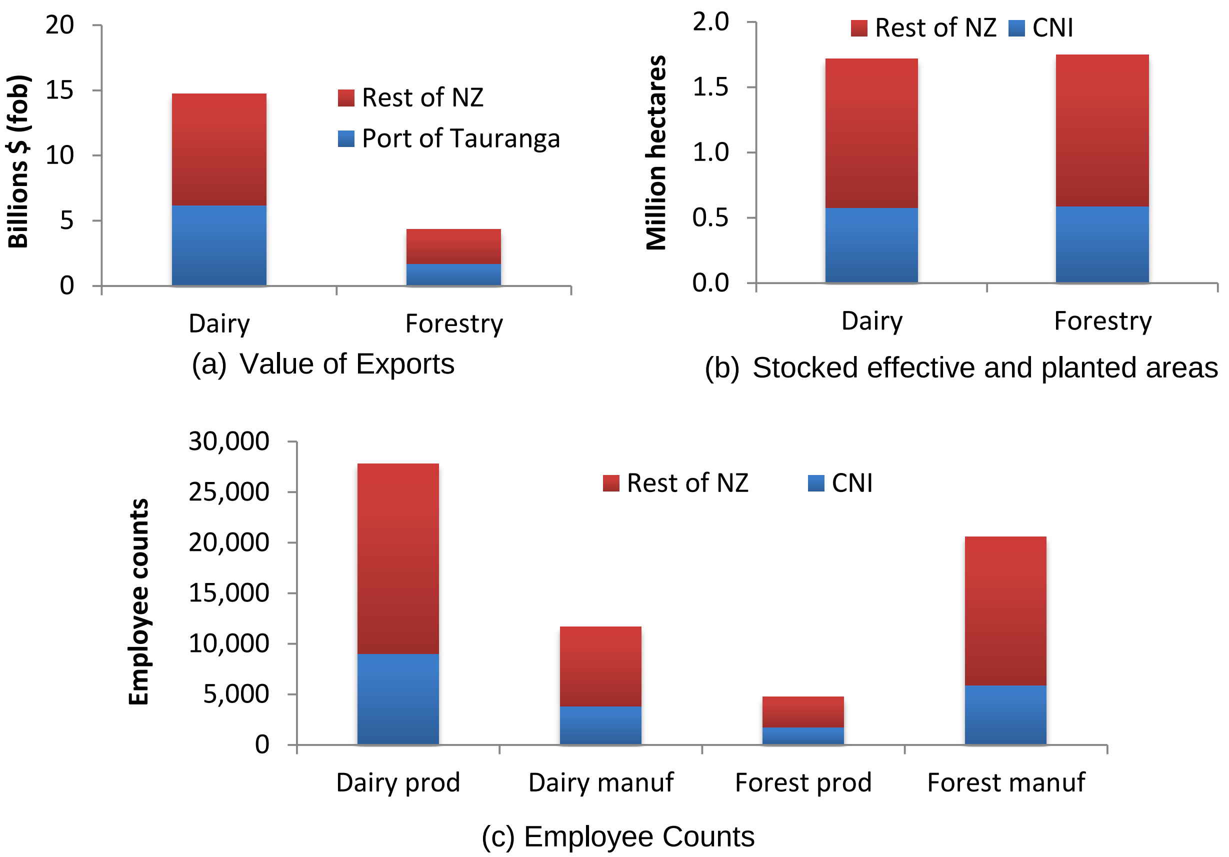

Figure 2. Economic Indices for the Dairy and Forestry Industries in the CNI and Rest of New Zealand

The Central North Island (CNI)[5] is the most important dairy and forestry production region in New

[3] *Ecosystem services are the benefits derived by people from ecosystems and are categorised into four groups: provisioning, regulating, cultural, and supporting services (MEA, 2005). All four groups of services contribute to human well-being attributes such as security, basic material for good life, health, social relations, and freedom, choice and action.*
[4] *Increasing export earnings has been identified as a lead priority in the 2014 National-led Government's Business Growth Agenda (BGA).*
[5] *The CNI is a geographical region mainly used to categorise wood supply regions in the National Exotic Forest Description (NEFD) report published by the Ministry for Primary Industries (MPI). It comprises the Waikato and Bay of Plenty territorial authorities as well as part of the Manawatu-Wanganui territorial authority (Ruapehu District only).*

Zealand according to official economic indicators. The regions within the CNI are the highest gross domestic product (GDP) contributor to the primary and primary manufacturing industries, accounting for approximately 23% and 18% of the national total by industry in 2012, respectively (Statistics New Zealand, 2015a). The Port of Tauranga is the most important port in the CNI. Dairy and forestry exports from this port account for approximately 42% and 39% of the national exported total values, respectively (Figure 2a) (Statistics New Zealand, 2015b).[6]

In terms of area stocked and planted, the dairy and forestry industries account for 34% each of the total national effective area, respectively, as depicted in Figure 2b (Dairy NZ, 2015b; MPI, 2015b). Approximately 32% and 30% of those employed nationally by the dairy and forestry industries, respectively, live in the CNI. These numbers include downstream manufacturing links (Statistics New Zealand, 2015c). The employee counts by industry in different parts of the dairy and forestry supply chains are shown in Figure 2c for the CNI and for the rest of New Zealand.

A substantial land area in the CNI has changed from forestry to dairy during the past decade leading to changes in the nature of rural jobs and service firms (Parliamentary Commissioner for the Environment, 2012). There has also been a consequent reduction in water quality and long-term (post 2030) security of log supply for wood processors. The 2014 annual deforestation survey showed total intended deforestation by all forest owners is about 67,000 hectares in the 2014–2025 period with 67% taking place in the CNI (Manley, 2015). Most of the deforested area has been converted to pasture for dairy cows, a conversion motivated by the combination of the recent high profitability experienced by the dairy industry and potential for capital gains through increased land values (Ministry for the Environment, 2015; Manley, 2015). Between 2004 and 2008, dairy payouts increased from \$5.69/kg to \$8.64/kg of milk solids (Dairy NZ, 2015a). An associated negative impact is that 5.4% more CO_2 equivalent (CO_2e) was released in 2013 as a result of national deforestation compared to the previous year (2012) according to the latest New Zealand's Greenhouse Gas Inventory report (Ministry for the Environment, 2015).

Current economic indicators, such as dairy payouts, do not take into account the full value of externalities, both positive and negative, that different land uses entail. Local government agencies, land owners and other investors in the CNI would be better placed to make evidence-based decisions about the use of land (and its management) if externalities were accounted for. Collectively, this would improve the sustainable use of natural capital in the region and would help ensure land prices reflect the 'sustainable' productive value of this resource.

This study was commissioned by Oji Fibre Solutions (OjiFS) and the Waikato Regional Council to provide sound evidence about the effects of land use in New Zealand using the dairy and forestry industries in the CNI as a case study. The study is <u>deliberately simple</u> in its approach and excludes other sectors of the economy to keep the scenarios easier to understand and focused. One of the aims of the study is to provoke and promote constructive discussion on how complementarity opportunities can be generated at the farm and catchment levels to create beneficial scenarios for both industries. Such a discussion will help stakeholders comply with current national environmental policies such as the NPS-FM; inform pathways for achieving regional economic growth within environmental limits; and indicate how the integration of land-uses at different scales (enterprise, catchment) can be achieved more effectively than in the past.

This study was initially motivated by the interest created by the "back of the envelope" calculations, developed by Parker (Appendix 1), from private industry and government. Such simple and comprehensive calculations were estimated with the objective of expanding the "narrow enterprise-only" perspective of land-use change to a wider thinking and conversation about its financial, environmental and social implications. This study has reinforced such calculations by supporting them through a comprehensive literature review on the environmental externalities and ecosystem services

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[6] The data used here was the HS2 code 04, which includes dairy, birds' eggs, natural honey and other edible products of animal origin. Animal meat and animal derived products are considered in other HS2 categories so sheep and beef products are not included in this Figure. The exports for the forestry industry include logs, sawn wood products, and pulp and paper products.

generated by both industries, policies addressing them, and the market and non-market values assigned to them; a regional analysis of the relative profitability and value-added created by both industries; and upstream and downstream complementarity examples. The upstream example (i.e. farm level) has been reinforced by a detailed economic analysis of the profitability of both land-use alternatives with environmental payments and under volatile product prices.

Review of environmental externalities/ecosystem services

Considerable literature exists on various environmental impacts of different land uses in New Zealand and in other countries. This review focuses on the environmental externalities/ecosystem services generated by the dairy and forestry industries in the CNI. Relevant literature on the relative economic and environmental impacts of dairy and forestry has been identified using the procedure outlined in Appendix 2. While national and local environmental policies will also be addressed, this will be limited to the creation of prices for different externalities/ecosystem services.

Provisioning ecosystem services have traditionally been considered more important than the other types of ecosystem services because of their market value (e.g. $8 per kg of milk solids).[7] For example, Yao and Velarde (2014) showed that dairy farming provided about four times as much profit per hectare as forestry in the 2012-2013 period in the Ōhiwa Catchment of the Bay of Plenty. However, as noted earlier, a market profit does not account for the positive and negative externalities associated with the production process such as provision of support for human infrastructures and nutrient leaching. Considerable work has been undertaken over the last few years to put an economic value on regulating services, such as carbon sequestration. The establishment of an emissions' trading scheme for carbon in 2008 was the first example of a nationwide economic valuation of an ecosystem service in New Zealand. More recently, nutrients have been traded in parts of New Zealand as a form of regulation e.g. $400 per kg of nitrogen in Taupo (Duhon et al., 2011). The use of adjusted indicative values of ecosystem services can enable straightforward comparison of different factors and land-use options so this approach has been adopted here.

Nutrient leaching

A major ecosystem disservice, or negative externality, from New Zealand dairy farms is the production, or addition of excess nutrients (i.e. nitrogen and phosphorus), chemicals, sediments and pathogens that find their way into waterways (Parliamentary Commissioner for the Environment, 2012). Median nutrient concentrations in rivers influenced by pastureland cover are significantly higher than those in catchments with indigenous land cover – 3.5 times higher for phosphorus and 10 times higher for nitrogen (Ministry for the Environment, 2013a).

With dairy farming activities increasing in the CNI, the volume of animal waste, fertiliser and pesticide applications are also likely to increase, and which without commensurate improvements in farming practice and infrastructure is likely to further reduce the quality of freshwater resources and the marine environment (Parliamentary Commissioner for the Environment, 2013). The reduction in water quality can have an impact on human health, environment, cultural values and the well-being of people participating in water-related activities. Contaminants from dairy farming can leach through the soil and get into the groundwater. In the Waikato region, about 31% of groundwater samples collected from dairy farms had nitrate levels above the drinking standard limit (Environment Waikato 2008). Low water quality restricts the ability of water ways to provide good habitats for native species (e.g. fish, frog) as well as restrict water related activities such as swimming, rowing, food gathering, fishing and wildlife viewing (Ministry for the Environment, 2003; Environment Waikato, 2008; Marsh and Mkwara, 2013). Conservation of native plants and animals in water ways and access to recreation are highly valued by people and they would be willing to pay for proposed programmes that would conserve and

[7] The ecosystem services approach covers anthropocentric (i.e. human centred) values that are the benefits derived by humans from ecosystems. This approach helps to identify and conserve ecosystems that provide the most benefits to society. However, the approach does not discount the possibility of intrinsic significance of ecosystems - independent of contribution to human wellbeing.

sustain the provision of those services (Marsh et al., 2009; Marsh and Mkwara, 2013; Yao and Kaval, 2010; Phillips, 2014). For indigenous Maori groups associated with the Waikato River, reduction in water quality has a negative impact on their cultural values such as tribal obligations of manaakitanga and kaitiakitanga (e.g. guardianship of the water resource for environmental conservation that would benefit the current and future generations, preventing the depletion of kai species) (Henry, 2014).

An independent scoping study of the Waikato River (NIWA, 2010) has identified key nutrient management actions for reducing the impact of dairy farming on waterways. Actions identified include fencing streams for stock exclusion, improved effluent management and planting of trees on riparian areas to intercept the contaminants. To evaluate the identified management actions, an economic model (with a 30-year time horizon), combined with an Input-Output model, was employed.[8] The analysis includes costs and benefits that have market values (e.g. savings in fertiliser costs, income from fencing, wages from employment) but does not include non-market values (e.g. biodiversity enhancement values, recreational visits). Results of the analysis suggest that the benefits from those management actions for dairy farming outweigh the costs of implementing each of them as indicated by the positive net present values.

Efforts to reduce the environmental impacts of dairy farms through improved farming practices can also provide high environmental and social benefits to New Zealand; benefits that have non-market values. Yao and Kaval (2010) conducted a contingent valuation study based on a sample of more than 700 households across New Zealand. They found that a typical respondent would be willing to pay $41 per year for a multi-year council-led programme that would increase native tree plantings on private land to provide habitats or corridors for native species. The non-market values of improved farming practices leading to a reduction in water pollution, reduced GHG emissions, better human health, improved ecological level and better scenic views have also been estimated in New Zealand (Tait et al., 2012; Takatsuka et al., 2009) and will be listed later in this report.

Table 1. Ranges of nutrient loss rates

Nutrient		**Land use**	
	Units	**Dairy**	**Forestry**
Nitrogen[a,b]	kg/ha/yr	15 – 115	3 – 28
Phosphorus[a]	kg/ha/yr	0.30 – 1.70	0.01 – 0.10

[a] Source: Menneer et al. (2004)
[b] Source: Rutherford et al. (2009) and Waikato Regional Council (2014a)

The amounts and sources of nitrogen and phosphorus loss from different New Zealand agricultural land uses were reviewed by Menneer et al. (2004). Although they found that the lowest nitrate leaching losses were from undisturbed exotic forest systems (average about 3 kg N/ha/year), these can increase up to 28 kg/ha/year at harvest when radiata pine forests are grown on volcanic soils with high nitrogen status (Menneer et al., 2004). In typical dairy farm systems, nitrate-leaching losses averaged approximately 65 kg/ha/year and ranged between 15 kg and 115 kg per ha per year (Table 1). The range of nitrogen leaching rates reported by Menneer et al. (2004) covers the average leaching rates in a Waikato study (30 kg and 45 kg over an 11-year period between 1998 and 2008) and a Lake Rotorua study (56 kg over a 7-year period between 2003 and 2009) (Rutherford et al., 2009; Waikato Regional Council, 2014a). The phosphorus leaching rates reported by Menneer et al. (2004) are considerably lower than those for nitrogen (Table 1).

The National Policy Statement for Freshwater Management (NPS-FM)[9] is designed to improve freshwater water quality and provides an opportunity to internalise (recognise) the environmental costs resulting from nutrient discharges. Among the several policies that could be used to reduce

[8] *An advantage of using the Input-Output model is that it enables an analyst to account for the complex interactions and interdependencies between different economic participants (NIWA, 2010).*
[9] *The NPS-FM is a working framework for councils to set objectives, policies and rules about fresh water quality and quantity in their regional plans. While council information on water quantity and quality should assess the current state of water and support the negotiation of objectives, the community will assess the means and timeframes to meet the objectives (Ministry for the Environment, 2014).*

nutrient discharges within the NPS-FM, the two widely known categories worldwide are command and control (CAC) and economic incentives (EI) (Harrington and Morgenstern, 2004).[10] One CAC approach that has been used to attain desired water quality targets is the establishment of nutrient caps. In some cases this has been combined with the market-based approach of trading either for nutrients or water-quality (Greenhalgh and Selman, 2012). This combined CAC/EI approach, known as 'cap-and-trade', has been promoted as a way to achieve increasingly more stringent water-quality goals in a less expensive manner (Shortle, 2013). With this approach, the environmental target (the nutrient cap) provides certainty (Barns and Young, 2013) while market trading should provide efficiency in the allocation exchange (Greenghalgh and Selman, 2012).

The two well-known instances in New Zealand of the application of combined CAC/EI approaches are Lake Taupo and Lake Rotorua.[11] Both lakes are critical to this review since they are the only instances in New Zealand to date where a price has been estimated for nitrogen. The governance structures managing the nutrient schemes in Taupo and Rotorua have and will use public funds (i.e. taxpayers' money) as incentives to comply with the set caps and reduction targets, respectively. The allocation of such funds to different land uses has required the establishment and benchmarking of Nitrogen Discharge Allowances (NDA) by land-use type in both regions.[12] The Lake Taupo Protection Trust was set up to buy and permanently retire NDAs at a nitrogen price range of $350-$400/kg (Morgan, 2012), reaching a high of $650/kg/yr (Mac Gibbon, 2011).[13] In the case of the Rotorua catchment, where a nutrient reduction scheme is under consultation, the Council intends to permanently remove 100 tonnes of nitrogen by 2022 with an incentive fund of $40 million, equivalent to a nitrogen price of $400/kg (Rotorua Lakes Council, 2015).[14]

Another approach to setting the price of a nutrient or pollutant is through contingent valuation. Takatsuka et al. (2009) used a choice-experiment approach to estimate the willingness to pay for two levels of nitrogen-leaching reduction (20% and 50%) in New Zealand through new policies that would improve farming practices. They estimated willingness-to-pay values ranging between $53 and $88/household/year (in 2009 dollar terms). This study was conducted in 2008 when nutrient leaching from farms was still an emerging issue and reduction in nutrient levels was not valued as highly as GHG reduction. At that time, prices for carbon credits were usually above $20/unit.

Dairy farms often use fertiliser containing phosphorous to improve pasture growth and excess nutrients wash off the land and into waterways (DairyNZ, 2010). Phosphorus is similar to nitrogen in that it promotes growth of algae in waterways causing water pollution. The cost of constructing wetlands to remove nitrogen and phosphorus in the Rotorua catchment has been estimated to be $79/kg and $2,548/kg, respectively (Hamill et al., 2010). There is currently no market price for reducing phosphorus leaching but it can potentially have a very high non-market value given the cost of water pollution it can generate (NIWA, 2010).

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[10] *The CAC approach consists of the government presenting an environmental standard (i.e. command) that certain sectors in the economy must comply with; otherwise, the government imposes negative sanctions for non-compliance (i.e. control). The EI approach involves taxes or subsidies used as incentives for compliance. Harrington and Morgenstern (2004) describe the efficiency and effectiveness implications of both alternatives.*

[11] *A cap-and-trade approach was adopted in Lake Taupo under the Regional Plan Variation (RPV5). An integrated framework (cap and reduction incentives) has been established in Rotorua under Rule 11. However, the inclusion of trading is still under discussion.*

[12] *Several NDA allocation approaches were discussed in both regions - grandparenting, averaging, auctioning and mixed approaches being the most common ones. Grandparenting was the preferred approach in Lake Taupo and involves allocating NDAs based on historical nutrient discharges. Grandparenting enable the buy-in of farmers and minimised social disruption (Barns and Young 2013). However, grandparenting restricts future development of forest land and reduces its value as a consequence. Hence, averaging and delayed-averaging were suggested by forest companies and involves estimating a catchment-wide average nitrogen discharge limit (Duhon et al., 2011). Under the latter approaches, landowners discharging nitrogen above the average would compensate low-nitrogen emitters under a cap-and-trade mechanism.*

[13] *The Lake Taupo Trust had a fund of $81.5 million available to buy back the NDAs. While initially the Trust started buying pastoral farms, converting them to forestry and then selling them without the NDAs; the Trust later moved to a pragmatic approach and set the price of the NDA by dividing the pool of funds available by the required NDA reduction (Barnes and Young, 2013).*

[14] *In Lake Rotorua, a nutrient reduction mechanism is under consultation and study. The Rotorua Lakes Incentive Board will implement an integrated programme that combines NDAs, incentives and gorse conversion.*

Carbon emission and sequestration

Estimates of GHG emissions from dairy farms mainly in the form of nitrous oxide from fertilisers and methane from livestock manure and gases range between 8 and 14 tonnes of CO_2e/ha/year, including low and high-input systems in the Waikato and Bay of Plenty regions (Smeaton et al., 2011; Adler et al., 2013) (Table 2). These emissions could be offset by increased afforestation. For example, *Pinus radiata* forests in the Waikato and Bay of Plenty regions have been estimated to have an average annual sequestration rate of 45 tonnes of CO_2e/ha/year, ranging between 35 and 55 tonnes. These sequestration rates were obtained from the Forest Investment Finder (FIF), a spatial economic framework described in Harrison et al. (2012), which in turn uses the C-change model to generate the annual sequestration rates of forestry (Beets et al., 2011; Beets et al., 2012).

Table 2. Ranges of Carbon Emission/Sequestration Rates in the CNI

Range	Units	Dairy emissions**	Forest sequestration*
Minimum	tonnes CO_2e/ha/yr	8	30
Maximum	tonnes CO_2e/ha/yr	14	55

* Generated using FIF (Harrison et al., 2012) and C-change (Beets et al., 2012).
** Obtained from Adler et al. (2013) and Smeaton et al. (2011).

Implementation of a national environmental Emissions Trading Scheme (ETS)[15] is designed to reduce greenhouse gas (GHG) emissions (Ministry for the Environment, 2007) and has created opportunities to internalise the environmental costs resulting from GHG emissions. Under the ETS, a price is assigned to the reduction of a tonne of CO_2e, also called New Zealand Unit (NZU). Under a true cap-and-trade system, sectors acting as net GHG emission sinks (such as forestry) would generate NZUs and these could be sold to the dairy industry to offset its nitrous oxide and methane emissions. The dairy industry could also obtain NZUs from GHG-offsetting practices in dairy farms. However, the New Zealand government exempted the agriculture sector from being part of the ETS in 2012 through the Climate Change Response (Emissions Trading and Other Matters) amendment.[16] Hence, according to Bertram and Terry (2010), the ETS is not yet operating as a true cap-and-trade scheme as understood by economists since it does not cap emissions.

The ETS provided incentives to the forestry sector for acting as a net sink and generating domestic NZUs.[17] These were initially valued at $25/NZU when the ETS started in 2008. This level of pricing was sufficient to provide landowners with a justification to retain forests. Consequently, deforestation rates declined after 2008 compared with the high level reported in the four previous years when land owners took the opportunity to change land use without paying a 'carbon penalty' prior to the introduction of the ETS (Ministry for the Environment, 2015). Some afforestation even occurred in certain regions. However, the price of an NZU subsequently fell and reached a record low of $2/NZU in 2013 (Luth Ritcher and Chambers, 2014). This decline was caused by users purchasing and surrendering international Kyoto carbon units (as permitted by the ETS) whose prices fell drastically during this period.[18]

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[15] The ETS is a domestic implementation of the United Nations Framework Convention on Climate Change (UNFCCC) to meet New Zealand's international obligations around climate change. It assigns a price to a recorded New Zealand Unit of GHG sequestered, representing a tonne of CO_2e, to provide an incentive to reduce emissions while encouraging GHG mitigating investment such as tree planting.

[16] https://www.climatechange.govt.nz/emissions-trading-scheme/ets-amendments.

[17] The eligibility criteria published in the Climate Change Information New Zealand website (2015) states that "the forest must be a minimum area of 1 hectare, a minimum average width of 30 metres, a forest species capable of growing to five metres plus, and established after 31 December 1989."

[18] The international Kyoto units that suffered a severe fall in prices were the Certified Emission Reduction (CER) and Emission Reduction Units (ERU) issued by the Clean Development Mechanism and Joint Implementation mechanism, respectively (The Economist, 2012). The drop in international carbon prices was due to a combination of: an oversupply of international carbon units; a low demand from the European Union (due to the economic crisis); and that the largest emitters either did not approve the Kyoto protocol (USA) or were not obliged by it to reduce emissions (China and India) (The Economist, 2012).

The current carbon price is $7/NZU, which generates an average annual payment of $315/ha from a radiata pine forest (OMF, 2015). This level of pricing does not provide sufficient incentive for landowners to either plant new forests or, in many instances, replant harvested forests. The carbon price in New Zealand was intended to be a signal of the impacts from GHG emissions to the economy but, in reality, it has been highly distorted. Reasons include: (1) the exclusion of some key emitting sectors, especially farming; (2) allowing the use of international units in the domestic market; and (3) the generous allocations of "free" NZUs to emission-intensive sectors (i.e. grandparenting) (Hood, 2013). Such price distortion has affected the emission/sequestration balance in a number of areas including the CNI, resulting in high rates of deforestation to provide land for conversion, in particular, to dairy farms.

Another consequence of such carbon price distortion is that the total national liability to comply with the 2020 target will be financed largely by taxpayers' dollars (Hood, 2013). Although the New Zealand Government has decided to take its next emissions reduction commitment (2013-2020) under the UNFCCC rather than under the Kyoto Protocol itself[19], it has stated that it will still comply with a non-binding 2020 target (Ministry for the Environment, 2013b). Such compliance will be achieved "through a combination of domestic emissions reductions, removal of carbon dioxide by forests, participation in international carbon markets and recognising surplus achieved during the first commitment period of the Kyoto Protocol" (Ministry for the Environment, 2013b). Hence, the funds to cover the liabilities above the committed emissions, either through the acquisition of international units or other alternatives, would mainly come from taxpayers (Hood, 2013).

More stable and predictable carbon prices may occur if New Zealand were to cut its links with international carbon markets and also encouraged a strong domestic supply of credits. As experienced previously, a higher NZU price would result in higher reforestation and afforestation rates. These increases in forested area would benefit regional economies (labour, capital and tax generation) and help New Zealand meet its international climate change targets. The most recent international poll on domestic NZU price indicates that 64% of respondents expected a 2015 price of NZ$ 3-9 for 2015 (Thomson Reuters, 2015).[20] A carbon price forecast for New Zealand however is not publicly available.[21] An important change has been made to the NZU market this year. Since 1 June 2015, Kyoto Protocol units have no longer been eligible for the ETS and cannot be surrendered or transferred to Crown accounts.[22]

Reduction of GHGs and sequestration alternatives also provide non-market benefits to society. These non-market values can be estimated using survey-based economic valuation techniques (e.g. contingent valuation or a choice experiment). The resulting estimates provide information on the willingness of people to pay for a proposed programme that would guarantee a reduction in GHG emissions. These non-market values can be over and above the traded value of carbon. For example, Takatsuka et al. (2009) used a choice experiment to estimate willingness-to-pay values for 20% or 50% reductions in GHG through improved pastoral farming practices. The estimates ranged from $60 to $97/household/year (2009 dollars), respectively. Baskaran et al. (2009) also applied a similar choice experiment to analyse survey data from a sample of 155 respondents in the Canterbury region. They found that the weighted average willingness to pay for a 10% or a 30% reduction in GHG emissions (i.e. methane) on dairy farms were $8 and $15/household/year, respectively. Such evidence indicates that the current market price of carbon does not fully internalise the cost incurred by society from GHG emissions.

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[19] *http://www.mfe.govt.nz/climate-change/international-forums-and-agreements/united-nations-framework-convention-climate*

[20] *The Point Carbon Market Survey is the annual market sentiment poll conducted by Thomson Reuters Commodities Research and Forecasts. The 2015 poll had 1,203 respondents, 58 of them followed the New Zealand market. These 58 respondents are the ones referred to here.*

[21] *The carbon price forecast in the Treasury briefing (Treasury, 2014) has been withheld throughout the document "to maintain the current constitutional conventions protecting the confidentiality of advice tendered by ministers and officials" and "to enable the Crown to negotiate without disadvantage or prejudice".*

[22] *http://www.eur.govt.nz/*

Water yield

Afforestation has both positive and negative externalities regarding water yields. Afforestation can provide positive externalities, or ecosystem services, in the form of flood mitigation and reduced sedimentation from decreased erosion. The reductions in flooding events due to afforestation of pasturelands range between 50% and 90% in small catchments (Dons 1987; Rowe et al. 2003) and can reach up to 230% in large catchments (Mulholland 2006). The potential non-market benefits obtained from the flood mitigation service offered by forestry have been assessed in a couple of different studies. Bicknell et al. (2004) concluded that flood events between 1995 and 2004 cost New Zealand insurers $247 million ($41 million a year). Bayfield et al. (1998) used cost estimates from the 1988 Cyclone Bola disaster in the East Coast to conclude that the flooding benefits from afforestation were between $1 and $18 million.

The negative externality generated by forestry of reducing water flow rates is not a concern in the CNI due to the relatively high rainfall and relatively small area of irrigated farmland.[23] Water yields were 30–37% lower for indigenous or planted forests compared with pasture in the Volcanic Plateau of the CNI (Dons 1987; Rowe et al. 2003). However, the irrigated dairy area in the CNI accounted for only 6% of the national total in 2012 (NZ Institute of Economic Research and AgFirst, 2014). Furthermore, Zonderland-Thomassen and Ledgard (2012) assessed the water footprint of a representative group of dairy farms in the Waikato (130 farms) and Canterbury (37 farms) regions. The authors separated absolute water demands into two categories: rainfall (green), and surface and groundwater (blue water). They concluded that contrary to the Canterbury region, the high annual rainfall in the Waikato region (1,260 mm) covered all the water needs in the representative group. The reduction of surface and groundwater is more of a concern in the Canterbury region since an average dairy farm uses approximately 15 litres of blue water for every kilogram of milk (corrected for fat and protein content) produced.

An important point to emphasise is that the flood mitigation generated as a forest ecosystem service will entail reduction in water yield. Hence, the monetary value of the reduction in water yield needs to be quantified as does the ecological values so that a true comparison can be made with the associated environmental benefits. Such a comparison is an identified gap in the literature and would have to be done on a spatial basis so as to reflect differences in rainfall and evapotranspiration in different regions in the CNI and in New Zealand. Such an exercise would help to answer uncertainties such as the value of water and the existence of a water surplus in the CNI.

Other ecosystem services and externalities

Forestry also provides a range of other valuable services, such as recreation, biodiversity conservation, understorey cropping, soil stabilisation, reduced erosion, and reduced sedimentation in waterways (Barry et al., 2012; Barry et al., 2014; Dhakal et al., 2012; Dymond et al., 2011; Yao et al., 2013). Logs and timber are tangible outputs from planted forests that have market values and these values can be reported in the national system of accounting (i.e. GDP). Other benefits are also important but are less tangible and less understood because they do not have market values.

The value of forestry to biodiversity conservation and enhancement is becoming clearer as studies are undertaken to measure these values. Many studies suggest that habitats for threatened native species can be enhanced through forest management (Carnus et al., 2006; Maunder et al., 2005; Seaton et al., 2009). Forest managers increasingly recognise the need to conserve indigenous biodiversity through adherence to sustainable management regulations such as those of product certification developed by the Forest Stewardship Council (FSC). New Zealand's planted forests provide habitats for at least 118 threatened native species (Brockerhoff et al., 2008; Pawson et al., 2010; Seaton et al., 2009). This is consistent with the findings of numerous studies overseas (e.g.

[23] *Reductions in water flow rates can adversely impact on the supply of water needed for other uses (e.g. irrigation, power generation, drinking water), as well as for recreation, biodiversity and stream dynamics (flushing and sediment transport).*

Carnus et al., 2006; Humprey et al., 2003). While a planted forest may support fewer native species than a native forest at the same site, Brockerhoff et al. (2008) suggest that planted forests may replace other human-modified ecosystems (e.g. degraded pasture) and provide alternative habitats. Yao et al., (2014) estimated that an average value of $69/household/year for 5 years was placed on increasing the abundance of threatened native species in planted forests by a sample of New Zealanders responding to a proposed biodiversity enhancement programme in New Zealand's planted forests.

Several studies have also estimated the value of recreation in planted or native forests as listed in Appendix 3. Some have applied a 'revealed preference approach' where value was estimated based on observed behaviour such as cost of travelling to and time spent in the forest. Other studies applied the 'stated preference approach' where value was elicited based on a simulated market such as contingent valuation or a choice experiment.[24] The recreational values from each study are listed as willingness-to-pay estimates in each case. Three economic valuation studies of individual planted forests showed that the value of recreation provided ranges between $34 and $67 per visit in 2012 New Zealand dollars (Appendix 3).

Forestry also provides other ecosystem services that have been empirically proven to provide significant values to society. For example, Rivas Palma (2008) used choice modelling to estimate the value of improving water quality and quantity (and also biodiversity) in planted forests in Hawke's Bay. The study found that Hawke's Bay households would be willing to pay hundreds of dollars per year for improvements in the provision of those services. The specific results from this study are listed in Appendix 3.

Estimates of other economic values are needed of forest ecosystem services. For instance, hunting activities occur in planted forests (e.g. Kaingaroa, Kinleith) and they could either be subsistence, recreational or trophy hunting. To the best of our knowledge, no valuation study has been done for hunting in planted forests. This is an identified gap that could be addressed in future studies.

Among the main externalities generated by forestry, wildings and post-harvest landslides are among the most pressing issues the industry has had to face in recent years. According MPI's New Zealand Wilding Conifer Management Strategy 2015-2030 (2014), wilding conifers "reduce the productivity of primary industries and damage the environmental, social, cultural and landscape values that New Zealand is renowned for." Since there are no robust studies assessing the economic impacts of wildings, Scion is currently performing this work for MPI. However, according to Ledgard (2001), wildings are mainly an issue in high country areas of the CNI such as Mount Tarawera and the Central Plateau (mainly in and around the Tongariro national park), excluding productive farm areas in lowlands or flatter terrain.

Landsliding risk increases when forests are harvested (every 28-30 years) and there is a high incidence of storms. According to Phillips et al. (2012), "landsliding and the mobilising of slash and debris from slopes into and through stream networks can have disastrous effects both within and beyond the forest boundary." Due to improved modelling tools for developing planting and harvesting plans, the effects of forest certification requirements (Forestry Stewardship Council) and the greater expectations from society, forest managers have considerably improved their understanding of

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[24] Although the revealed and stated preference approaches are useful, care is required in the use of both non-market valuation techniques. Among their weaknesses, revealed preference approaches "are based on stringent assumptions concerning the rationality of agents and the functioning of markets" (Welsch, 2006) and their reliance on historical data precludes them from valuing non-use and new ecosystem services (Whitehead et al., 2008). Although stated preference techniques can be designed to overcome such shortcoming, one of their major weaknesses is their hypothetical nature (Whitehead et al., 2008), "which may entail unreliable results and strategic behaviour" (Welsch, 2006). However, different approaches have been developed to fully address some of the technique's inherent biases of this technique (i.e. cheap talk, careful framing of valuation question and improved econometric modelling techniques). Regarding policy implementation, the reliance of such non-market valuation techniques on the demand-side concept of consumer surplus, often ignoring supply-side concepts such as opportunity costs, precludes their use and inclusion into national accounting systems, which are mainly based on supply-side or production indicators such as GDP (Edens and Hein, 2013; Zhang and Stenger, 2015). However, by 2025, most governments around the world will likely move beyond GDP as their main indicator of economic growth by complementing it with welfare indicators (Henninger et al., 2015).

landscape response and how to control erosion and sediment loss. Such responses are reflected through improved logging systems and harvest planning (Phillips et al., 2012; Marden and Rowan, 2015).

Economic indicators for primary industries

Considering pure market drivers, dairy has experienced an unprecedented rise in profitability compared with other land uses. A 10-year average milk payout of $6.50/kg MS would result in an approximate surplus of $1,600/ha considering an average farm in the Waikato region with a yield of 1,017 kg MS/ha (Dairy NZ, 2015a) (Figure 3). In comparison, the average surplus for forestry is $1,260/ha under a pruned regime and a constant annual yield of 678 m^3/ha (MPI, 2015b). Therefore, dairy is generating surpluses 27% and 52% higher than a steady-state forest under pruned and unpruned regimes, respectively (Figure 3).[25] Such profitability indicators were estimated using average milk and timber prices over the last 10 years. It is worth emphasising that the objective of comparing average profits is not to identify the best use of a hectare of land but to give the reader an idea of the relative profitability of well-established enterprises, as it is often believed that forestry is far less profitable than dairy. To keep the objectivity of the comparison, no adjustment was made for the fact that dairy generally occurs on higher quality land than forestry. If the objective were to identify the best use of a hectare of land then a marginal analysis comparing potential yields (adjusted for land quality) and profits from both land uses would be more appropriate than a comparison of average profits. All the data sources and methodologies to estimate the aforementioned surpluses are described in Appendix 4. However, consideration of profitability alone largely ignores environmental externalities and the volatility of milk payouts over the last 10 years.

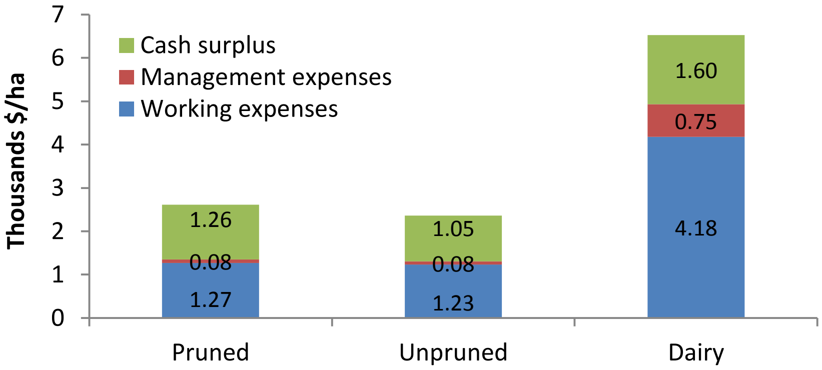

Figure 3. Breakdown of per-hectare expenses and surplus by land-use alternative using average yields (regional) and prices (for the 10-year period commencing 2005)

Small economies, such as most developing countries and a few industrialised ones, are highly dependent on international commodity markets suffer from high price volatilities (Huchet-Bourdon, 2011). Such is the case of the dairy industry in New Zealand. Its dependence on international markets has caused high price volatility affecting farmers' financial positions, their ability to plan long term and acquire credit to stay operationally efficient (Nolan, 2013; Kiernan, 2013). The high volatility experienced by the dairy industry over the last ten years is shown in Figure 4 with last year's high payout of $8.47/kg to this year's forecast of $4.60kg, a price reduction of approximately 47% being a particularly sharp adjustment.[26]

[25] To compare a representative dairy farm to a corporate forest, the latter had to be annualised considering a sustainable forest that has reached a steady state regarding annual harvest yield. For this, the yield and working costs were divided by the predominant rotation age in the CNI – 28 years. This calculation is similar to dividing a representative forest area into 28 sections, earning the revenues from each harvested section (one section a year), and incurring all of the expenses every year in different sections of the forest except for the management costs, which are incurred in every section every year.
[26] While this report was being developed, Fonterra's forecast for the 2015/2016 season dropped further to $3.85/kg.

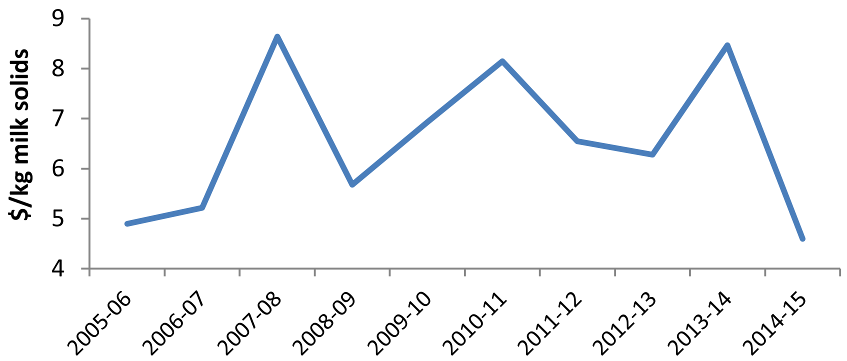

Figure 4. Real milk solids payouts for 2005–2014 including Fonterra's latest forecast in 2015.

Although the forestry industry also experiences price volatility, its impact on land or forest owners is not as pronounced as for the dairy industry. One reason for this is that the forestry industry does not depend on the export market as much as the dairy industry as will be illustrated later. Approximately 51% of the annual harvest in 2014 was destined to the export market. Export logs, being the least processed forestry exports, show higher price volatility (i.e. standard deviation) compared with domestic prices across grade categories (Figure 5). Such domestic/export market combination results in an overall lower volatility compared to dairy.

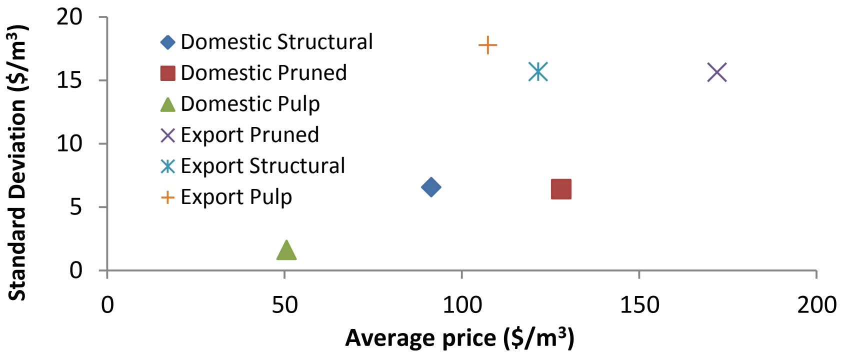

Figure 5. Average log prices and respective standard deviations (volatility) for different grades and destination markets in the last 10 years

A direct comparison of relative volatilities from the previous two figures is difficult due to the difference in product units – kg MS for the dairy industry and m^3 for the forestry industry. A widely used statistic to compare relative volatilities is the coefficient of variation due to its dimensionless nature. The coefficient of variation is a standardised measure of volatility and is estimated as the ratio of the standard deviation to the mean. The milk payout volatility experienced in the last 10 years results in the highest coefficient of variation among all the prices listed in Table 3 followed by log exports and domestic prices. The low coefficient of variation for domestic log prices contributes to a lower overall price volatility for the forestry industry.

Table 3. Log and milk average prices, ranges and coefficients of variation for the last 10 years

Markets	Products	Units	Mean	Minimum	Maximum	Coeff. Var.
Domestic	Pruned	$/m^3	136	126	155	5
	Structural	$/m^3	93	82	99	5
	Pulp	$/m^3	53	50	55	3
Export	Pruned	$/m^3	183	161	208	7
	Structural	$/m^3	119	98	142	10
	Pulp	$/m^3	97	67	128	20
Domestic	Dairy	$/kg MS	6	5	9	21

High milk payout volatility increases the likelihood of economic losses occurring for dairy farmers. Monte Carlo techniques, described in Appendix 5, were applied to estimate the probabilities of obtaining surpluses or losses for dairy farming and forestry based on the annual price volatility of the last 10 years. This showed a 13% chance of losses being incurred for an average dairy farm in the Waikato region under current yield and management regimes (Figure 6). However, there are also high probabilities (53%) of dairy farms obtaining a surplus higher than $1,500/ha than forestry (18% for pruned and 0% for unpruned). Interestingly, none of the predominant silvicultural regimes in the CNI result in a loss.

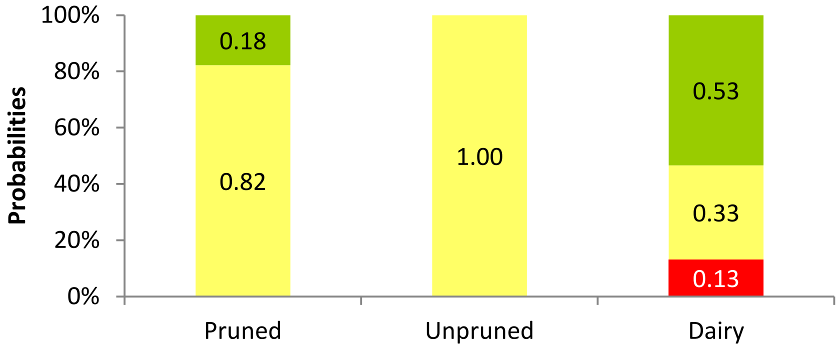

Figure 6. Probabilities of obtaining an annual per-hectare surplus lower than $0 (red), greater than $1,500 (green) and intermediate values (yellow)

It is worth mentioning that the burden imposed by price volatility on farmers' ability to meet financial obligations has not been considered in this analysis. Farm working expenses, which are the cost data used to estimate the annual cash surplus, do not consider capital expenses such as interest payments on a loan. These additional cost considerations are critical to the current situation experienced by dairy farmers because they impact farmers' ability to repay already committed capital.[27] Including annual interest payments to the estimation of annual dairy surplus would increase the probability of incurring losses and reduce the likelihood of high surpluses.

Supply chain economic and environmental indicators

Environmental policies impacting land-use patterns in the CNI will not only affect the forestry and dairy primary industries but their subsequent value chains as well. Such impacts on the value chains, from the farm/forest to the port, will be reflected on the value-added economic indices to the region such as employment, capital and export-revenue generation and are reflective of the magnitude of physical and monetary flows resulting from both land-use alternatives. However, no "what if" scenarios were assessed as this would require more sophisticated regional modelling frameworks than applied here (i.e. input-output or computable general equilibrium models).

Export and employment indices

As previously mentioned, the dairy and forestry industry form a big part of the regional economy in the CNI. Evidence of this is the employment and export revenue generated by both industries. Since there is no publicly available reference on the value-added generated by both industries in the CNI, we undertook a rough estimation of such regional value-added flows (Table 4) by creating an inventory of the processing facilities in the region and gathering production and export information from different public data sources as described in Appendix 6. The quantities of raw and processed products destined to the domestic and export markets, processing facilities and employment

[27] The inclusion of debt levels would be a relatively simple addition to the current analysis since Dairy NZ publishes annual and regional debt-to-asset ratios in their annual economic survey.

generated along the value chains are shown in Table 4. The complete list of dairy and timber processing facilities and their respective production capacities are included in Appendix 7.

Table 4. Annual production and value of primary and manufactured products in the Central North Island in 2014

Industry	**Dairy**		**Forestry**	
	Quantity	**Unit**	**Quantity**	**Unit**
Yield of product per hectare	1,033	kg MS/ha	685	m^3/ha
Effective stocked and planted areas	575,992	hectares	587,100*	hectares
Employment of primary industries	8,995	employee counts	1,753	employee counts
Primary products supply	594,892	tonnes MS/year	12,600,000	m^3/year
Domestic	594,892	tonnes MS/year	6,180,000	m^3/year
Export	0	tonnes MS/year	6,420,000	m^3/year
Value of primary product exports	0	$/year	1	billion $/year
Number of manufacturing plants and mills	13	plants	41	mills
Employment of manufacturing industries	3,790	employee counts	5,870	employee counts
Manufactured products supply	899,516	tonnes/year	2,100,406	m^3e/year***
Value of manufactured products**	5	billion $/year	2	billion $/year
Total value of primary and manufactured	5	billion $/year	3	billion $/year

* The approximate area harvested that year was 18,400 hectares (= 12.6 million m^3 / 685 m^3 ha^{-1})

** Valued at export prices

*** m^3e refers to the roundwood equivalent of 312 tonnes/m^3 used by MPI (2015c)

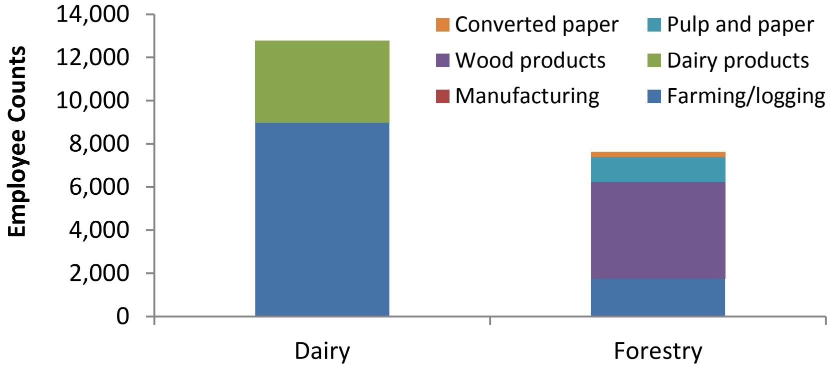

Figure 7. Regional employment by the dairy and forestry industries at different stages of the value chain in 2014 in the Central North Island

In 2014, the dairy industry produced in 2014 approximately 595,000 tonnes of milk solids at the farm level from 576,000 hectares at an average regional yield of 1,033 kg MS/ha. This supported approximately 9,000 employees in the region (Figure 7) and is valued at approximately $3.9 billion using the 10-year average dairy payout of $6.50/kg MS (including Fonterra's 2014/2015 forecast of $4.60/kg MS).[28] The total supply of milk was transported to 13 plants, the majority of which are owned by Fonterra (Appendix 7). This milk was manufactured into a wide array of dairy products including whole and skim milk powders, butter and cheese, and other products (Appendix 7), amounting to approximately 900,000 tonnes of product and provided approximately 3,790 jobs (Figure 7). Approximately 95% of the manufactured dairy products were exported to countries such as China, Japan, U.S. and Europe among others (Fonterra, 2015b). Total production of manufactured dairy products was valued at approximately $5 billion using a weighted average export price of $5,715/tonne for 2014 (Statistics NZ, 2015b) (Table 4).

[28] *While this report was being developed, Fonterra's forecast for the 2015/2016 season dropped further to $3.85/kg.*

In 2014, the forestry industry produced approximately 12.6 million m^3 of logs at the forest level from 18,400 hectares harvested at an average regional yield of 685 m^3/ha. This log production generated approximately 1,750 jobs in the region (Figure 7). In contrast to the dairy industry, 51% of the supply of raw material (i.e. logs) is destined to the export market mainly to China, Australia, South Korea and Japan. Log exports from the Port of Tauranga were valued at approximately $0.95 billion (Statistics NZ, 2015b) (Table 4).

The industry also generates export revenues from the export of cull cow manufactured meat and veal. Over the period 2008/09 to 2013/14 income from meat averaged 5% of dairy farm revenue. To account for meat income in the “back of the envelop” contrast developed by Parker (Appendix 1), typical dairy farm survival, herd replacement and culling rates were applied. Carcass weights were based on the economic weights used in the Dairy NZ genetic improvement model, Beef+Lamb New Zealand export volumes and free-on-board (FOB) earnings for the five years from 2008/09; and advice from a North Island bovine meat processor.[29] Over the 26,600 hectares approximately $15 million would be earned annually from meat exports. Most manufactured beef is exported to the United States (Beef+Lamb New Zealand, 2016).

The manufacturing stage of the forestry supply chain is more complex than the dairy industry due to the 41 mills owned by different companies. Such mills can be grouped into four major manufacturing categories: saw, pulp, paper, and remanufacturing mills (Appendix 7). Sawmilling is the most fragmented sector with most mills being privately owned and operated. In contrast, OjiFS mills process half the total log supply in the region. Wood products including sawn timber, pulp, paper and remanufactured material (Appendix 7), amount to approximately 2.1 million m^3 of roundwood equivalent (m^3e). Approximately 45% of manufactured timber products were exported to countries such as China, Australia and Japan among others. Total production of manufactured timber products was valued at approximately $2 billion using 2014 export prices (MPI, 2015c) (Table 4).

Timber manufacturing plants employed approximately 5,870 employees in total (Figure 7), which is 55% higher than total employment by the dairy plants in the CNI. This higher employment figure in the downstream stages of both industries should be a critical factor considered in the development of environmental policies affecting land-use change and the regional economy. Hence, a higher domestic supply of logs coupled with greater investment in the manufacturing stage of the forestry industry would potentially result in more employment opportunities in the CNI.

Following Parker’s “back of the envelope” contrast, a bottom-up approach was used to estimate the value of wood manufactured products when increasing the proportion of logs manufactured domestically. As described in Appendix 1, Parker used the technical conversion coefficients for from Red Stag (for lumber) and OjiFS (for pulp and paper). Using the same coefficients, updated export prices and assuming an increase in the proportion of domestically manufactured wood products (from a current proportion of 49% of total log supply to 100%); the difference in export revenues is narrowed down. From the representative 28,000 hectares, the values of total production end up being approximately $161 million for forestry compared to $179 million for dairy. This is evidence of the complementary approaches applied in this study (i.e. regional analysis) and in the “back of the envelope” contrast (i.e. bottom-up).

Environmental indicators

In this section, the environmental impacts of the processing segment of forestry and dairy value chains are examined. A brief literature review was undertaken to identify published statistics on environmental impacts as detailed in Appendix 8. For the purposes of this report, only the impacts

[29] The total revenue for culled cows was estimated by assuming a stocking rate of 2.5 cows/ha in 26,600 ha of grazable pasture, 18% cull-empty rate pa and 197 kg carcass weight (Dairy NZ, 2014; Greenlea Premier Meats, 2016). The total revenue for bobby calves was estimated by assuming a stocking rate of 2.5 cows/ha in 26,600 ha, 97% calf survival rate, 70% of total calves bobbied and 15 kg carcass weight (Dairy NZ, 2014; Greenlea Premier Meats, 2016). Five-year average FOB prices for bobby veal ($4.83/kg) and beef ($4.94/kg) were estimated from export quantities and values published in Beef+Lamb New Zealand’s Mid-Season Update 2015-16 (2016).

associated with the point source processing location (i.e. milk processing plant, sawmill, and pulp and paper mill) were included; other ‘upstream’ processes such as milking, tree harvesting, and milk and log transport were excluded.

The environmental impacts reviewed included nitrogen and phosphorus loading, greenhouse gas emissions, and water consumption. Emphasis was placed on reviewing literature based on industries within the CNI (predominantly the Waikato and Bay of Plenty regions). The particular processing sites examined were: Kinleith Mill (OjiFS), Taupo Mill and Mouldings plant (Tenon Ltd), Putaruru sawmill (Kiwi Lumber Ltd), and dairy factories across the Waikato region (Fonterra Ltd). Respective industry environmental impacts are summarised in Table 5.

Nitrogen loading from the dairy factories within the Waikato region range from 11 to 17 t/yr, whilst phosphorus loading ranges from 0.5 to 11 t/yr (NIWA, 2010; Vant, 2014).[30] The Kinleith Mill produces an average of 145 t/yr of nitrogen loading and 19 t/yr of phosphorus loading (Carter Holt Harvey, 2009; Vant, 2014). Comparing the emissions from non-point (i.e. different land uses) and point sources (i.e. plants and mills), the former contribute to a substantially higher proportion of total emissions in the Waikato River catchment (6,840 t/yr of nitrogen and 425 t/yr of phosphorus) (Vant, 2014). Neither sawmills generate any significant amounts of nitrogen and phosphorus loading.[31]

Table 5. Summary of environmental impacts associated with dairy factories, sawmills, and pulp and paper mills in the Central North Island

Externalities	**Units**	**Manufacturing facilities**		
		Dairy	**Sawmill**	**Pulp & paper**
Nitrogen loading	t/yr	11 – 17		145
Phosphorus loading	t/yr	0.5 – 11		19
GHG emissions	t CO_2e/litre	0.09		
	t CO_2e/m^3		0.02 – 0.2	
	t CO_2e/t pulp			0.3
Water use/discharge	m^3/day	3,800 – 6,300	40 – 80	87,600 – 89,953

Greenhouse gas emissions are reported in kgCO_2e, which are inclusive of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Dairy processing produces on average 94 kgCO_2e per litre of liquid milk (Fonterra, 2010). The Kinleith Mill produces 324 kgCO_2e per tonne of output product (or 200,835 tonnes CO_2e per year) (Carter Holt Harvey Pulp, Paper & Packaging, 2013). The Taupo Mill produces 21.7 kgCO_2e per m^3 of surfaced lumber, 43.2 kgCO_2e per m^3 of clear board lumber, 41.7 kgCO_2e per m^3 of clear moulding products, and 176.3 kgCO_2e per m^3 of Lifespan™ house trim product (Drysdale & Nebel, 2009). It is worth highlighting that the GHG emissions associated with the Kinleith Mill are relatively low since the energy utilised is largely (81%) from renewable sources (lignin and wood residues) (Carter Holt Harvey Pulp, Paper & Packaging, 2013); without utilisation of renewable energy sources, the GHG emissions of the Kinleith Mill would be considerably higher.

No information on water usage was obtained for dairy factories. However, the Reporoa dairy factory has reported discharging up to 3,800 m^3 wastewater per day (Waikato Regional Council, 2014c) whilst the Lichfield dairy factory has reported discharging up to 6,300 m^3 wastewater per day and, with a planned factory expansion, the wastewater discharge may be up to 13,500 m^3 per day (Waikato Regional Council, 2014d). The Kinleith Mill discharges approximately 87,600 m^3 of wastewater per day (Carter Holt Harvey, 2009) and uses 89,953 m^3 of water per day (Carter Holt Harvey Pulp, Paper

[30] The figures reported for nitrogen and phosphorus loading of dairy factories are maximum limitations as set within resource consent agreements. During the milk processing season (early August to late May of the following year), peak processing months during the summer will have higher loading rates (in some cases reaching the nutrient loading limitations) than during the beginning and end of the season.

[31] The subsequent leaching effects of nitrogen and phosphorus loading depend highly on the surrounding soils of the factory or mill. In the Waikato region, the soils are generally considered to have high nutrient retention capacity, especially for phosphorus (Waikato Regional Council, 2014b). Such favourable soils will limit the effects of nitrogen and phosphorus leaching; other regions with soils of less nutrient capacity may experience higher rates of leaching.

& Packaging, 2013). The Putaruru sawmill has reported using 40-80 m^3 of water per day (Waikato Regional Council, 2014e).

Synergies and complementarities

This section describes a complementarity example at the land-use level that involves monetary recognition of two forest ecosystem services (carbon and nitrogen) and how they can be integrated into dairy farms to help farmers cope with environmental limitations and price uncertainty.

Environmental payments

The ETS and NPS-FM have provided mechanisms for generating monetary values for carbon and nitrogen emissions and present an initial opportunity to acknowledge some of the positive and negative externalities provided by the dairy and forestry industries. The nitrogen and carbon values listed in the second section of this document set the stage for a more comprehensive quantitative assessment of the integration of forestry into the landscape considering at least the market values of a subset of the entire array of ecosystem services, namely carbon and nitrogen.

The example used in this section involves the economic implications of the required nitrogen reductions in Lake Rotorua, through Rule 11, on dairy farm profitability. It is of the utmost importance to emphasise that the NDA allocation used in the example serves to convey the message that ecosystem services add value to forestry as a land use. Alternative mechanisms should also be considered in policy recommendations.

As previously stated, the Rotorua Lakes Incentive Board will implement an integrated programme that combines NDAs, incentives and gorse conversion. Under the NDA scheme, dairy farmers are required to reduce nitrogen discharges from an average catchment-benchmark of 54 kg/ha to an established NDA of 35 kg/ha by 2032.[32] Furthermore, the Board includes public funding of $40 million to incentivise a further reduction of 100 tonnes of nitrogen through the retirement of NDAs in perpetuity. Hence, by afforesting a hectare previously devoted to dairy, a landowner would receive a potential one-time lump sum payment of $12,800 at a price of $400 kg of nitrogen from a reduction of 32 kg/ha.[33] Although a nitrogen-trading scheme has not been implemented, we considered scenarios where the farmer pays for the right to operate above the assigned NDA at different nitrogen prices.

Based on Monge et al. (2016), a cash-flow approach with an 8% discount rate was used to compare the net present values generated by dairy and forestry in a rotation of 28 years with nitrogen and carbon payments. To avoid relying on specific and deterministic milk and timber price forecasts, Monte Carlo techniques were used to simulate uncertain future milk and timber prices as explained in Appendix 5. Following the frequentist or classical probability school, price uncertainty is based on the historical uncertainty experienced in the last ten years.

Forestry, like any other investment, has proven to be quite risky and uncertain due its long time horizons (price uncertainty and lack of revenues in 28-30 years), lack of knowledge of forestry practices and relatively high initial investment (afforestation costs) (Parks, 1995; Goldstein et al., 2006). To overcome such financial barriers, payments for the ecosystem services provided by forestry would offer farmers an improved early cash flow. Hence, we have assumed that the upfront lump-sum nitrogen payment for the reduction of NDAs would be annualised over the forest rotation at an interest rate of 8%, similar to the discount rate. All the methodology, price and costs data sources used to estimate the cash flows are based on Monge et al. (2016).

[32] Such NDAs were established using Overseer version 5, which is a nutrient management tool supporting regional councils and farmers to benchmark current nutrient discharge rates and to comply with the allocated NDAs.
[33] The nitrogen price of $400/kg was estimated by dividing the $40 million over 100 tonnes (Barns, 2014). The reduction was estimated by subtracting forestry's NDA of 3 kg/ha/yr from dairy's NDA of 35 kg/ha/yr.

Dairy farmers will face the dilemma of complying with environmental regulations by de-intensifying current operations, by including forestry, or by paying for the right to operate above the assigned NDA. With the latter the farmer can either keep or intensify current operations. The yield and profit levels of the different dairy intensity scenarios were estimated following the procedure described in Monge et al. (2016) using the profit-leaching curves estimated by Yeo et al. (2012) and the yield-leaching curves estimated by Smeaton et al. (2011).

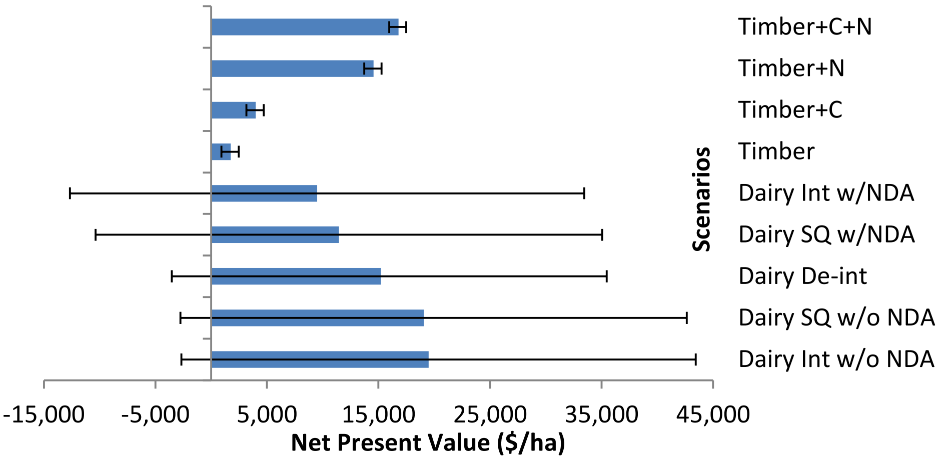

Figure 8. Means and ranges of per-hectare net present values for forestry (with and without environmental payments), and dairy (with and without NDAs) at different intensity levels (status quo (SQ), de-intensified (De-int), and Intensified (Int)) at current nitrogen (N = $400/kg) and carbon prices (C = $6.8/NZU)

The NPVs and ranges for both dairy at different intensity levels (with and without NDA compliance) and forestry (with and without environmental payments) are shown in Figure 8. The procedure to estimate the NPVs and ranges is detailed in Monge et al. (2016). As expected, intensive dairy results in the highest NPV followed by dairy under current intensity levels. The difference is minimal due to the decreasing marginal returns of nitrogen usage. Dairy also has the highest uncertainty due to the high milk payout volatility. The NPV for forestry is the lowest without the recognition of ecosystem services. Even when carbon is recognised, forestry's NPV is still low compared to the rest at current carbon prices of $6.8/NZU. However, forestry with both carbon and nitrogen payments result in a higher NPV compared with de-intensified dairy. Even without carbon prices, forestry and nitrogen follow de-intensified dairy closely.[34] If the farmer decided to pay for the right to operate above the assigned NDA, dairy under current and intensive operations becomes less profitable than the de-intensification alternative at the assumed nitrogen price of $400/kg.

Figure 9 shows graphically that the combination of milk payout volatility and limiting environmental policies affects farmers risk profiles. All dairy alternatives result in potential losses. Such loss potential increases when environmental limits are placed through NDAs. By intensifying operations, a dairy farmer has higher probabilities of incurring a loss (35%), compared to the status quo (32%), due to decreasing marginal returns from nitrogen use and the higher payments for nitrogen to operate over the NDA. The lower and more predictable returns from forestry result in no probabilities of a loss under all forestry alternatives. The only possibility of forestry resulting in a return above $17,000/ha is when nitrogen and carbon payments are considered. This is indicative that an optimal combination of both land use alternatives at the farm, catchment and regional levels would result in a more resilient regional economy. Although a diversified land-use arrangement has not been considered in this report, portfolio theory states that the optimal combination should be the one that reduces volatility and potentially increases relative profitability. Such an optimal combination could also result in a better environmental outcome, as would be the case with the inclusion of forestry since it results in lower nitrogen-leaching and carbon-emission rates.

[34] *It is worth considering such a scenario due to the current uncertainty in New Zealand around carbon policy.*

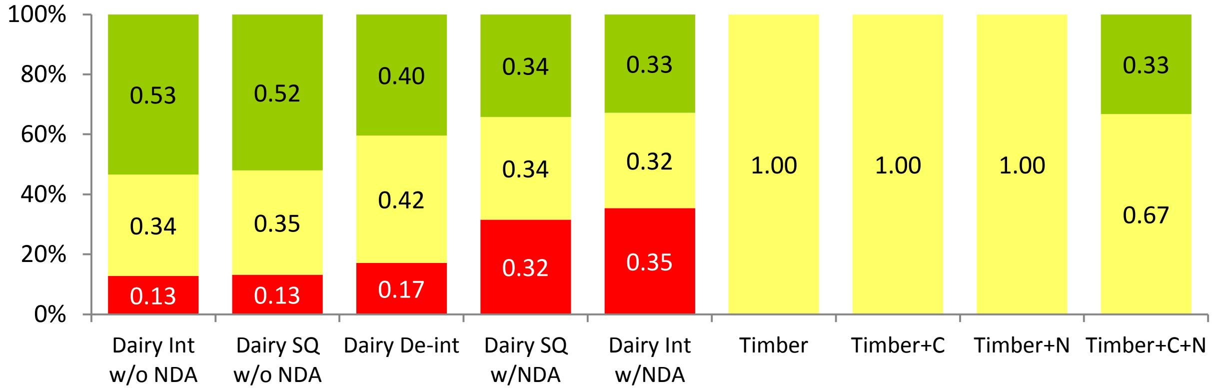

Figure 9. Probabilities of obtaining a per-hectare net present value lower than $0 (red), greater than $17,000 (green) and in between (yellow) for dairy (with and without NDAs) and forestry (with and without N and C payments at current prices)

By performing a sensitivity analysis of the carbon and nitrogen prices, Table 6 shows that at low nitrogen prices dairy is the best land-use alternative. However, at nitrogen prices above $200/kg, forestry becomes an appealing land-use when also combined with high carbon prices. At currently assumed nitrogen ($400/kg) and carbon ($6.8/NZU) prices, forestry is the best alternative. When considering price volatility, Figure 10 shows that de-intensification is the best alternative within the dairy land-use alternative at nitrogen prices above $100/kg. Further intensification of current operations becomes a riskier alternative (higher loss probabilities) at nitrogen prices above $50/kg.

Table 6. Sensitivity analysis of per-hectare net present values with different nitrogen and carbon prices for forestry and dairy under different intensity levels (green is the preferred and red is the least preferred land use)

Nitrogen	Forestry				Dairy w/NDA		
Price	Carbon Price ($/NZU)				Intensive	Status Quo	De-intense
($/kg)	0	6.8	15	25			
0	1,749	3,985	6,681	9,969	19,500	19,065	15,216
25	2,549	4,785	7,481	10,769	18,875	18,590	15,216
50	3,349	5,585	8,281	11,569	18,250	18,115	15,216
100	4,949	7,185	9,881	13,169	17,000	17,165	15,216
200	8,149	10,385	13,081	16,369	14,500	15,265	15,216
300	11,349	13,585	16,281	19,569	12,000	13,365	15,216
400	14,549	16,785	19,481	22,769	9,500	11,465	15,216

As stated by Duhon et al. (2011), the afforestation option appeals mainly to landowners who have a long-term perspective towards land ownership since short-term land values are not a concern.[35] For example, Maori landowners follow a collective-ownership structure and are motivated by environmental and cultural reasons and a long-term perspective towards land ownership. Out of a total 1.2 million hectares available as Maori freehold land, approximately 37% (441,154 ha) is within the major regions composing the CNI (Bay of Plenty and Waikato) and 30% (347,853 ha) is in Land Use Categories (LUCs) higher or equal to 6 (PwC, 2014).[36] Hence, Maori freehold land currently in dairy or drystock presents a great potential to comply with catchment-level restrictions.

[36] LUCs 6 to 8 are unsuitable for arable land and have moderate (LUC 6), severe (LUC 7) and extreme (LUC 8) limitations for perennial vegetation such as pasture and forest. In more detail, the distribution of Maori freehold land as follows: 13% in LUC 6, 11% in LUC 7 and 6% in LUC 8.

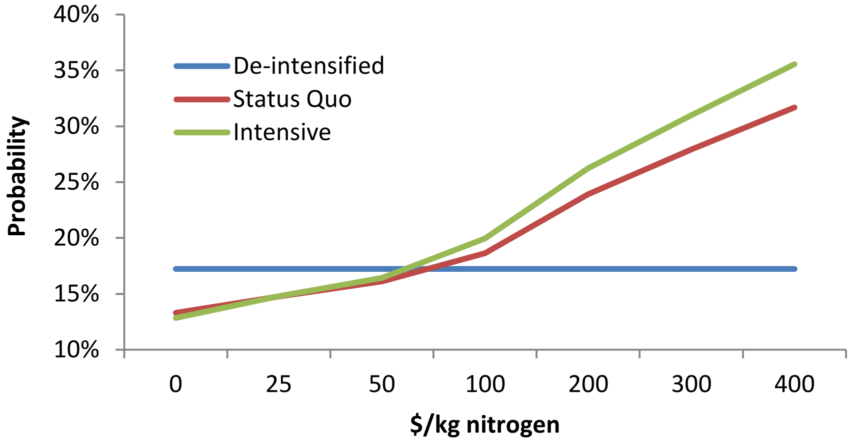

Figure 10. Probabilities of incurring in a loss at different nitrogen prices and dairy management intensity levels under NDAs

Summary and conclusions

This study was commissioned by OjiFS and the Waikato Regional Council to provide sound evidence about the effects of land use in New Zealand using the dairy and forestry industries in the CNI as a case study. The study was deliberately restricted to dairy and forestry because these were the two main production systems affected by land-use change and to ensure the scenarios are easily understood and focused. The aim of the study is to provoke constructive discussion on how complementarity opportunities can be generated at the farm and catchment levels and along the supply chain in order to generate beneficial scenarios across different sectors. Such a discussion will help stakeholders comply with current national environmental policies such as the National Policy Statement for Freshwater Management (NPS-FM) and the Emissions Trading Scheme (ETS); inform pathways for achieving resilient regional economic growth within environmental limits; and, indicate how the integration of land-uses at different scales can be achieved more effectively than in the past.

Table 7. Quantity and Value Ranges of Externalities Generated by the Dairy and Forestry Industries

Externalities/Services	Units	Land uses	
		Dairy	Forestry
Quantities			
Nitrogen leaching	kg/ha/yr	15 – 115	3 – 28
Phosphorus leaching	kg/ha/yr	0.30 – 1.70	0.01 – 0.10
Carbon emissions	t CO_2e/ha/yr	8 – 14	
Carbon sequestration	t CO_2e/ha/yr		35 – 55
Values			
Carbon	$/t CO_2e	3 – 9	
Nitrogen	$/kg	350 – 650	
Flood mitigation	$/year	1 – 41 million	
Biodiversity*	$/person	69	
Recreation*	$/visit	4 – 92	
Land stabilisation* (1% incr)	$/ha/yr	1	
Water sediments*	$/ha/yr	105	
Algae in water*	$/ha/yr	111	
Level of water flow*	$/ha/yr	12	

* Non-market values

Relevant literature on the relative economic and environmental impacts of dairy and forestry was reviewed to describe the implications of various externalities/ecosystem services on both industry supply chains. National and local environmental policies were also addressed as avenues in the establishment of prices for different externalities/ecosystem services. The ETS and NPS-FM have provided mechanisms for generating monetary values for carbon and nitrogen emissions and present an initial opportunity to acknowledge the entire set of positive and negative externalities provided by the dairy and forestry industries. Taking such externalities into account would help ensure sustainable use of land and water (and other elements of natural capital) in the CNI. Table 7 shows the externalities/ecosystem services generated by each land use and their associated market and non-market values.

An economic analysis was undertaken to assess the profitability of a representative farm in the Waikato region and a representative steady-state forest in the Central North Island. Considering pure market drivers and average yields (regional average) and prices (10-year average), a hectare of dairy ($1,600/ha) is generating 50% higher returns than a hectare of steady-state forest under a structural regime ($1,050/ha). However, the present high dependence on international commodity markets exposes the dairy industry resulting in high milk payout volatility. Such high volatility could result in losses (13% probability) being incurred by farmers affecting their ability to plan long term and acquire working capital to remain operationally efficient. Although the forestry option generates lower returns, it results in no losses and a lower return volatility due to: (1) its larger domestic market and comparatively less exposure to export markets; and (2) the low price volatility experienced in the domestic market.

A broad economic and environmental assessment of their respective supply chains was also undertaken to identify complementarities at the manufacturing level. Value-added economic indicators, such as employment and exports, were estimated for both value chains. Although the dairy industry currently employs 67% more people than the forestry industry along the entire value chain, most of them are employed at the farm level. The largest percentage of employment along the forestry value chain takes place within manufacturing plants (saw mills, remanufacturing plants, etc.). The forestry sector exports both raw (i.e. logs) and manufactured products whereas the dairy industry exports only manufactured products. Hence, export revenues are greater for the dairy industry.

The potential for higher levels of afforestation presents opportunities to the forestry industry to capitalise from greater domestic wood processing to generate more employment in the region as well as grow the value of exports as shown in the NZ Wood Council's "$12 billion of exports by 2022" strategic action plan (Wood Council of NZ Inc., 2014). The estimation of such value-added indicators sets the stage for future modelling work on the impact of land-use change on value chains using more complex economic frameworks.

A complementarity example at the land-use level was used to showcase the potential economic and environmental complementarities created by the NPS-FM and ETS through forestry's lower return volatility coupled with the potential payments for ecosystem services (e.g. nitrogen and carbon). The example pertains to the economic implications of reducing nitrogen leaching into Lake Rotorua, through Rule 11, on dairy profitability. A cash flow approach was used to compare the net present values (NPV) generated by dairy and afforestation in a rotation of 28 years with nitrogen and carbon payments. When comparing individual options on a per-hectare basis, afforestation coupled with carbon and nitrogen payments resulted in a higher NPV ($16,785/ha) and lower return volatility compared with de-intensified dairy ($15,216/ha). Although a nitrogen-trading scheme has not yet been implemented, we considered scenarios where the farmer pays for the right to operate above the assigned NDA at different nitrogen prices. For nitrogen prices below $300/kg, dairy is the preferred land-use alternative unless carbon prices are high enough (e.g. $25/NZU) to make forestry more appealing. The afforestation option appeals mainly to Maori landowners due to their environmental and long-term perspective towards land ownership. Such potential is critical to the CNI since 37% of national Maori freehold land is located in the Bay of Plenty and Waikato regions. Of this area, 80% is non-arable (i.e. Land Use Categories 6 to 8).

This report provides evidence that profitable land-use within environmental limits and with lower GHG emissions could be achieved through more intentional catchment and regional scale planning and more appropriate incentives for ecosystem services than is presently practiced. To support this, a more detailed economic regional analysis is recommended to fully assess the complementarity opportunities across the full scope of land-use supply chains. Such analysis would utilise regional modelling frameworks such as input-output or computable general equilibrium models to inform regional policies for use of land and natural resources within prescribed limits that would also support economic growth. Furthermore, such a study could provide a marginal analysis that would indicate where nutrients such as nitrogen could best be allocated to generate future economic returns.

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Appendix 1: A "back of the envelope" model of the forest and dairy industries in the Central North Island

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Recently I did some "back of the envelope" calculations on the value of forestry versus dairy and their related value chain for the Central North Island (CNI). My purpose was to stimulate broader thinking and conversation about the wider financial, environmental, and social and value chain implications of land use change as too often these are viewed from a narrow enterprise-only perspective. The model is deliberately "simple" because it is the 'bigger picture' items that are of most interest, not the minutiae of the biophysical processes for nutrient leaching *per se*. Actual performance data for commercial processing units are dynamic and difficult to obtain so are 'best estimates' derived from conversations with sector experts and published reports.

The essence of the comparison assuming 28,000 hectares of land under either use is distilled in the table below. The essential assumptions, which have been discussed with an agricultural consultant practicing in the region and with executives at OjiFS and Red Stag (solid wood processing and timber markets), are outlined below. The CNI, by virtue of its free-draining soils and climate has comparative advantages in plantation forestry (such as year-round harvesting) and the configuration of processing infrastructure (such as short road haulage distances) provides greater scope for higher returns from forest biomass than in some other New Zealand regions. The CNI pumice soils, as the Parliamentary Commissioner for the Environment described, are generally prone to nitrogen leaching and to achieve economic levels of milk production generally require initial high levels of capital nutrient inputs to build-up soil fertility.

	Forest		Dairy	
Hectares	28,000		26,600	grazable
Stocking	550	trees/ha	2.5	cows/ha
Yield/unit	650	m3/ha	380	kg MS/cow
Rotation	28	years	1	seasonal
Total yield	650,000	m3/yr	25,270,000	kg MS/yr
Ave price	90	$ m3	5.55	$ payout
Total income	58,500,000	$ to forest owner	140,248,500	$ to farmer
Net	35,100,000	$ stumpage	9,142,420	$ EFS
Product	64,760	t pulp	24,268,625	kg whole milk powder
	263,900	green timber m3		
Export price	875	Pulp $US/t	7.80	$NZ kg MS
	310	timber $/m3		
Export $	**154,456,436**		**189,295,273**	
Land value	10,000	$/ha	36,100	$/ha
Employment	>300	Kinleith	242	on farm
Nitrogen	140	tonnes/yr	1,835	tonnes/yr
Phosphate	?		1,290	tonnes/yr
Carbon (GHG)	1,003	t stored/ha	6	t GHG/ha/yr emitted

The forest is mature and harvested on a uniform 28 year rotation, yielding 650m^3 of logs per hectare. Of the logs, 70% are supplied for solid wood processing where they yield 58% solid wood products, 32% wood chips and 10% residues (used to fuel co-generation). The balance (30%) is assumed to be processed at Kinleith at a 20% conversion rate. Log harvest and transport costs are \$20/m^3 (reflecting relatively flat terrain and mechanisation) and $15 per tonne (<60km cart), respectively.

Pulp has been fairly steady at $US865/tonne and timber exports are about $310/m^3$ green FOB (these include lower quality grades and prices lower than domestic sales).

The dairy farms utilise 95% of their area for grazing, are stocked at 2.5 cows per hectare and produce 380kg milk solids (MS) per cow, or a fairly typical 950kg MS/hectare on this land class with a low level of non-pasture feed inputs. The dairy farms conservatively apply 400kg of superphosphate (9.7% P) and 150kg of urea (46% N) per hectare annually. Additional potassium, magnesium and other elements (not estimated) will be required. Radiata pine forests store carbon at about 1,000 tonnes/hectare for a 28 year rotation (300 site index), and cows and nitrogen fertilisers both emit greenhouse gasses – approximately six tonnes per hectare per year. Dairy returns are based on this season's expected payout of $5.55 per kg MS (including 25-35c dividend) to the farmer and $2.25/kg MS (or $7.80 per kg MS) for dairy company export earnings. Dairy expenses are $4.00/kgMS and not achievable for some highly geared farms. Labour productivity on the new large scale dairy units is 1 FTE/275 cows.

The distinctive elements of this comparison are:

1. Changing to dairy significantly boosts land value, perhaps a two-fold non-taxable capital gain, after allowing for $15k of system conversion costs and buying dairy company shares.

2. Due to the vertically integrated cooperative ownership structure in the dairy industry, a higher share of the milk value is received by the dairy farmer compared to the share of the log value received by the forest owner.

3. The aggregate export returns favour dairy, even at current prices but this should not be surprising given dairying occurs on some of the best quality land and has for the past two decades has had better coordination across the value chain.

4. However, the environmental impacts are substantially larger for dairy with large tonnages of nitrogen and phosphate introduced to the system compared to forestry, as well as increased greenhouse gas emissions rather than carbon sequestered by forests. The impacts of these annual inputs on water quality are more difficult to quantify (they are farm dependent) but it is not unreasonable to assume on historical evidence that urine N, in particular, and some phosphate and faecal contaminants will end up in waterways.

5. The relative supply chain environmental effects of milk vs wood processing have not been quantified – both are reasonably large users of water and energy (although wood processing mills gain from co-generation fired through wood residues).

6. Assuming 275 cows per labour unit about 266 people would be employed on farms – similar to the numbers working at the Kinleith mill. Forest harvesting and silviculture also generate employment.

Undoubtedly there will be disputes about some of these assumptions. However this should not be at the expense of encouraging people to think more holistically about the wider consequences of land use change and more thoughtful considerations of the total cost and net economic benefits – both private and public – of land use change.

The 'back of the envelope' estimates suggest further consideration by both policy and industry is merited, in particular:

1. The link between the ETS (C price) and water eutrophication (water quality). The collapse in the C price associated with changes to the ETS lowered the 'carbon externality' barrier to land-use change and subsequently imposed additional environmental costs and/or restraints on land use change on most land owners (including paradoxically dairy farmers) in the region and Waikato

River catchment. Indeed, this land-use change probably has 'undone' some of the gains from the reduction of N inflows to Lake Taupo.

2. There are obvious complementarities between the ecosystem services of dairy and forestry production as well as further up the value chain (e.g. the production on improved pulp products from forest biomass can be a source of sugar (molasses) and potential feed substitute for imported palm kernel and other feeds; renewable packaging from wood fibre is widely used for dairy food packaging; and wood biomass energy with lower emissions than coal). Mechanisms to optimise these synergies should be explored.

3. Current 'tax-free' capital gains encourage wealth creation through land-use change and consequent high land prices reduce export sector competitiveness by raising the average total cost of production and making it more difficult for new entrants in farming and/or forestry.

4. The dairy and forest industries both need to move beyond the high current dependence on commodity products. This requires focussed investment for science and innovation into higher value and margin products that are less subject the volatility of commodity cycles. New capital investment into plant and equipment and, given growth is principally for exports, in international market development.

Appendix 2: Methodology for literature review on externalities/services

The literature review was performed by searching a set of keywords in peer-reviewed journal articles, reports developed by regional/district councils and reports contracted by the national government to independent consultant firms using Google Scholar and SCOPUS. The search was restricted to studies performed in the CNI for the last ten years. Studies from other regions were included in the review only when critical information could not be found for the CNI. The search was limited to policies and environmental externalities/ecosystem services affecting the dairy and forestry industries in the CNI. The discussion around public policies, such as the NPS-FM and ETS, was limited to the creation of prices for different externalities/ecosystem services.

The set of keywords used to perform the literature review was: forestry, dairy, nitrogen, phosphorus, greenhouse gases, water quality, water yield, water demands, discharge, emissions, leaching, public policy, environmental policy, environmental economics, New Zealand, Emissions Trading Scheme, National Policy for Freshwater Management, externalities, ecosystem services, regional council, district council, Central North Island, Rotorua, Taupo, lakes, Waikato, Waipa, rivers, non-market valuation, biodiversity, recreation, health, command-and-control, economic incentives.

Appendix 3: Non-market values of additional forest ecosystem services

Estimated values of ecosystem services provided by New Zealand planted forests

Forest(s) studied	Region	Forest area (ha)	Ecosystem service	Valuation method used (year valued)	Authors (year publish)	Willingness to pay (2012 fourth quarter $)	Number of visits for one year (data source)
Whakarewa-rewa Forest	Bay of Plenty	5,700	Recreation (walking and mountain biking)	Travel cost (2009)	Dhakal et al. (2012)	$36 per walking visit $52 per mountain biking visit	309,000 (APR 2010)
Planted forests	Planted forest areas in New Zealand	1,720,000	Indigenous biodiversity enhancement	Choice modelling (2010)	Yao (2012)	$69 per person per year for 5 years	Not applicable
Coromandel State Forest Park	Waikato	71,900	Recreation	Travel cost (1982)	Everitt (1983)	$92 per visitor group per year	23,639 (Everitt 1983)
TECT (Tauranga Energy Consumers Trust) all terrain park	Bay of Plenty	1,650	Recreation	Contingent valuation (2011)	Barry et al. (2012)	$4.40 per walker visit $7.70 per mountain biking visit $9.04 per horse riding visit $18.76 per motocross visit	Number of visits still not available according to a TECT Park staff member
Planted forests in Hawke's Bay	Hawke's Bay	128,800	Water quality and quantity, and biodiversity	Choice modelling (2005)	Rivas Palma (2008)	$1/ha/yr for land stabilisation 1% improvement; $105/ha/yr for decreasing sediment in water; $111/ha/yr for decreasing algae in water; −$12/ha/yr for level of water flow	Not applicable

Appendix 4: Cost and price data to estimate average returns

Following Evison (2008), the annual cash surplus from forestry and dairy were compared on an annual basis and estimated in the following manner:

$$cs_l = nci_l - fwe_l - mgt_l$$

where *l* is a set including different land use alternatives (dairy and forestry), cs represents annual cash surplus, *nci* represents the net cash income, *fwe* represents farm working expenses, and *mgt* represents management expenses.

All the productivity, price and cost information for dairy was obtained from the latest Dairy NZ Economic Survey 2013-14 (2015a). All prices were deflated using the Consumer's Price Index (CPI) time series reported by Statistics New Zealand (2015d). The net cash income was estimated in the following manner:

$$nci_{l=d} = myd * mpr$$

where *d* is an element of *l* representing the dairy land-use alternative, *myd* represents the yield of milk solids in kg/ha, and *mpr* represents the milk solid payout in $/kg including milk price plus dividend.

The farm working expense was estimated from the operating expenses for the dairy industry in the following manner:

$$fwe_{dairy} = opex - mgt - invadj - blockadj - dep$$

since the operating expenses (opex) include farm working expenses (*fwe*),[37] labour adjustment (*mgt*), feed inventory adjustment (*invadj*), owned support block adjustment (*blockadj*) and depreciation (*dep*). Although there are regional operating expense estimates available for Waikato, their components are only available at the national level. Hence, the national adjustment parameters (labour, feed and support block), administration and depreciation figures were subtracted from the regional operating expenses to come up with regional farm working expenses for the Waikato region ($4,180).[38] Inventory and owned support block adjustments and depreciation were not included in the comparison since no similar information could be obtained or estimated for forestry. Administration expense items such as administration, insurance, ACC and rates were added to the management expenses.

The Dairy NZ national labour adjustment includes management expenses. The labour adjustment Figure for 2013-14 was $415/ha. Adding the aforementioned administration items to the management expenses, the latter adds up to $748/ha. Evison (2008) used the Wages of Management (WOM) reported by MAF's Dairy Farm Monitoring publications (2007).[39] However, no further reports have been published since 2012 with the latest WOM estimate being $714/ha. The final estimated cost structure is presented in the following Table:

[37] Farm working expenses include wages, benefits, feed (hay, silage, crops and grazing), fertilizers, transportation (freight and fuel), pest control, repairs and maintenance, administration, etc.

[38] Waikato operating expenses were $5,400/ha in 2013-14. The national adjustment factors and depreciation added to $887/ha including a labour adjustment of $415/ha and administration expenses of $333/ha. Hence, the resulting Waikato farm working expenses estimate was $4,180 (= $5,400 - $887 - $333).

[39] The WOM is estimated with a $38,000 allowance for labour input plus 1% of opening total farm assets to a maximum of $85,000.

Expense item	$/ha
Farm working expenses	4,180
Management expenses*	748
Total expenses**	4,928

* Include labour adj., admin., insurance, ACC and rates.
** Exclude adj. factors (inventory, supp. block) and depreciation.

The estimation of the net cash income was somehow complex due to the different log grades produced by different silvicultural regimes and destined to the domestic and the export markets. Two different net cash income figures were estimated considering the main silvicultural regimes currently practiced in the CNI according to the share of total area covered: pruned (36%) and unpruned (42%) without production thinning. The net cash incomes were estimated as weighted averages in the following manner:

$$nci_{l=f,silv} = \sum_{g} wyd_{silv,g} * \left(\sum_{mkt} wpr_{silv,mkt} * mktshr_{mkt}\right)$$

where *f* is an element of *l* representing the forestry land-use alternative, *silv* is a set including different silvicultural regimes (pruned and unpruned), *g* is a set including different log grades (pruned, structural and pulp), *mkt* is a set including the different markets (domestic and exports), *wyd* represents annualised wood yields,[40] *wpr* represents the weighted price of wood, and *mktshr* represents the share of the market where wood is destined from the CNI.

Most of the price and markets information was obtained from MPI's Forestry Statistics and Forecasting website (2015e). The destination market share was obtained from the latest wood flow published by MPI (2015d): 51% for exports and 49% for the domestic market. The historical domestic and export prices by log grade for the last 10 years were obtained from MPI (2015e).[41] The following Table lists the total recoverable volume by log type and regime for a 28-year rotation age in the CNI (MPI, 2015f).

	Total recoverable volume by log types (m^3/ha)		
Regime	**Pruned**	**Structural**	**Pulp**
Pruned w/o thinning	123	427	128
Unpruned w/o thinning	0	496	200

One weighted average price was estimated for each destination market and silvicultural regime considering the different log grade yields presented in the previous Table as weights:

$$wpr_{silv,mkt} = \sum_{g} gpr_{mkt,g} * grdshr_{silv,g}$$

$$grdshr_{silv,g} = wyd_{silv,g} / \sum_{g} wyd_{silv,g}$$

where *gpr* represents the prices by log grade and *grdshr* represent the grade shares used as weights.

The forestry farm working and management expenses were obtained from a technical study performed by Scion using data from different corporate forests in the CNI (Moore et al., 2012) and

[40] To compare annual net cash income between dairy and forestry, the wood yields obtained from MPI were annualised by dividing them by the rotation age (i.e. 28 years).
[41] For the domestic market, pruned is the average of P1 and P2; and structural is the average of S1, S2, L1&L2, S3&L3. For the export market, structural is the average of the A and K grades.

listed in the following Table. These were compared to the costs reported in the New Zealand Forest Products Industry Review by DANA Limited (2014) and to the ones reported by Evison (2008). The total costs reported by Moore et al. (2012) were between the lowest and medium cost range reported by DANA Limited (2014). This reflects the low harvesting costs in relatively flat terrain, as is the case in the CNI. The costs reported by Evison (2008) were between the medium and the highest cost range reported by DANA Limited (2014).

Year	Operation	Pruned ($/ha)	Unpruned ($/ha)
0	Site Prep	80	80
0	Planting	600	500
4	Dothistroma	60	60
5	Pruning	900	
7	Pruning	350	
7	Thin to Waste	450	405
8	Pruning	350	
8	Dothistroma	60	60
10	Thinning	250	
27	Roading	2,000	2,000
28	Harvesting*	16,950	17,400
28	Transport*	13,560	13,920
All	Management**	80	80

* Harvest and transport cost were originally $\$25/m^3$ and $\$20/m^3$.

** Management includes admin., property maintenance, insurance, rates and management costs.

To compare a representative dairy farm to a corporate forest, the latter had to be annualised considering a sustainable forest that has reached a steady state regarding annual harvest yield. For this, the yield and working costs were divided by the predominant rotation age in the CNI – 28 years. This calculation is similar to dividing a representative forest area in 28 sections, earning the revenues from each harvested section (one section a year), and incurring on all of the expenses every year in different sections of the forest except the management costs, which are incurred in every section every year.

Appendix 5: Description of Monte Carlo simulation methodology

Following the frequentist or classical probability school, price uncertainty is based on the historical uncertainty experienced in the last ten years. Past uncertainty was modeled as deviations from the mean rather than the trend since prices were deflated and do not show any signs of following a trend.[42] Since the number of deviations was not enough to fit a parametric distribution (e.g. normal distribution), they were used to develop non-parametric univariate (UVE) and multivariate empirical (MVE) distributions using the procedure developed by Richardson et al. (2000) and used by Monge et al. (2014) and Monge et al. (2016).

The UVE, previously described in Richardson (2010), is a simpler version of the multivariate empirical (MVE) probability distribution developed by Richardson et al. (2000) where the random and deterministic components of the price variable are separated. The MVE is a non-normal alternative distribution that uses limited data on historical prices for different log grades and a correlation matrix to represent intra-temporal (across grades) and inter-temporal (across time) relationships. The MVE is equivalent to simulating the random variables using a linear copula.

All milk, dairy export, log and wood product export prices were tested for correlation. Milk payouts and dairy export prices did not show any correlation with any of the log or wood product prices. However, there were statistically significant correlations among certain log and wood product prices. Hence, a UVE distribution was used to simulate milk payouts and dairy exports. An MVE was used to simulate log and wood product export prices. The correlation matrix is available upon requests from the authors.

The generation of the uniform standard deviates, used to simulate the UVE and MVE, was performed with the Excel Add-in SIMETAR for 500 iterations.

[42] A simple linear trend regression was estimated for all deflated prices and none of them showed a statistically significant relationship.

Appendix 6: Description of data sources for value chain assessment

All exported quantity data was obtained from Statistics NZ (2015b) for the port of Tauranga. The data used was the HS2 code 04, which includes dairy, birds' eggs, natural honey and other edible products of animal origin. Animal meat and animal derived products are considered in other HS2 categories so sheep and beef products are not included in this Figure. The exports for the forestry industry include:

- HS2 code 44: Wood and articles of wood and wood charcoal. This category includes boards, panels and remanufactured material among others.
- HS2 code 47: Pulp of wood, waste and scrap of paper. This category includes mechanical, chemical and semi-chemical wood pulp among others.
- HS code 48: Paper and paperboard, articles of paper pulp. This category includes newsprint and paperboard among others.

Dairy and wood manufactured product prices were obtained from public sources. The historical data on dairy export prices was estimated by dividing values (in NZ$) over quantities (in tonnes) of dairy manufactured products exported from New Zealand obtained in Statistics NZ (2015b). Such estimates were verified with the historical series published by the Dairy NZ Economic Survey 2013-14 (2015a). The historical data on wood manufactured exports was estimated by dividing values (in NZ$) over quantities (in tonnes for pulp and paper and m^3 for roundwood and lumber) from MPI exports dataset (2015c). All estimated export prices were deflated using the Consumer's Price Index (CPI) time series reported by Statistics New Zealand (2015d).

Employment data was obtained from Statistics NZ (2015c) for the CNI including Waikato and Bay of Plenty regions as well as the Ruapehu District. Such data was obtained for the following industries: dairy cattle farming; forestry and logging; dairy product manufacturing; wood product manufactruing; pulp, paper and paperboard manufacturing; and converted paper manufacturing. The agriculture, fishing and forestry support services were excluded since it was difficult to divide the agriculture and fishing share that corresponds to dairy only.

The inventory of wood manufacturing mills was obtained from an unpublished database at Scion and websites. The unpublished database is an updated inventory of all wood manufacturing mills in New Zealand. Only the mills in the CNI were included in this study. The database was developed by Peter Hall at Scion (personal communication, 2015). Inventory of dairy manufacturing mills was obtained from Fonterra (2015c), Open Country (2015), Tatua (2015) and Miraka's (2015) websites. All of these websites provide data on daily input rates and annual output rates as well.

All of the quantities of products supplied from the CNI were obtained by using the production from inventoried mills and matched with public data. Public data used to match the inventories were the wood flow statistics from MPI (2015d).

All export and domestic prices were simulated using historical price data and the methodology described in Appendix 5.

Appendix 7: Inventories of wood and dairy processing facilities in the CNI

Inventory of timber processing facilities in the Central North Island and their respective annual production capacities (Source: Personal Communication with Peter Hall at Scion, 2015)

Owner	Principal product	Log intake (m3/year)	Annual product output	Unit output
CHH Wood Products	Particle board		31,000	m^3
CHH Wood Products	Plywood	150,000	75,000	m^3
OjiFS	Kraft pulp	1,290,000	285,000	t
OjiFS	Kraft pulp (batch)	909,000	330,000	t
OjiFS	Kraft Pulp	988,000	290,000	t
OjiFS	Carton Board	65,000	115,000	t
Norske Skog Tasman	Newsprint	290,000	120,000	t
SCA	Tissue paper	-	35,000	t
Winstone Pulp International	CTMP	250,000	190,000	t
CHH Kawerau	Sawn lumber	550,000	320,000	m^3
Claymark	Sawn lumber	100,000	56,000	m^3
Claymark	Sawn lumber	70,000	40,000	m^3
Donnelley sawmilling	Sawn lumber	70,000	38,000	m^3
WPI Tangiwai	Sawn lumber	260,000	120,000	m^3
Kiwi lumber	Sawn Lumber	49,000	35,000	m^3
McAlpines	Sawn Lumber	75,000	43,000	m^3
Pacific Pine Industries	Sawn Lumber	60,000	30,000	m^3
Pukepine Sawmills Limited	Sawn Lumber	90,000	50,000	m^3
Red Stag Timber Ltd	Sawn Lumber	800,000	450,000	m^3
Sequal Lumber	Sawn Lumber	320,000	166,000	m^3
Tenon Taupo	Sawn Lumber	420,000	210,000	m^3
OJI ex SCFP	Sawn Lumber	170,000	95,000	m^3
Vanner sawmills	Sawn Lumber	17,000	11,000	m^3
Waiariki TITC	Sawn Lumber	18,500	10,000	m^3
OJI ex SCFP	Reman.		90,000	m^3
Max Birt sawmilling	Reman.		17,000	m^3
Purepine Mouldings	Reman.		14,000	m^3
Intalok	Solid wood houses and Glulam			
Jointwood	Reman.		9,000	m^3
KLC Ltd	Reman.		40,000	m^3
Lockwood	Solid wood houses			
Verda	Reman.			m^3
Laminex	Particle board		30,000	m^3
Humepine	Reman.		40,000	m^3
Mamaku Sawmilling	Kiln Dried lumber		50,000	m^3
Arbor Resources	Reman.		18,000	m^3
Tauriko Sawmill and Timber supplies	Lumber	3,000	2,000	m^3
Century Timber products	Lumber	3,000	2,000	m^3
Budget Timber Mill	Lumber	3,000	2,000	m^3
Mount Timber Homes	Prefab buildings			
Colville sawmill company	Lumber, posts, boxes	3,000	2,000	m^3
Total wood manufacturing			2,096,000	m^3
Total pulp			1,095,000	tonnes
Total paper			270,000	tonnes

Inventory of dairy processing facilities in the Central North Island and their respective annual production capacities

Location	Company	Input		Output
		Quantity*	Units	tonnes/year
Waitoa	Fonterra	3,000,000	liters/day	65,000
Morrinsville	Fonterra	1,200,000	liters/day	25,320**
Waharoa	Fonterra	355,450**	liters/day	7,500
Tirau	Fonterra	2,900,000	liters/day	11,400
Lichfield	Fonterra	3,200,000	liters/day	68,000
Edgecumbe	Fonterra	3,000,000	liters/day	68,510
Reporoa	Fonterra	2,500,000	liters/day	15,300
Te Awamutu	Fonterra	4,850,000	liters/day	102,335**
Te Rapa	Fonterra	8,000,000	liters/day	325,000
Hautapu	Fonterra	4,100,000	liters/day	77,208
Waharoa	Open Country	500,000,000	liters/year	85,000
Morrinsville	Tatua	147,647,758	liters/year	16,943
Mokai	Miraka	210,000,000	liters/year	32,000
Total				**899,516**

***** Daily rates represent maximum capacity during the peak of the milk season.

** Values estimated using an average conversion rate of 47 milk litres processed daily for every tonne of product processed annually.

Appendix 8: Methodology for literature review on value-chain externalities

A brief literature review (including grey literature) was undertaken to identify published statistics on environmental impacts by the industries of milk manufacturing, sawmilling, and pulp and paper processing. A variety of literature was sourced such as peer-reviewed journal articles, theses, resource consent documents, and government and industry reports. The statistical units, methodologies, and system boundaries (i.e. exclusions and inclusions) varied greatly between each study/report. Such a variance, although somewhat expected, increases the difficulty to meaningfully and accurately compare statistics. The dairy industry in particular does not utilise standardised terminology as dairy manufacturing statistics were found to be reported using different units. For example, greenhouse gas emission statistics are published with a range of associated units such as kgCO2eq per ‘kg milk fat + protein’ (Beukes, Gregorini, & Romera, 2011), ‘energy corrected milk’ (Flysjö, Henriksson, Cederberg, Ledgard, & Englund, 2011), and ‘litre of liquid milk’ (Fonterra, 2010).