The Real Economics of the Adaptation to Climate Change on the Tahamata Dairy Farm – Assessing Future Scenarios from an Integrated Economic Production and Ecosystem Services Valuation Approach

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Executive Summary

Tahamata Incorporation is an iwi-owned 310 hectare dairy farm, located on the Horowhenua coast on low-lying, mainly sandy soils that are susceptible to water inundation, which is projected to happen due to Climate Change, as early as within the next 30 years. Given this problem, our case study analysis focused on 3 scenarios for how the dairy farm's management could adapt to those situations:

Scenario 1: (No Adaption) – this is essentially a 'do nothing scenario', where dairy production was adversely affected by the deterioration of the land and soil conditions due to water inundation;

Scenario 2 (Some Expansion of Wetlands) – this considers expanding an existing wetland area, to actively develop another 25 hectares of wetlands;

Scenario 3 (Full Expansion of Wetlands) – this sees even more active development of wetlands, to an expanded coverage of 194 hectares, which meant the wetland covered more land than the dairy farming operations.

In all scenarios, the amount of land covered by commercial forestry (21.2 hectares) and scrub (64.4 hectares) remains constant throughout the 30 years of the scenario, which started from a base year of 2015/2016. These scenarios were assessed using an **ecosystem services approach** which enabled their economic valuation to be directly compared with an economic valuation of the dairy farming operations, with the intent of integrating 'economic', 'ecological' and other values into one analytical framework. All of these scenarios were based on an Intergovernmental Panel on Climate Change (IPCC)[1] mid-range climate projection for sea-level rise over the next 30 years, which was modelled by Horizons Regional Council, to produce projected water level and drainage patterns for the Tahamata farm.

The first stage of this research involved compiling comprehensive **financial accounts** for the dairy farm and the small forestry operation, for the base year of 2015/2016, as well as **ecosystem services accounts** that covered 18 different ecosystem services, and attaching an economic value to each of these services. This involved GIS analysis of land cover areas in a matrix of 18 ecosystem services by 8 different land use/land cover combinations. From this information, for each of the land use/land cover combinations (which were mainly human modified ecosystems), we used our New Zealand data sources to determine an economic value ($/year) of each of their ecosystem services. For our assessment of the economic value of the wetland ecosystem services, we depended on The Economics of Ecosystems and Biodiversity (TEEB)[2] database, which covers 244 'inland wetlands'. Also included is a very useful regression equation that summarises this data, which enabled us to use it, along with other information, to adapt the TEEB ecosystem services valuation data to Tahamata. The ecosystem services account enables us to compare the ecosystem services value per hectare of various different land use/land cover combinations: Wetlands, dominated by Vegetation ($13,852/ha/yr); Wetlands, dominated by Open Water ($4,042/ha/yr); Surface Water or Ponding on Land; ($106/ha/yr); Forestry ($1,272/ha/yr); Scrub ($573/ha/yr); Stocked Dairy Pasture in Good Condition ($1,411/ha/yr); Dairy Stock on Poorly Drained and Puggy Soils ($704/yr/ha); and Poorly Drained and Puggy Soils with No Stock

[1] See http://www.ipcc.ch/

[2] See http://www.teebweb.org/; also Kumar (2010); and TEEB (2013).

($395/ha/yr). These data underscored the very high comparative economic value of wetlands compared with other types of landcover/use.

The second stage of this research was to develop a **scenario modelling tool** (in the spreadsheet environment), to project the scenarios forward to 2045/2046, and then to assess for that year the overall economic value of each scenario across each of the 18 ecosystem services and various financial information about the dairy farming and forestry activities. In terms of the all-important 'net value' (value added), **Scenario 1 (No Adaptation)** had a net annual value of $563,533 for 2045/2046, which represents a decrease of 17.3%, essentially because 35.3 hectares became unavailable for dairy farming due to water inundation. **Scenario 2 (Some Expansion of Wetlands)** had a net annual value of $838,759 for 2045/2046, which had the same decrease in dairy farm output as the first scenario, but this was more than compensated for by the high economic value associated with the development of an expanded wetland area. **Scenario 3 (Full Expansion of Wetlands)** had a net annual value of $1,838,316 for 2045/2046, which is considerably more than the first two scenarios. Although this scenario saw an even larger drop in the economic production of the dairy farm, this is greatly outweighed by the extra economic value generated by developing the wetlands, essentially on areas that were no longer suitable or impossible to use for dairy farming. Other indicator variables for the scenarios are reported in the following table:

Descriptors	Units	Base Year: 2014/15	Scenario 1: No Adaption 2045/46	Scenario 2: Some Expansion of Wetlands 2045/46	Scenario 3 Full Expansion of Wetlands 2045/46
Dairy Farm	Hectares	310.00	274.71	274.71	172.64
Forestry	Hectares	21.19	21.19	21.19	21.19
Wetlands	Hectares	21.06	21.06	56.36	193.71
Net Value	$\$NZ_{2015/16}$	681,579	563,533	838,759	1,838,316
Commercial value of Dairy and Forestry Products	$\$NZ_{2015/16}$	328,844	241,173	241,173	189,342
Non-Commercial Value of Ecosystem Services	$\$NZ_{2015/16}$	352,735	322,360	597,587	1,648,974
Provisioning Ecosystem Services	$\$NZ_{2015/16}$	334,561	246,077	250,208	213,643
Cultural Ecosystem Services	$\$NZ_{2015/16}$	66,776	65,628	167,782	564,142
Regulating Ecosystem Services	$\$NZ_{2015/16}$	280,242	251,829	420,769	1,060,531
Supporting Ecosystem Services	$\$NZ_{2015/16}$	681,579	563,533	838,759	1,838,316
Commercial Value Per Hectare	$\$NZ_{2015/16}$ / hectares (dairy +	993	815	815	977

Table E1: Summary of Changes in Key Indicators Associated with Different Scenarios for Wetlands on Tahamata Farm, to 2045/46

In all three scenarios, there was a decrease in the commercial (net) revenue of the Tahamata farm, decreasing as low as $189,342/yr in Scenario 3 compared with a base year figure of $328,844/yr. Although this is the case, it should be noted that the Tahamata farm still remains viable and profitable, but just operating at a lower level of production, which incidentally is still at a higher level than the average New Zealand dairy farm or, for that matter, the average Lower North Island dairy farm.

The report concludes by identifying a number of areas that require further research and stakeholder consultation. The economic analysis needs to be integrated into a full cost-benefit framework, which will require us to collect and process data on the costs of land use changes, particularly the active conversion of land to wetlands; this includes costs such as planting, engineering works, fencing, pest control and so forth. Other adaptation strategies, such as for example draining the inundated land or planting grass species that will be tolerant to the new high water table environment, need to be considered in consultation with stakeholders. If any of the wetland conversion scenarios, or variants of them, are to be implemented, for cases that seem to have a good economic justification, further research investigation needs to be undertaken on how this is to be achieved. The fact that ecosystem services values are 'diffuse' – particularly for wetlands that benefit a large number of often ill-defined stakeholders across site-specific, local, regional, national and global scales – complicates and makes difficult any concerted implementation aimed at capturing those very significant ecosystem services values that are highlighted in some of the scenarios.

Finally, it is acknowledged that farmer adaptation and technological development will play a role in response to climate change beyond that which can be reasonably captured by the scenario modelling undertaken in the study.

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1. Introduction and Context

Background

This research is part of a wider project entitled, Adaptation Strategies to Address Climate Change Impacts on Coastal Māori Communities (CO1X1445), funded within the Vision Mātauranga programme of The Deep South Te Kōmata o Te Tonga National Science Challenge. The project contributes to the Vision Mātauranga component of the Deep South National Science Challenge, by providing insights into how coastal Māori communities and businesses can adapt to Climate Change, which is forecasted to happen within the next 30 to 50 years. The project was undertaken for the 18 months ending June 2017 with Māori coastal communities in the Horowhenua–Kāpiti rohe. The research explored how a better understanding of aspects of the Mātauranga Māori worldview could be explored and developed alongside climate change science, geomorphology, ecological economics and design principles, to inform new paradigms for resilience and adaptation to climate change for coastal Māori communities. Readers are encouraged to refer to the technical report and journal article that detail the project's vision, methodology and findings (see Smith et al., 2014; Smith et al., 2017).

In this context, the case study reported on in this report analysed how Tahamata Incorporation's farm will be affected by climate change, and what options Tahamata and other iwi/hapū farm managers have to adapt to such changes. The Tahamata Incorporation farm is located on the Horowhenua Coast on predominantly sandy country that is particularly susceptible to water table levels increasing with sea level rises, which makes it probable that some of the existing farm will be inundated by water and/or soils will become puggy and waterlogged, particularly in the winter months, thus making farming more difficult and less productive on such areas. The farm's production is also affected by soils that are prone to drying in the summer months, which presents another climate change challenge for the farm managers. Farmers are also challenged by the fact that, although the farm is productive in the sense that it provides an income for three workers and it is profitable, its level of productivity is lower than both the national average for dairy farms and the average for lower North Island dairy farms. In other words, the Tahamata Incorporation farm has less 'financial breathing space' than other farms, and hence any negative impacts on dairy production brought about by climate change puts this farm at more financial risk than many other farms.

In the middle of the Tahamata Incorporation farm is the Te Hākari Wetland, which is a 33.7 ha wetland restored in 2001 from previous farmland, which is protected with a covenant. Restoration work has included:

- Supplying and planting more than 10,500 indigenous plants throughout 2002-2006.
- Construction of temporary weirs to prevent further drainage from the wetland. (This is part of an ongoing hydrology project whereby, through raising the water levels within the wetland, water has returned to its original levels according to land contours. This has enabled regeneration of native wetland grasses and encouraged the return of larger populations of wading species).
- Clearing the choked Te Hākari Lake of raupo. Water levels were lowered from October 2005 so the mechanical dig could be started in February 2006. This created open areas of water, which in turn enhanced fish and bird life within the lake habitat.

- Fencing the wetland area to keep livestock out.
- Implementation of an ongoing pest control programme.
- Implementation of a fire protection scheme.

Te Hākari wetlands now provides habitat to 62 native and introduced bird species (see Appendix A) including endangered, indigenous birds such as matuku (bittern). While once a habit for the puweto (spotless crake), this bird has not been observed since revitalisation began in earnest in 2002. Revegetation plants include native species such as as koromiko, toetoe, ngaio, tīkouka, harakeke, karamu, manuka and kahikatea.

Te Hākari Wetland is located within a culturally significant ancestral landscape for a range of hapū including Ngāti Te Rangitāwhia, Te Mateawa, Ngāti Manu and Ngāti Kapumanawhiti - all of whom are affiliated to the iwi Ngāti Tukorehe. From 1842 to 1855 a series of recorded seismic activities, with associated uplifts of land, drained the shared river mouth of Ōhau and Waikawa Rivers, and shallowed the lagoons and other adjacent watercourses. Before this time, the wetland area actually formed part of the Ōhau River. In those ensuing years, Te Hākari became a vast wetland region that supplied adjacent papakāinga and hapū with key resources. Hapū (whanau groupings) lived in mutual respect of each other and resources of this coastal plain. The contiguous wetland and dune lakes system, stretched south to incorporate dune wetland lakes such as Pekapeka, Manga Pirau, and further onto other dune lakes such as Huritini, Kauhuera through to Waiorongomai near Ōtaki. To the north, Te Hākari dune wetland also formed part of the shared lake and wetland systems of Waitaha, Rotokare at Waiwiri, Lake Waiwiri (or Papaitonga) and Lake Waipunahau at Levin.

From 1823, historic cultivations in the region produced kumara and taro, such as the Tutangata-kino cultivation, which was situated within a sharp bend in the lower reaches of the Ōhau River. Later the extensive gardens produced potatoes introduced by whalers in 1830. From 1839, ancestors dealt in harakeke, pigs and potatoes for the markets appearing in a burgeoning Wellington. By the mid-1840s, wheat fields were evident at bush-screened bends in the river, away from the normal fords, which was the coach road access way across the Ōhau River.

Today, Tahamata Incorporation is a farming enterprise named after one of the areas within the coastal landscape of research interest, and when operating under its inherited name, the farm exists upon the former entrepreneurial trading and horticultural activities of ancestors, who were feeding a burgeoning Wellington from 1839.

Report Objectives

With the onset of climate change and water inundation on the current Tahamata farmland, there is potential to convert some of the farmland to wetlands, or to further consider other uses of the land. To inform this decision making concerning the appropriate use of this Tahamata land, the purpose therefore of this study is to investigate, from an 'ecosystem services perspective', three future scenarios for the use of the farmland in 30 years' time when it is expected that there will be significant water inundation of the land – the three scenarios that will be evaluated are:

- **Scenario 1 – No Adaption:** Under this scenario, much of the farm's soil will become puggy by 2045/46 as sea level rises and in some places surface water will accumulate. In this scenario, the farm management will use this puggy land the best they can, which means intermittent grazing in some areas, less intensive grazing and in some places no grazing at all. No additional attempt is made to 'drain the land' or to convert the inundated land to some other economic or ecological use.

- **Scenario 2 – Some Conversion to Wetlands:** Under this scenario, by 2045/46 the existing wetland will be actively extended from 21 hectares to 56 hectares, using land which is impossible or very difficult to farm effectively. This will require the planting of native trees and vegetation, pest control, engineering works and so forth.

- **Scenario 3 – Full Conversion to Wetlands:** This scenario goes further than Scenario 2, by actively converting all land to wetlands where the land has become puggy and is not well drained, as well as areas where there is now persistent surface water. This would be a significant undertaking, extending the existing wetland areas in 2015/16 from 21 hectares to 194 hectares by 2045/46. As with Scenario 2, this would require significant investment in actively planting areas, engineering works and so forth.

Accordingly, in this context, the **research objectives** of the case study were to:

1. Produce a spreadsheet-based model for evaluating future land use and management options (scenarios) for the Tahamata farm from 2015/16 to 2045/46.
2. Produce financial accounts for the dairy farm's operation and production for the base year of the scenarios (2015/16), and build this data into the spreadsheet model's capability for considering alternative financial budgets for the Tahamata farm, to allow for possibilities such as changes in milk solids payout.
3. Produce ecosystem services accounts for 2015/16, taking account of the different commercial land use covers (e.g., pasture for dairy farming, forestry) and non-commercial land use covers and ecosystem types (e.g., wetlands, coastal scrub), and build this data into the spreadsheet model's capability for considering alternative land uses on the Tahamata farm. These ecosystem services would be valued using the on-site information and data to allow for local situations, as well as drawing on an international database of 224 individual studies of ecosystem services and wetlands.
4. Produce three scenarios (non-adaption, some expansion of wetlands, full expansion of wetlands) from 2015/16 to 2045/46. For each scenario, quantify both the economic value ($) of the dairy farming operations and the products it produces, and the economic value ($) of 18 ecosystem services. These scenarios would then be compared with each other in terms of a number of parameters including – the economic value (value added, as it contributes to GDP) across the entire farm including the dairy production, forestry production and ecosystem services that don't currently have a market value. All three scenarios would be compared with each other using these parameters.
5. Discuss the above results drawing out the implications for future farm management, the possible role for public agencies and iwi organisations, and barriers to optimising the management of the farmland in terms of maximising the ecosystem services.
6. Pinpoint how Phase 2 (MBIE funding from 1 August 2017 - 31 January 2019, through the Deep South National Science Challenge) research to further develop and improve this model can include further adaptions such as draining water-inundated land, and considering other land uses such as harvesting materials from the wetlands.
7. Pinpoint areas where the current spreadsheet model can be improved, particularly in regard to obtaining local data rather than depending on data from the literature.

Rationale for the Ecosystem Services Approach

The management of a system like Tahamata farm is difficult, due to the range and complexity of different values that need to be taken account of, some of which could be classified as 'private goods' (e.g., income from selling milk) and some of which could be considered 'public goods' (e.g., climate regulation functions of wetlands). Deciding what is the 'best' option for the future management of the farm from a welfare economics point of view, is a difficult proposition as it requires not only the valuation of private goods, which is usually straightforward as they have a market price, but also public goods (and bads), which usually don't have a market price. This problem can be resolved by adopting the 'ecosystem services valuation' approach, which estimates the price and value of ecosystem services that had been hitherto unpriced public goods. The process of 'pricing' ecosystem services serves a number of functions including: making 'visible' to stakeholders and decision-makers those ecosystem services that are usually ignored; serving an education and pedagogical function by making different audiences more aware of the importance and functioning of ecosystem services; and enabling decision-makers to weigh up the importance of various ecosystem services relative to each other and relative to market goods and services. In the case of the Tahamata farm, it is hoped that this ecosystem services valuation approach will provide some guidance on deciding the preferred option/s for the future use of the farm in light of the likelihood of climate change impacts, which are forecasted to become significant in the next 30 to 50 years.

Many would argue that biodiversity and ecosystem services cannot or should not be priced or valued in economic terms, which emphasises utilitarian value and ignores important ethical, moral and spiritual dimensions of value. In this context, it is often contended that a Kauri forest ecosystem, for example, or a tuatara is 'priceless', much the same as a rare piece of art is 'priceless'. Although this may be the philosophical position of some, we argue that there are compelling pragmatic reasons for being explicit about the value of ecosystems and biodiversity if true progress is to be made in ecosystem management.

First of all, as others such Perrings (1995a, b) and Costanza et al. (1997) argue, in reality all of us implicitly place value on ecosystems and biodiversity in terms of our everyday behaviour – even those deep ecologists who are strongly motivated by ethical concerns to preserve biodiversity. All the valuation process does, is to be explicit about the value of ecosystems and biodiversity, based on an examination of people's revealed or stated preferences. In stating this, the authors wish to acknowledge that there are significant operational problems in validly and reliably measuring these preferences – e.g., refer to Blamey and Common (1994) for a fuller discussion. Also, it needs to be acknowledged that the standard neoclassical valuation approach that we are alluding to here is fundamentally anthropocentric and as such has a number of significant limitations. For example, it needs to be recognised that the neoclassical approach is predicated on short term perceptions of instrumental value often based on incomplete ecological knowledge.

Secondly, the authors consider it imperative to assess the value of ecosystems and biodiversity, so that its value can be appreciated and compared with other yardsticks of progress. Most importantly, there is a need to compare the value of New Zealand's ecosystems with the Gross Domestic Product (GDP) indicator that measures the value of the output of the economy. Only then will the values of ecosystems and biodiversity become 'visible' and apparent to many decision-makers who are more used to dealing with indicators such as the GDP. Environmental Accounting exercises such as this have been very successful in other countries in highlighting the importance of natural resources and the environment relative to economic indicators – e.g., in the United States (Daly and Cobb, 1994) and Australia (Hamilton and Saddler, 1997). Probably of most significance in terms of its impact on the policy community was Costanza et al.'s (1997) analysis, which showed that the world's ecosystem services were surprisingly more than double the world's GDP in terms of their contribution to human welfare.

Our analysis is undertaken in the spirit of methodological pluralism, where it is acknowledged that no one methodology is correct or comprehensive, but a number of methodologies need to be used to gain a fuller appreciation of the value of biodiversity and ecosystem services. This particular study uses the standard neoclassical valuation approach, which is fundamentally anthropocentric, even when it encompasses non-use values such as existence value. Costanza (1991) argues that this neoclassical approach can lead to anomalies based on human beings having imperfect knowledge of ecological processes and functions. For example, he points out that human beings generally assign higher value to species of direct commercial value and/or species that are easy to empathise with, whereas less visible species such as invertebrates are often ignored.

Insights from Previous Studies

Over the last three decades, there have been many studies of the benefits of ecosystem services provided by wetlands, particularly in the overseas literature. These studies consistently show that wetlands are one of the most valuable types of ecosystems, producing a whole multitude of ecosystem services, many of which are poorly understood by decision-makers and perhaps underappreciated by the general public. For example, Patterson and Cole (1999)[3], found for New Zealand that, in terms of the total ecosystem services value, Inland Wetlands had a value of $56,506 per hectare per year expressed in 2015/16 dollars, which compares in descending order with:

Rivers ($24,663/ha/yr),
Lakes ($24,651/ha/yr),
Horticulture and Cropping ($9,193/ha/yr),
Mangroves ($5,832/ha/yr),
Agriculture ($1,702/ha/yr),
Forests ($1,538/ha/yr),
Intermediate Agriculture-Forest ($1,146/ha/yr),
Forests-Scrub ($1,009/ha/yr),
Native Scrub ($905/ha/yr),
Marine ($690/ha/yr), and
Intermediate Agriculture-Scrub ($680/ha/yr).

Patterson and Cole (1999) found that only Estuarine ecosystems recorded a higher value than Inland Wetlands, at $66,127/ha/yr.

The most rigorous and comprehensive summary of the economic value of inland wetland ecosystem services (by 9 "biomes") is contained in the "TEEB Valuation Database", which was compiled by van der Ploeg, de Groot and Wang (2010) and is further summarised by de Groot et al. (2012). In total, the economic values per hectare and other data, including spatial and temporal data, were recorded for 1,350 ecosystem services. Fortunately, in terms of our study, there were

[3] The values from Patterson and Cole (1999) are updated from $1994 to $2015/16 by using the New Zealand Consumer Price Index obtained from the Reserve Bank's CPI calculator.

a significant number of estimates (244) for Inland Wetlands, representing a real advance on our previously used Costanza et al. (1997) study, which did not cover the full array of wetland ecosystem services.[4]

The "TEEB Valuation Database" data, consisting of 244 observations for Inland Wetlands, has been statistically modelled to identify the main factors that determine the actual ecosystem services value. The results of this statistical modelling (ordinary least squares regression) are summarised in Table 1. This table contains powerful information that can be used to adapt global averages for wetland ecosystem services values ($ per hectare) to local situations such as, for example, the Tahamata farm.

Table 1: Regression Model of the Determinants of the Value ($ per hectare) of Inland Wetlands from 244 Observations

Variable	Variable definition	Coefficient	Standard Error
Constant	Natural log of US$/ha/annum	1.386	1.89
Study site area	Natural log of the study site area (ha)	−0.321***	0.055
Freshwater marsh	Dummy (1=freshwater marsh; 0=other)	0.576	0.443
Wooded marsh	Dummy (1=wooded marsh; 0=other)	0.681***	0.303
Salt-brackish marsh	Dummy (1=salt/brackish marsh; 0=other)	1.489***	0.48
GDP per capita	Natural log of country level GDP per capita (PPP USD 2007)	0.37***	0.118
Population	Natural log of population within 50 km radius of study site	0.339***	0.093
Wetland abundance	Natural log of area of wetlands within 50 km radius of study site	−0.203***	0.047
Lake and river abundance	Natural log of area of lakes and rivers within 50 km radius of study s	0.092	0.077
Hedonic pricing	Dummy (1=hedonic pricing; 0=other)	−1.219	1.112
Travel cost	Dummy (1=travel cost; 0=other)	−1.658***	0.426
Replacement cost	Dummy (1=replacement cost; 0=other)	−0.567	0.403
Net factor income	Dummy (1=net factor income; 0=other)	−1.355***	0.495
Production function	Dummy (1=production function; 0=other)	−1.298**	0.635
Market price	Dummy (1=market price; 0=other)	−1.391***	0.392
Opportunity cost	Dummy (1=opportunity cost; 0=other)	−0.726	0.804
Choice experiment	Dummy (1=choice experiment; 0=other)	−0.573	0.832

Notes:
1. This table of data was obtained from de Groot et al. (2012). Based on 244 world-wide observations recorded in the 'TEEB Valuation Database'.
2. Adjusted $R^2 = 0.442$
**means significant at the $2p = 0.05$ level
*** means significant at the $2p = 0.01$ level

These regression results clearly show the effect of a number of variables on the economic values ($ per hectare) – the following broad categories were tested:

1. *Type of wetland* (with the results showing that salt-brackish marsh had the highest value, followed by wooded marshes and then freshwater marshes).
2. *GDP per capita.* As is to be expected, the logGDP coefficient was positive, indicating that the higher GDP per capita, the higher the value of the wetland. Many of the valuation methods, in one way or another, measure willingness of the consumer to 'purchase' an ecosystem service, and not surprisingly the more income (GDP per capita) the survey respondent has, then the more likely they are willing to pay a higher amount of money for that service.

[4] Other useful summaries of economic valuation data for inland wetlands, apart from the TEEB valuation database, are: Chapter 20 of the Millennium Ecosystem Assessment, which was lead authored by Finlayson and D'Cruz (2005), Finlayson et al., (2005), and the publication by Schuyt and Brander (2004).

3. *Population within 50 km radius of the site.* This variable had a positive coefficient indicating that the higher the number of people that live within 50 km of the wetlands, the higher the economic value ($ per hectare) of the wetlands. Framed in terms of economics, this simply means that there is a greater number of 'consumers' – and *ceteris paribus* this translates into higher total income ($) derived from the wetland ecosystem services.
4. *Wetland abundance* (measured by area of wetlands within a 50 km radius of the site). In this case, the coefficient is negative, meaning that the more wetlands there are, then the value of the study site wetland decreases. In Economics, it has been shown that for almost all goods and services, there is a diminishing marginal utility (hence a downward sloping demand curve), which means that the more the good becomes 'consumed', the less its utility with each extra increment of consumption.
5. *Lake and river abundance* (measured by area of wetlands within a 50 km radius of the site). Lakes and rivers can be seen as competitive goods to wetlands so *a priori* you would expect there to be a negative coefficient for this variable. However, the opposite occurred, with a very small positive coefficient (0.092), which means that when lakes and/or rivers coexist with wetlands, the value of wetlands slightly increases – although this coefficient is not significant at the 0.05 level, which indicates that there is significant uncertainty with this measurement.
6. *Valuation methods.* It is well known in the field of Resource and Environmental Economics that the economic value that has been measured is significantly dependent on the valuation method. *Ceteris paribus,* all of the valuation methods had a negative coefficient, meaning that they all decreased the economic value ($ per hectare) of the wetlands. The travel cost method decreased the ecosystem service value of wetlands by the most, followed in smaller and smaller decreases by: the market price method, net factor income method, production function method, hedonic pricing, opportunity cost method, choice experiment method and, finally, by the replacement cost method, which had the smallest negative effect on the economic value of wetlands.

The existence of this 'summary' regression equation means that, at least, we can estimate the economic value ($/ha) in a far more nuanced and accurate way compared with our previous New Zealand estimates of the value of wetland ecosystem services (Patterson and Cole, 1999; Patterson and Cole, 2013).

Unfortunately, in New Zealand there have been only a very few quantitative studies of the economic value of wetland ecosystem services based on primary data collection. Clarkson et al. (2013), however, does qualitatively discuss the nature and importance of wetland existence services in New Zealand, and summarises the handful of economic valuation studies of wetlands in New Zealand. The most studied wetland in New Zealand from an economic valuation perspective is the Whangamarino wetland in the Waikato (Waugh, 2007) with, for example, Kirkland (1988) estimating $\$US_{2003}$ 9.9 million benefit per year, with most of this ($\$US_{2003}$ 7.2 million) being passive or non-use value. Ndebele (2009) estimates, by using the contingent valuation method, that the Pekapeka Swamp generates ecosystem services worth between NZ$1.64 million to NZ$ 3.78 million per year (see also Ndebele & Forgie, 2017). Due to the lack of specific 'ecosystem services' valuation data in these studies, it was very difficult to use any of these studies on estimating the wetland economic value in our Tahamata case study, although Clarkson et al.'s (2013) discussion of New Zealand wetlands was useful in providing guidance on how to transfer the de Groot et al. (2012) data to the New Zealand situation.

Caveat – Role of Farmer Adaptation

To some extent, the scenarios projected in the study are 'simplistic', as they assume that many factors remain unchanged. For example, it is assumed that the mix of inputs into dairy farming remains the same, and the same technologies are used over the entire period of the scenario up until 2045. However, even if more sophisticated trend analysis was able to project improvements and technologies, and efficiency gains could be incorporated into the scenario analysis, there is much that still remains unknown and unquantifiable, which is therefore not included in the scenarios. In this context, even though climate change challenges are difficult to address and may even seem insurmountable, it is likely that effective adaptations to climate change by improved farming techniques will play a significant role over the 30 period of the analysis

An example of how adaptation to climate change has given impetus to improvements in farming practice is in cropping farms in Australia, where ABARES[5] has reported recent productivity gains after some period of stagnation, as farmers changed their practices to adapt to drier conditions that were attributed to climate change. That is, evidence suggests that winter cropping farms have made a range of changes over the last decade, to better exploit soil moisture left from the summer period (Hughes et al., 2017). The most obvious is the shift toward conservation tillage during the 2000s, where some or all of a previous crop's residue (such as wheat stubble) is left in a field when planting the new crop. Based on this type of evidence, it can therefore be concluded that there is little doubt that dairy farming and other types of farming could also, over a 30 year period, adapt to climate change in ways that cannot be predicted or incorporated into our Tahamata scenario analysis.

[5] ABARES (Australian Bureau of Agricultural Resource Economic Sciences) reported productivity gains using time series data from 1997 to 2013. This analysis is reported in Hughes et al. (2017).

2. Conceptual Framework and Methodology

Classification of Ecosystem Services

The concept of ecosystem services emerged in the 1990s as a mechanism for understanding how ecosystems directly and indirectly contribute to human welfare (de Groot 1987, 1992; Daily 1997; Barbier et al., 1997). Ecosystem services can be defined as *ecosystem goods (such as food) and services (such as climate regulation) that benefit humans*. For simplicity, these ecosystem goods and services are usually collectively referred to as 'ecosystem services'. The following 18 ecosystem services, derived from Costanza et al.'s (1997) analysis, were used in our analysis, with some renaming and rewording plus the addition of primary production, which Costanza et al. (1997) did not use: gas regulation, climate regulation, disturbance regulation, water provisioning, water storage and retention, erosion control and sediment retention, soil formation, nutrient cycling, waste treatment, pollination, biological control, refugia, food production, raw materials, genetic resources, recreation, cultural and primary production. Table 1 provides a full definition and examples of each ecosystem service.

We used the Millennium Ecosystem Assessment (MEA) framework (2005) to classify ecosystem services into the following categories: provisioning, regulating, cultural and supporting ecosystem services (see Figure 1).

Figure 1 Millennium Ecosystem Assessment's Ecosystem Services Framework.

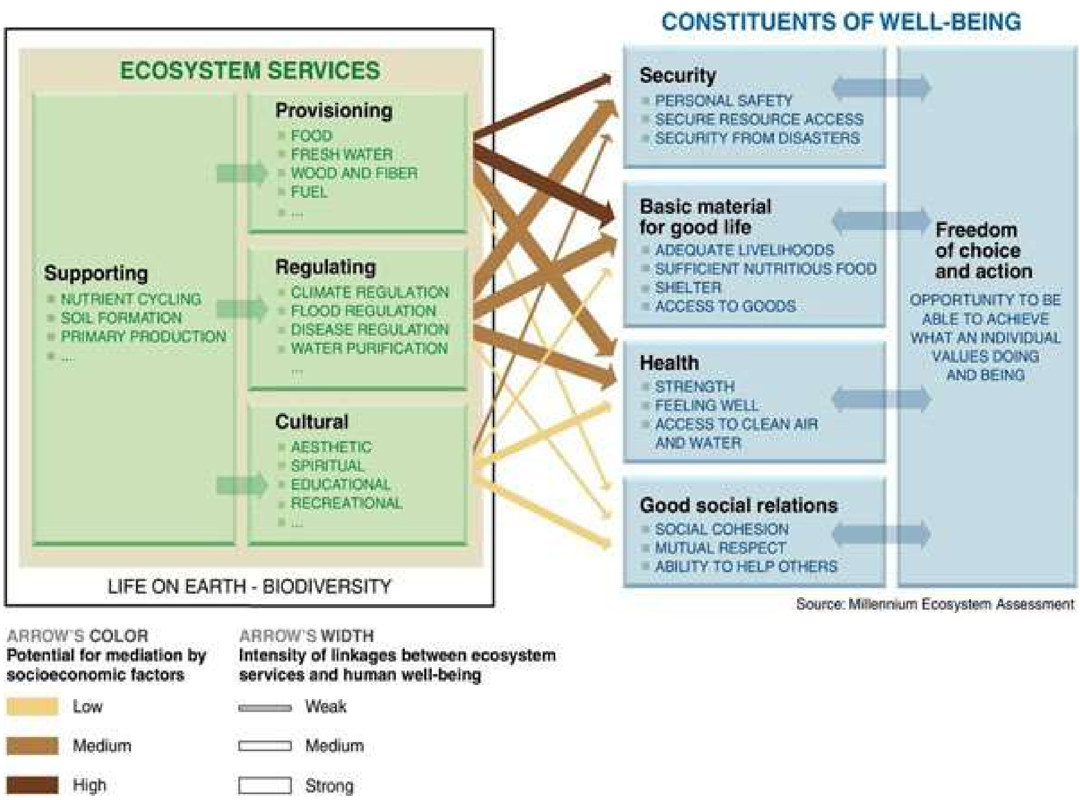


Table 2: Definitions, Examples and Classification of Ecosystem Services

Ecosystem Services	Definition	Examples	Ecosystem Service Classification
Gas regulation	Regulation of atmospheric chemical composition	CO_2 /O_2 balance, O_3 for UV protection, and SO_X levels	Regulating
Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global or local levels	Greenhouse gas regulation, DMS production affecting cloud formation	Regulating
Disturbance regulation	Capacitance, damping, and integrity of ecosystem response to environmental fluctuations	Storm protection, flood control, drought recovery, and other aspects of habitat response to environmental variability mainly controlled by vegetation structure	Regulating
Water provisioning	Regulation of hydrological flows	Provisioning of water for agricultural, industrial processes or transportation	Provisioning
Water storage and retention	Storage and retention of water	Storage of water by watersheds, reservoirs, and aquifers	Supporting
Erosion control and sediment retention	Retention of soil within an ecosystem	Prevention of loss of soil by wind, runoff or other removal processes. Storage of silt in lakes and wetlands	Supporting
Soil formation	Soil formation processes	Weathering of rock and the accumulation of organic material	Supporting
Nutrient cycling	Storage, internal cycling, processing and acquisition of nutrients	N, P and other element or nutrient cycles	Supporting
Waste treatment	Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds	Processing dairy cow urine, faeces and fertiliser run-off	Regulating
Pollination	Movement of floral gametes	Pollinators for the reproduction of plant populations	Supporting
Biological control	Trophic-dynamic regulations of populations	Keystone predator control of prey species, reduction of herbivory by top predators	Regulating
Refugia	Habitat for resident and transient populations	Nurseries, habitat for migratory species, regional habitats for locally harvested species or overwintering grounds	Supporting
Food production	That portion of primary production extractable as food	Production of animals, fish, fruit and vegetables for human consumption	Provisioning
Raw materials	That portion of primary production extractable as raw materials	The production of timber, fibres (e.g. wool) or fodder	Provisioning
Genetic resources	Sources of unique biological materials and products	Medicine, genes for resistance to plant pathogens and crop pests	Provisioning
Primary Production	Synthesis of organic compounds CO_2 mainly from the atmosphere via the process of photosynthesis which 'captures' solar energy as the primary source of energy in the ecosystem.	Growth of grass in the dairy pasture agro-ecosystem. Growth of harakeke (flax) in the wetlands ecosystem	Supporting
Recreation	Providing opportunities for recreational activities	Tourism (visitors to wetlands), birdwatching, fishing and other recreational pursuits	Cultural
Other Cultural	Aesthetic, artistic, educational, spiritual and/or scientific values of ecosystems	Iwi/hapū cultural values associated with the wetlands	Cultural

Note: Adapted from Costanza et al. (1997), with some changes to names of ecosystem services, adding primary production and the classification column.

The advantage of using the Millennium Ecosystem Assessment framework is that it separates 'supporting services' from the other services (particularly regulating), which means that double counting of 'supporting services' can be easily avoided when summing ecosystem service dollar values. That is, in aggregating the dollar values of ecosystem services in our Tahamata study, 'provisioning', 'regulating' and 'cultural' values could be added together, but not that of 'supporting' services', as their value is already included in the dollar values of the first three types of ecosystem services.

Departing from the Millennium Ecosystem Assessment framework, we have not included 'pollination' as a 'regulating' service – rather, we have considered pollination to be a 'supporting' service. That is, pollination supports the provisioning services of food and fibre production, and in that sense is clearly a support service and does not directly contribute to human well-being. In doing this, we agree with Haines-Young and Potschin (2009) that pollination is an 'intermediate service' rather than a 'final service/benefit'. We also question whether pollination is a regulating service, as it does not regulate the environment *per se* as do, for example, the gas or climate regulation services – rather pollination *indirectly* enhances human well-being by providing mass (pollen) for fertilising plants that then in turn produce products (food and fibre) that are directly consumed by humans. A second departure from the framework was considering 'erosion control' to be primarily a supporting service. That is, erosion control enhances and supports provisioning services such as food and fibre production and perhaps regulating services such as 'flood control', but by itself does not *directly* contribute to human well-being or a 'final service'.

Classification of Land Cover and Use

In the 'Ecosystem Services Account', for the base year (2015/2016) and for the three scenarios (2045/46), the following categories of land cover and use were used:

1. wetlands dominated by vegetation such as tree species and harakeke;
2. the water surface area of the wetlands, not including those areas dominated by vegetation;
3. water surface area that is not part of the wetland, with little or no biological features;
4. commercial forestry plantation;
5. dairy farming on well-drained soils;
6. dairy farming on puggy and poorly drained soils;
7. land that consists of puggy and poorly drained soils that is not farmed and has no stock on it.

Classification of Values

The following ecosystem services values are accounted for in this study, based on some modifications of the Millennium Ecosystem Assessment Framework, which were discussed above:

1. ***Provisioning Services Value (PSV).*** This refers to the direct provision of goods and services by an ecosystem. This includes services such as the provision of food, fibre, fresh water and genetic resources. Usually, provisioning services are measured by the System of National Accounts and therefore they are included in GDP calculations, as they are traded on commercial markets, when they are supplied. Frequently, however, provisioning services values are not recorded in the national accounts, as their provision involves no commercial transaction – e.g. the use of firewood obtained free-of-charge from forests.

2. ***Regulating Services Value (RSV).*** This refers to the regulation of biophysical and ecological processes in the environment in order to provide life support and a suitable habitat for human existence. This includes services such as regulation of the climate, flood control, drought recovery, control of pest species and so forth.
3. ***Cultural Services Value (CSV).*** This refers to how the ecosystem contributes to the maintenance of human health and well-being by providing services such as spiritual fulfilment, aesthetics, education, scientific knowledge and cultural well-being.
4. ***Supporting Services Value (SSV).*** This refers to the ecological and biophysical processes that support the provisioning and regulating services of ecosystems. This includes services such as nutrient cycling, soil formation and provision of habitat.

It is very important in adding up or aggregating these values to make the distinction between **Total Gross Value** and **Total Net Value**. In algebraic notation, Total Gross Value and Total Net Value are defined as follows:

$$\text{Total Gross Value} = PSV + RSV + CSV + SSV \quad (1)$$

$$\text{Total Net Value} = PSV + RSV + CSV \quad (2)$$

Although Total Gross Value is frequently used in the literature to 'add up' ecosystem services values for an entire system, it is arguably incorrect to use this as a measure of the total value of ecosystem services (Haines-Young and Potschin 2009). This is because it involves 'double counting' of the supporting services value (SSV). In adding up values across the entire system, it is therefore highly recommended that Total Net Value be used.

Methodological Process

The methodology is comprised of 10 distinct steps that were integrated into a spreadsheet model. First of all, a set of 'Financial Accounts' were constructed for the Tahamata farm (Steps 1-4) for 2015/2016, and for the 'Ecosystem Services Accounts' (Steps 5-7) 2015/2016; we then utilised these accounts to produce three future scenarios (Steps 9-10) to the year 2045/2046 for the Tahamata farm. These methodological steps, and the interrelationships between the steps, are outlined by Figure 2, Figure 3 and Figure 4.

Figure 2   Methodological Steps for Construction of Financial Accounts

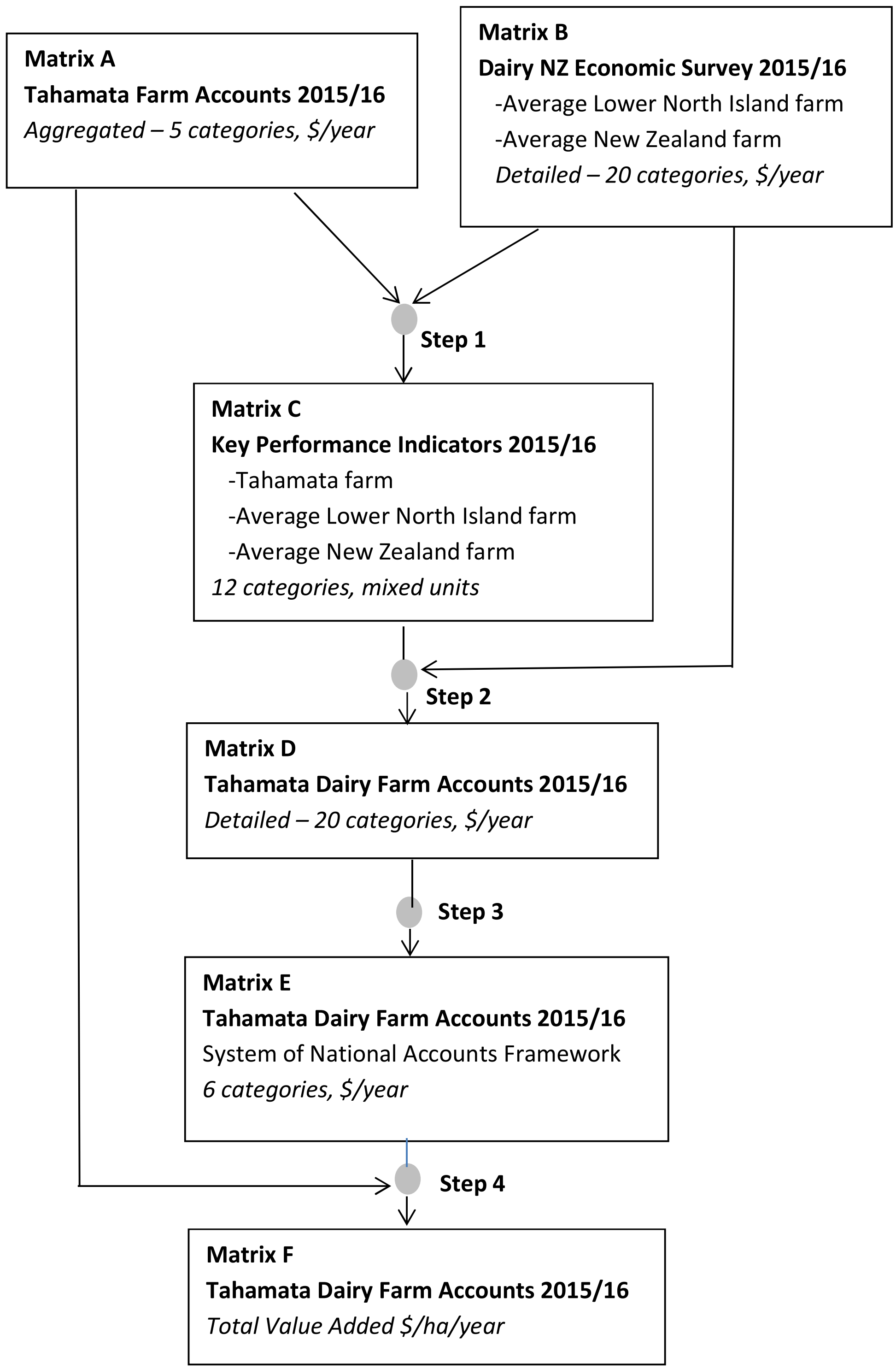


Figure 3 Methodological Steps for Construction of Ecosystem Services Accounts

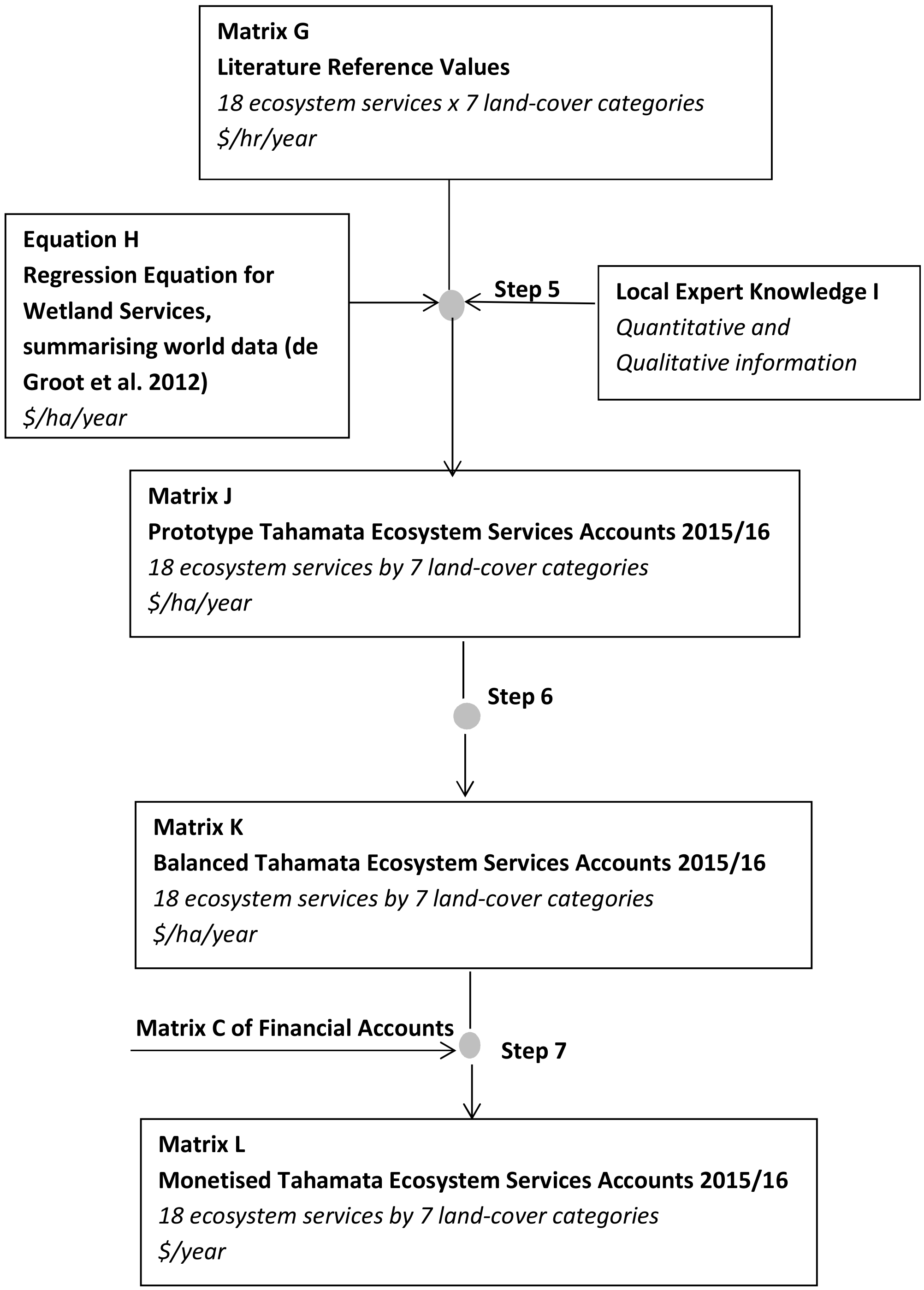
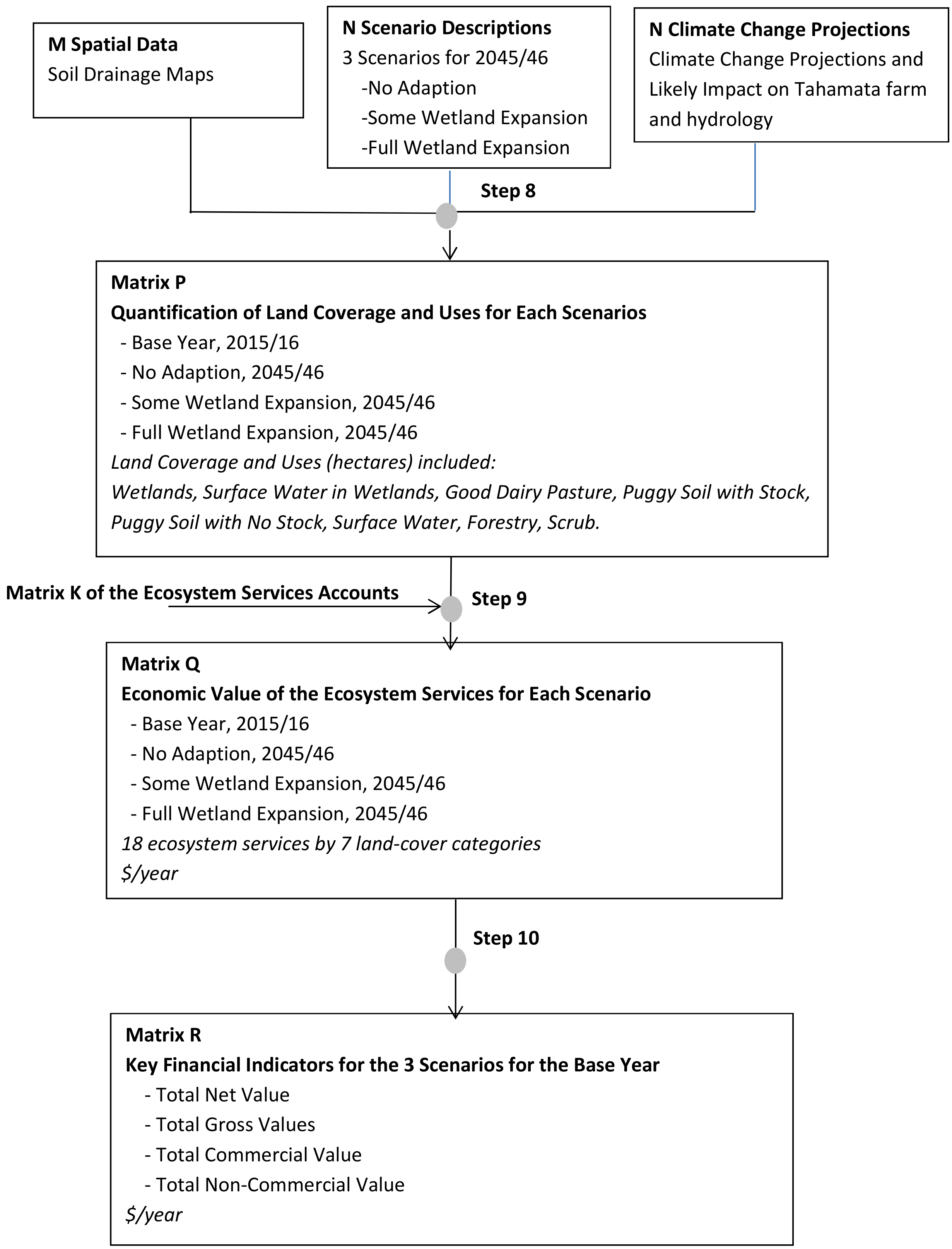


Figure 4 Methodological Steps for Construction of Scenarios



3. Financial Accounts and Ecosystem Services Accounts for the Tahamata Farm

Both the financial accounts and ecosystem services accounts for 2015/2016 for the Tahamata farm were constructed using the methodology outlined in Chapter 2 (Steps 1 to 7). These accounts were used as the base year (2015/2016) for the scenario modelling that is reported in Chapter 4.

Financial Accounts

The indicators that compare the 2015/16 performance of Tahamata farm with the performance of the average Lower North Island dairy farm and the average New Zealand dairy farm are outlined in Table 3. These indicators show that the Tahamata farm covers an area more than double the average for a North Island and New Zealand farm, covering 310 effective hectares. The stocking rate (2.27 cows per hectare) of the Tahamata farm is lower than for the average farm, essentially because most of the Tahamata farm is on light sandy soils that are not as productive compared with other situations – the Tahamata farm, for example, has a productivity of 674.29 kg milk solids/ha/yr, whereas the average North Island farm has a productivity of 995.59 kg milk solids/ha/yr and the average New Zealand farm has a productivity of 1,082.16/ha/yr. However, in spite of this lower productivity of the Tahamata farm, it still has an annual production of 209,030 kg, which is significantly more than the average lower North Island farm at 147,148 kg and the average New Zealand farm at 160,270kg.

Table 3: Benchmark Indicators --Tahamata, Lower North Island Average and New Zealand Average Dairy Farms, 2015/16

Indicators	Tahamata[1]	Lower North Island Average[2]	New Zealand Average[2]
Key Indicators			
Effective Area (hectares)	310.00	147.80	148.10
Peak Cows Milked (number)	703	391	418
Stocking Rate (cows per hectare)	2.27	2.65	2.82
Milksolids Sold (kg)	209,030	147,148	160,270
Milksolids Sold per Cow (kg/cow)	297.34	376.34	383.42
Milksolids Sold (kg /hectare)	674.29	995.59	1,082.17
Milksolids Payout ($/Kg milk solids)	4.13	3.85	3.92
Revenue			
Milksolids Sold ($ /hectare)	2,785	3,833	4,242
Milk Sales ($)	863,294	566,520	628,258
Net Livestock Sales ($)	189,630		
Other Dairy Cash Income ($)	31,344		
Total	1,084,268		

Data Sources:
1. Base data for the calculation of all of these indicators was supplied by the Tamataha Dairy Farm
2. Dairy Economic Survey:2015/16 published by Dairy NZ (2017)

A more detailed picture of the financial accounts of the Tahamata farm and how these compare to the average Lower North Island and the average New Zealand farm is presented in Table 4. The financial data for the average Lower North Island farm and the average New Zealand farm were obtained from the 'Dairy Economic Survey: 2015/16' published by Dairy NZ (2017). The revenue data (milk sales, net livestock sales, other cash income) and total expenditure for the Tahamata farm was supplied by a Tahamata farm representative.

Table 4: Revenue and Expenditure for Tahamata, Lower North Island Average and New Zealand Average Dairy Farms, 2015/16

Revenue/Expenditure Category	Tahamata[1]	Lower North Island[2]	New Zealand[2]
Revenue ($)			
Milk Sales	863,294	569,030	580,552
Net Livestock Sales	189,630	101,982	84,417
Other Cash Income	31,344	5,912	5,924
Total	1,084,268	676,924	670,893
Expenditure ($)			
Compensation for Employees	174,326	104,938	96,265
Animal Health	46,651	28,082	28,139
Breeding and Herd Improvement	29,463	17,736	17,772
Farm Dairy	9,821	5,912	7,405
Electricity	31,919	19,214	16,291
Net Feed Made/Purchased	243,074	146,322	109,594
Stock Grazing	56,472	33,994	59,240
Support Block Lease	29,463	17,736	11,848
Fertilizer	93,301	56,164	62,202
Irrigation	2,455	1,478	7,405
Regrassing	12,276	7,390	7,405
Weed and Pest Control	12,276	7,390	4,443
Vehicles and Fuel	49,106	29,560	25,177
Repairs and Maintenance	56,472	33,994	32,582
Freight and General	14,732	8,868	7,405
Administration	34,374	20,692	17,772
Insurance	19,642	11,824	8,886
ACC	7,366	4,434	2,962
Rates	29,463	17,736	14,810
Total	952,653	573,464	537,603
Capital Depriciation ($)	103,122	62,076	57,759

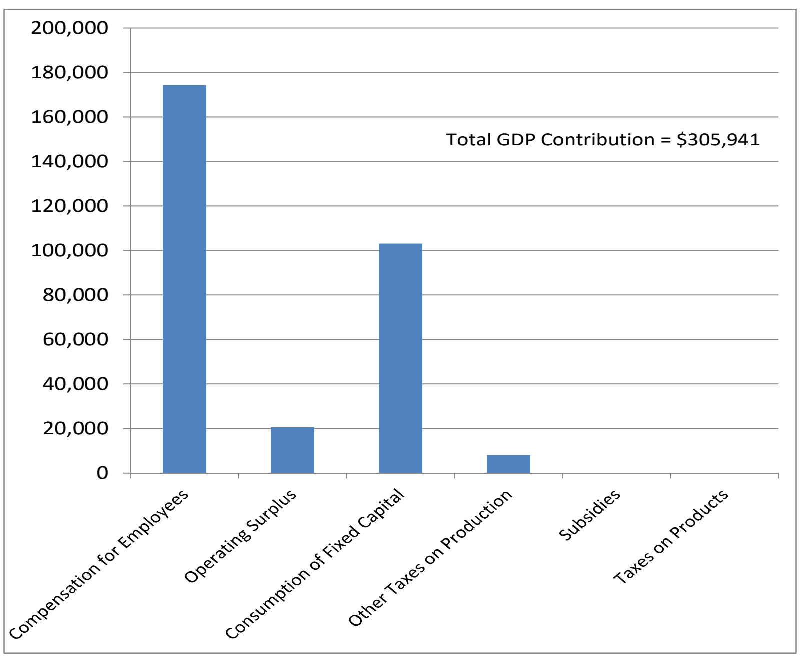
Data Sources:

1. Some data was supplied by Tamataha Dairy Farm including 'Total' values. Most of the data are estimated (disaggregated) using average 'Lower North Island' Average Data obtained form Dairy NZ's Economic Survey (2015/16)
2. Dairy Economic Survey:2015/16 published by Dairy NZ (2017)

All of the other expenditure items ($) and the capital appreciation ($) were estimated by applying the same proportions that occurred for each expenditure item for the average Lower North Island farm – for example, because 'administration' is 5% of the average North Island farm expenditure, the same percentage (5%) was assumed for the administration cost of the Tahamata farm. The authors of this report recognise that some of the detailed expenditure items could be confidential, and thus regional/national averages were used; but it seems unlikely that the Tahamata will vary significantly from our estimates, as on examining the DairyNZ (2017) data for different farm types, there is usually not much variance in expenditure items between types. If more accurate estimates of these items or accountancy data become available, it is very easy to automatically update the accounts and the scenario spreadsheet model and hence to generate new estimates of ecosystem services values of the Tahamata farm.

From the economic perspective of the study, it is important to estimate the farm's contribution to GDP, which is equivalent to the value added by the farm operation – this was calculated using the standard categories that Statistics New Zealand uses in constructing the National Accounts. There are various methods (e.g., income, expenditure, production) for calculating the contribution to GDP – in this study, we use the 'income approach', which sums the total of: compensation for employees, operating surplus, consumption of fixed capital, taxes on production, and taxes on products and subsidies (as a negative item). On this basis, the GDP contribution for the Tahamata farm is calculated to be $305,941 for the year 2015/16, made up of the following components: $173,326 (57.0%) for compensation of employees; operating surplus $20,515 (6.7%); consumption of fixed capital (33.7%); and taxes on production $7,978 (2.6%).

Figure 5: Calculation of GDP Contribution of the Tahamata Farm for 2015/16, Using the Income Method



Finally, as is discussed in detail in Chapter 4, the payout for milk solids ($/kg) is a critical factor, not only in determining the profitability of the farm, but also in determining the GDP contribution of the Tahamata farm. The payout of 4.13 $/kg, when adjusted for inflation, is very low compared with data going back to 1973, and if this payout to the Tahamata farm was to increase, then *ceteris paribus* the 'operating surplus' and hence the total contribution to GDP would increase, as well as perhaps upward pressure on 'compensation to employees'.

Ecosystem Services Accounts

The ecosystem services accounts consists of a matrix of the economic value of 18 ecosystem services by 8 land cover categories, as well as additional rows of data measuring these services according to various valuation metrics outlined in the methodology section (Chapter 2). This matrix was assessed in terms of total economic value ($) and total economic value per hectare ($/ha).

Data Sources and Benefit Transfer. The data for the construction of such ecosystem services accounts for the Tahamata farm are mainly drawn from the following sources:

1. For wetlands, from de Groot at al. (2012) averages for ecosystem services for wetlands, based on a comprehensive analysis of 242 different ecosystem services for inland wetlands worldwide. In addition, in adjusting de Groot at al. (2012)'s wetlands ecosystem services data ($/ha) to the Tahamata wetlands, particular attention was given to the value of their regression coefficients, which measure the influence of various local determinants to the $/ha value – refer to Table 2.

2. For the seven[6] other land cover/use categories, Patterson and Cole's (2013) data was used. Patterson and Cole's (2013) analysis of the 'total economic value' of terrestrial ecosystem services in New Zealand updated revised and corrected data from Cole and Patterson (1997) and Patterson and Cole (1999), by drawing on the New Zealand Centre for Ecological Economics' 'Ecosystem Services Database' that was constructed in 2008–09 for the project, 'Ecosystem Services Benefits in Terrestrial Ecosystems for Iwi' (MAU0502, Foundation for Research, Science and Technology).

   This database contains 282 records for the 7 types of systems (wetlands, forestry, coastal, rivers, lakes, agriculture, conservation parks) across 15 categories of ecosystem services, with most entries directly relevant to the New Zealand situation.

3. Expert knowledge about the Te Hākari wetlands in the Horowhenua region was gained in an interview between Professor Patterson and Derrylea Hardy (Massey University ecology economics) with Dr Huhana Smith (Trustee, Tahamata farm; lead Maori researcher on this project). Dr Smith has vast experience in environmental research with a focus on wetlands, having led the restoration of Te Hākari wetlands and completed a PhD thesis on this topic (Smith, 2007). Dr Smith also co-led major ecological/cultural research programmes in the

[6] These 'other seven other land cover/use categories' include:
(1) water surface of wetlands,
(2) other water surfaces,
(3) commercial forestry plantation,
(4) scrub,
(5) dairy farming on well-drained soils,
(6) dairy farming on puggy, and poorly drained soils,
(7) puggy and poorly drained soils with no farming or stock.

Horowhenua region with Professor Patterson ('Ecosystem Services Benefits in Terrestrial Ecosystems for Iwi' and 'Manaaki Taha Moana' – www.mtm.ac.nz) since 2005, funded by the Foundation for Research Science and Technology and the Ministry of Business Innovation and Employment – refer to Smith et al. (2014), Hardy et al. (2015) and Hardy and Patterson (2012) for a summary of the latter research programmes, and Cole (2009a, b) for further details of the ecological research from the former programme.

As is outlined in the methodology section (Chapter 2), the first step in establishing ecosystem services accounts was to estimate what proportion of the 'reference level' in $/ha [obtained from de Groot at al. (2012) and Patterson and Cole (2013)], translated into actual economic values for each of the Tahamata land covers/uses – refer to Table 5 for a summary of these 'proportions to the reference level' determined in this study, as well as the text below for a more detailed explanation.

Wetlands. In our analysis, considerable emphasis was placed on calculating appropriate levels relative to the world 'reference level', because the economic value of wetlands ecosystem services was a significant factor in all of the scenarios, and in particular for scenario three. As the current Te Hākari wetland is under a covenant (and we are assuming the same situation will be the case for all wetlands on the Tahamata farm), this prevents using the wetland as a food source. Thus, we assume that these wetlands will not be used as a food source and therefore attributed an economic value of 'zero' or 'zero %' of the world average. That is not to say that in the future, iwi/hapū and other stakeholders may choose to use the wetlands as a food source – if they did, the economic value of these wetlands would increase, accordingly. Similarly, for raw materials, although there is some evidence of using a very small amount of harakeke, it was found that the actual use of wetlands for raw materials was very low (10%), but the potential use (and economic value) could be quite high if, for example, harakeke from the area was used as a source of fine fibre for high-end cloth and dress materials. However, even with greater use of the wetlands for food and fibre products, it is unlikely that it will reach the level of many overseas studies, particularly in the developing world. For example, as cited by the Millennium Ecosystem Assessment (2005), these products from wetlands around the world include: fruit, fish, shellfish, deer, crocodile and other meats, resins, timber for building, fuelwood, peat, reeds and fodder for animals.

Table 5: Estimated Levels (%) of Use of Ecosystem Services in the Tahamata Farm, Relative to 'Reference Levels' (expressed in $NZ_{2015/16}$ per hectare, except where noted)

Landcover and/or Landuses	Wetlands Dominated by Vegetation	Surface Water - Wetlands	Forestry	Scrub	Dairy Pasture	Puggy and Poorly Drained: No Stock	Puggy and Poorly Drained: With Stock	Surface Water - Other
Reference Level	De Groot et al.'s (2012) 'Inland Wetlands', except 'Gas Regualtion' from Patterson and Cole (2013)	Patterson and Cole's (2013) 'Lake Ecosystem'	Patterson and Cole's (2013) 'Forestry Ecosystem'	Patterson and Cole's (2013) 'Scrub Ecosystem'	Patterson and Cole's (2013) 'Agricultural Ecosystems'	Patterson and Cole's (2013) 'Agricultural Ecosystems'	Patterson and Cole's (2013) 'Agricultural Ecosystems'	Patterson and Cole's (2013) 'Lake Ecosystem'
Food	0	0			Actual Data[7]	0	50% of 'Dairy	0
Water Provisioning	10	0			100	0	50% of 'Dairy	0
Raw Materials	10		Estimated[6]		100	0	50% of 'Dairy	
Genetic/Medicinal Resources	100							
Climate Regulation	100		100	100				
Disturbance Regulation	35							
Water Storage and Retention	60	60						Residual[4]
Waste treatment	100	100	100	100	100	100	50% of 'Dairy	5% of 'Lake
Erosion Control	10		100	100[3]	100	100	50% of 'Dairy	
Nutrient Cycling	100		100	100[3]				
Biological Control	100		100	100	`	`		
Gas Regulation	100				100	100	50% of 'Dairy	
Refugia	100							0 `
Cultural - Other	110	Residual[2]	110	110	110	110	50% of 'Dairy	0
Recreation	30	30	30		100	100	50% of 'Dairy	
Soli Formation	100		100	100[3]	100	100	50% of 'Dairy	
Pollination	100				100	0	50% of 'Dairy	`
Primary Production	Residual[1]		Residual[1]		Residual[1]	Residual[1]	50% of 'Dairy	

Notes:
1. 'Primary Production' is the Residual Value Required to Balance: ∑ $ Supporting Services = ∑ $ Provisioning Services +∑ $ Cultural Services + ∑ $ Regulating
2. 'Cultural Services - Other' is the Residual Value Required to Balance: ∑ $ Supporting Services = ∑ $ Provisioning Services +∑ $ Cultural Services + ∑ $ Regulating
3. 'Erosion Control', 'Nutrient Cycling' and 'Soil Formation' are multiplied by 0.88 to Balance: ∑ $ Supporting Services = ∑ $ Provisioning Services +∑ $ Cultural Services + ∑ $ Regulating
4. 'Water Storage and Retention' is multiplied by 0.523 so that: $ Water Storage and Retention (Supporting Service) = $ Waste Treatment (Regulating Service)
5. A blank space means that that ecosystem services (for the specified land cover) has no recorded 'reference level' in the literature
6. Based on Average Forestry Production ($/ha) for New Zealand. Data sources for this calculation are: Yao et al. (2013) and Market Economics Ltd (2013)
7. Data directly obtained from Tamataha Farm 2015/16 Accounts for milk and livestock sales. Not all milk is used to produce 'Food' products - hence, in strict terms some proportion of the farm's production should be classified under 'Raw Materials'.

Wetlands have also been noted in the literature as a being a good **source of water** for human consumption, animal consumption and irrigation. The exact hydrology of existing and potential Wetlands on the farm, although appreciated in broad terms, is uncertain; for example, in terms of its role in the recharge/discharge of groundwater. However, it is known that some water from the wetland is currently used as a water source for stock, although this use is minimal, hence 'water provisioning' was assessed to be at 10% of the world reference level.

In overseas studies, the role of wetlands in **storm protection and flood control** is very widely cited; for example, de Groot et al. (2012) calculate the world average for disturbance regulation' (storm protection, flood control, drought recovery) to be $\$US_{2007}$ 4,585 per hectare per year. An often cited example of this in the literature is the role that wetlands have historically played in protecting New Orleans and other population centres in coastal Louisiana from storm surges, and how the removal of these wetlands catastrophically contributed to the damage to these population centres with the onset of Hurricane Katrina (Tibbits, 2006). That said, the situation on Tahamata farm is very different to many of these economic valuations of storm protection and flood control services for wetlands, simply because the Tahamata farm does not protect (and will not protect in the future) large population areas such as in New Orleans. Hence, even accepting that the Tahamata wetlands would be an effective buffer against storm events, which are projected to increase with frequency and magnitude from climate change, there is very little property, assets or even the risk of loss of human life that would result from such a storm event. On the other hand, there would be, particularly under scenario three, circumstances whereby wetlands would provide good protection of farmland from storm events, which cause negative impacts on farm production as well as loss of soil/erosion. Therefore, on balance, we attributed 30-40% of the world reference level for 'disturbance regulation' for the Tahamata wetlands.

The role that wetlands play in '**water storage and retention**' and in moderating hydrological regimes is well known. Firstly, from an accounting point of view, it needs to be recognised that the 'water storage and retention' ecosystem service is a support service – that is, it does not directly impact on benefiting human welfare; rather, it delivers benefits to humans via other ecosystem services, namely the provisioning, regulating and cultural services. For example, 'water storage and retention' underpins the 'disturbance regulation' (storm protection, flood control, drought recovery) services by absorbing water during times of peak hydrological flows and releasing water during times of drought. Similarly, 'water storage and retention' underpins services such as 'recreation' (e.g., water body for kayaking), refugia (e.g., providing habitat for native species), food production (e.g., source of water vital to many living species) and water provisioning (e.g., source of water for stock). So, in calculating the percentage of the world reference level for 'water storage and retention', we needed to take account of the Tahamata ecosystem services that 'water storage and retention' contributes to – because some, but not all, of the provisioning, cultural and regulation services that 'water storage and retention' contribute to was relatively low, we calculated the level for 'water storage and retention' at 60% of the world reference level.

The role that wetlands play in processing nutrients, animal wastes and human waste is also well cited in the literature. In their calculation of the world average from 242 observations, de Groot et al. (2012) put **waste treatment** as the highest economic value of any wetland ecosystem service, at $\$NZ_{2015/16}$ 8,608 per hectare, which is almost double the amount for 'disturbance regulation', which is calculated to be the second highest wetland ecosystem service. Wetlands play an important role in removing and processing high amounts of sediments, nitrogen and phosphorus, which are commonly associated with agricultural run-off. If such things were not removed by wetlands, there would be significant eutrophication of receiving ground, surface and coastal waters. For example, Brown (1981) found that cypress swamps in Florida can remove 98% of nitrogen and 97% of phosphorus that would otherwise have entered the groundwater. Similarly, Arcadis Euroconsult (2001) found that wetland vegetation along the edge of Lake Victoria in East Africa had a phosphorus retention of 60-92% of nutrients entering the system. For New Zealand, Clarkson et al. (2013), confirming that New Zealand wetlands play similar roles in removing nutrient run-off, pointed out that wetlands in the lower parts of catchments with large contributing areas are more efficient in removing nitrogen, while wetlands in the upper reaches are most effective at removing phosphorus. In regard to the existing Te Hākari wetland, we know from our knowledge of the local hydrology that had been monitored using piezometers, that nutrients and sediments from the surrounding farmland area flow directly into the Te Hākari wetlands. In our Scenario 3, Full Expansion of Wetlands, much of this wetland will be at the mouth of the Ōhau River, being optimally placed to process nutrients not only from the Tahamata farm, but also further up the catchment. Therefore, by considering all of these factors, we have assumed in our analysis that the 'waste treatment' ecosystem service is at 100% of the world 'reference level'. This gives a value of $\$NZ_{2015/2016}$ 4,612 per hectare for 'waste treatment' for our Tahamata case study. This is a lower level than what Dominati et al. (2010, 2014) found for filtering nitrogen ($\$_{2010}$554 ha/yr), phosphorus ($\$_{2010}$ 2,922 ha/yr), and contaminants ($\$_{2010}$ 5,659 ha/yr), on a Horotiu silt loam on a dairy farm in the Waikato, although their data is not strictly comparable with the analytical frame of our current study.

de Groot at al. (2012) calculate a relatively high value of $\$NZ_{2015-2016}$ 4,003 ha/year for "**erosion prevention**". It is difficult to see how this figure could be applicable to the Tahamata wetland, particularly as it exists currently; it seems this figure might be more applicable to wetlands that border watercourses or coasts where the land might be more susceptible to erosion. However, it is possible that wetlands in the Tahamata farm may play some role in stabilising dune systems, and insofar as wetlands moderate hydrological flows through the 'water storage and retention' service, there may be an indirect 'erosion control service' provided. In light of the uncertainty and lack of information about these factors, we conservatively assessed our Te Hākari wetlands at 10% of the world 'reference value' for this service.

Worldwide, inland wetlands are important for **recreation** and indeed a source of **tourism** income, particularly when they are protected as national parks, world heritage sites or wetlands of international importance (e.g., Ramsar sites). The attraction is undoubtedly the rich biodiversity of animal and plant life, the aesthetic appeal and the wilderness characteristics. All of these features are evident at the current Te Hākari wetlands and neighbouring estuary, as described in Chapter 1. For these reasons, Te Hākari wetlands are visited by educational and school groups, birdwatchers, and birdlife is monitored by Horowhenua's Royal Society of Forest and Bird group. That said, the level of visitation by these group as well as iwi/hapū/whanau is low when compared with studies in the literature that underpin the de Groot's (2012) world reference level; therefore, we have selected 30% for the Tahamata wetlands, relative to the world average.

Cultural ecosystem services is a 'catchall' category that is used in the ecosystem services literature to cover not only recreation and tourism as mentioned above, but also aspects such as **aesthetic values, artistic values, educational values and spiritual characteristics**. For many, this 'catchall' category is problematic on a number of levels. Firstly, the actual label 'cultural' is a vague descriptor, and it could be argued that all of the ecosystem services are cultural to some extent because they are defined and given meaning by the 'cultural lense' used by the observer. Secondly, it is used in a very inconsistent way, with barely one study to the next using the same bundle of so-called cultural values. Thirdly, confining iwi/hapū values to one category, for one box in the overall "ecosystem services framework", could be argued as confining, simplistic and not a reflection of the way Māori see or experience the world. This general issue is very well argued by Šunde (2008, 2012), who points out that it is not only wrong for indigenous cultures to be treated this way, but also other cultures as well. Fourthly, perhaps a more value neutral term is 'non-material' or 'non-physical' ecosystem services. Thus, it is very difficult not only to translate world averages for so-called 'cultural' values to the Tahamata wetlands, but even undertaking primary surveys relevant to the so-called 'cultural' values of the Tahamata wetland is deeply problematic. For example, how could one possibly calculate the 'willingness to pay' of a spiritual value or the 'replacement cost' of a spiritual value.

In Smith's PhD (2007), she went to great lengths to document and validate the importance of the landscape in this general area to Ngāti Te Rangitāwhia, Te Mateawa, Ngāti Manu and Ngāti Kapumanawhiti, all of whom are affiliated to the iwi Ngāti Tukorehe. None of these values described by Smith (2007, 2012) are amenable to economic valuation. Being clearly cognisant of these problems, we decided to recognise the fact that these wetlands are important to iwi/hapū by nominally rating 110% of the world reference level, which was calculated by de Groot et al. (2012). Another option would have been to delete this value entirely, but some would argue this is tantamount to giving cultural values a zero value. Smith (2007) writes in her thesis, and in a later report (Smith, 2012) for a FRST-funded research project *Ecosystem Services Benefits in Terrestrial Ecosystems for Iwi*, that:

> *'There is a need to re-engender the role of human interdependencies and inter-relationships to each other, to the natural, spiritual and cultural in landscape, and to allow dynamic movement between them. Such thinking is central to a Māori environmental worldview.'*

The **climate regulation** function, in particular the ability of wetlands to store carbon, is a significant ecosystem service provided by wetlands, although the picture is a complex one with wetlands also emitting methane, which is potent greenhouse gas. According to Clarkson et al. (2013), when the overall dynamics of wetlands as a source and sink of greenhouse gases is considered, they generally compare favourably with other terrestrial ecosystems. Although the net carbon release versus carbon sequestration changes over the lifetime of a wetland, Whiting and Chanton (2001) concluded on the longer term scale (>500 years) and on the global level that carbon sequestration is greater than carbon release in the atmosphere. Costanza's (2008) proximal global ecosystem services made a distinction between global (non-proximal), local proximal, directional flow, and user movement-related ecosystem services. Within this classification system, climate regulation is clearly a global ecosystem service, as it benefits everyone on the planet. This strongly implies that 100% of the world reference level is the appropriate assessment for the climate regulation service of the Tahamata wetlands, unless we can establish some ecological reason why the greenhouse gas emission/sequestration profile of the Tahamata wetlands differs from the world average.

The other wetland ecosystem services (**genetic/medicinal, nutrient cycling, biological control, gas regulation, refugee, soil formation, and pollination**) that we have yet to consider, are mainly support services, which are inherently more difficult to calculate, as they do not directly contribute to human welfare. However, they do indirectly contribute to human welfare via other ecosystem services, as in the case of gas regulation as it is a global ecosystem service. Therefore, because of these complications in calculating the percentage level of these ecosystem services relative to the world reference level (world average) provided by de Groot (2012), we initially assumed all of the services to be at the 100%, and considered primary production to be the balancing factor in making sure that the following accounting identity held true:

$$\sum \$ \text{ Supporting Services} = \sum \$ \text{ Provisioning Services} + \sum \$ \text{ Cultural Services} + \sum \$ \text{ Regulating} \quad \text{[equation (3)]}$$

Primary production was used as the balancing factor because: (1) de Groot et al. (2012) neglected to include primary production in their database of world ecosystem services including wetlands ecosystem services; and (2) the fact that ∑ $ Supporting Services < ∑ $ Provisioning Services +∑ $ Cultural Services + ∑ $ Regulating, suggesting that either there are inaccuracies in the data and/or something is missing – in this case of the wetlands (and other land covers/land uses covered in this study), 'primary production' seemed to be the obvious candidate to make sure the above accounting holds true and is 'balanced'.

Other Land Uses and Land Covers. The economic valuation of the other land covers and land uses also required assessment relative to some reference level. In this case, the economic valuation of terrestrial ecosystem services in New Zealand by Patterson and Cole (2013) seemed more appropriate than using data from the de Groot et al. (2012) database. This was essentially because the latter mainly considered 'natural' biomes, whereas the Patterson and Cole (2013) data was not only New Zealand specific, but it also had a stronger focus on 'human modified' ecosystems such as different categories of agricultural and horticultural land use, as well as forestry land use and scrub, which are more applicable to the Tahamata analysis. The selection of a % value in reference to the New Zealand 'reference level', in most cases, is far easier to justifying and the selection of a % value in relation to a world average 'reference level' was used in the case of wetlands. This is because, unless the Tahamata situation is significantly different from the typical New Zealand situation, the straightforward conclusion that we made in most cases was to assign a 100% level, with the exceptions being for 'poorly drained soil with stock' and 'surface water-other'. In the case of 'poorly drained soil with stock', there was a simple algorithm in the spreadsheet model which required the end user to: (i) specify the number of months per year such land was available for grazing – the default value is eight months based on the assumption that the pasture would be unavailable for the winter months of the year; and (ii) loss of productivity due to a lower stocking rate on this "puggy and poorly drained" pasture. Taking both of these factors together, the default value was calculated to be productivity per hectare of 50% of the New Zealand reference level, obtained from Patterson and Cole (2013).

For food production, economic value was directly taken from the financial accounts for the Tahamata farm and worked out on a per hectare basis, so this figure could be applied to the scenarios as well as for the base year. The forestry production was similarly calculated on a $/hectare basis using production data and in land use from Yao et al. (2013) and Market Economics Ltd. In doing so was assumed that the net economic value of commercial plantation forestry ($/ha) was the same as the New Zealand average value, which may be an over estimate given the somewhat harsh coastal location of the Tahamata forest.

Economic valuation data ($/ha) for the ecosystem service of 'primary production' was not available for forestry and dairy pasture (whether it be on well-drained soils or puggy soils) –

this data for primary production was not available from Patterson and Cole (2013) or de Groot et al. (2102). Therefore, for primary production of wetlands, it was estimated by assuming it was the residual required to balance the accountancy identity specified by equation (3). This method of balancing the accounting identity was found to give plausible results.

The most difficult land cover to calculate the existence services value for was for the 'surface water–other' category. This essentially refers to ponding of water that may to some extent be seasonal, which occurs in Scenario 1, and accounts for 35.3 hectares of coverage. Because this surface water really only represents a volume of water sitting on the surface that has very little biological activity and certainly no significant vegetation or habitat for animal species, it is assumed that it has a low level of ecological value and services. Of course, in time through ecological succession, sequences that are very evident in dune systems will evolve, but not within the time span of our analysis. Therefore, we have assigned a nominal 5% to the provisioning service of 'waste treatment', based on the assumption that there will be at least some waste treatment, perhaps due to microbial activity and/or simply a dilution effect. We used the 'reference level' of a New Zealand lake ecosystem, which indicates the provision of two ecosystem services: 'waste treatment' and its supporting service, 'water storage and retention'. Therefore, on a $per hectare basis, by applying the accounting identity equation (3), if waste treatment is 5% of the New Zealand lake reference system, then by arithmetic implication, 'water storage and retention' must be 2.62%.

To make sure that equation 3 applied to this growth coverage, all of the supporting services needed to be scaled down using a scalar of 0.88. Unfortunately, this process assumed that there was no value attributed to the 'primary production' service of scrub, although we know that the 'erosion control' ecosystem services on the dune systems on which the scrub mostly occupies is of significance to the Tahamata farm.

The surface water of wetlands was calculated using the 'lake ecosystem' New Zealand reference level from Patterson and Cole (2013), which contained no value for the 'cultural–other' ecosystem service that would be expected for this category, given the importance of the wetlands to iwi/hapū, as discussed above. This anomaly was accommodated by using 'cultural–other' as the residual to balance equation 3, which fortunately was broadly commensurate with the relative level of 'cultural–other' as was assigned to 'wetlands dominated by vegetation'.

Value of Ecosystem Services per Hectare. The ecosystem services accounts for the Tahamata farm on a '$ per hectare basis', for 18 ecosystem services x 8 land covers/uses are outlined in Table 6. The standout feature of the data in Table 6 is the high value per hectare attributed to wetlands. The analysis found that, for 16 of the 18 ecosystem services, wetlands had the highest per hectare value of any of the other land covers/uses covered in our analysis. The only exceptions were that dairy pasture (whether on drained or puggy soils) had a higher value per hectare for 'food production' and for dairy pastures that were well-drained, they had a higher value for 'erosion control'. Overall, wetlands (combining vegetative and water features) had a per hectare value of ($$_{2015/2016}$ 17,894 ha/yr), which is nearly 13 times higher than dairy pasture on well-drained soils at ($$_{2015/2016}$ 1,411 ha/yr). None of this is surprising given that it is very widely accepted in the scientific community that inland wetlands are amongst the most productive, diverse, complex and valuable ecosystems worldwide, and consistently on a per hectare basis outrank virtually all other natural and modified ecosystems on a value per hectare basis – with the exceptions being 'coral reefs', which de Groot et al. (2012) assess to have a world average value of (US_{2007}$ 352,249 ha/yr) and 'coastal wetlands'[7], which are assessed to have a world average value of (US_{2007}$ 28,917 ha/yr).

Our estimate of the overall net value ($NZ $_{2015/2016}$ 17,894 ha/yr) for wetlands compares with de Groot et al.'s (2012) 'total economic value' of ($NZ $_{2015/2016}$ 23,305 ha/yr) – our estimate is lower because our Tahamata value does not include food production, has a very low value for raw materials, and some of our other ecosystem services (recreation, disturbance regulation) have moderate to low values, essentially because there is a low population base in the Tahamata area and the broader Horowhenua, which decreases the per hectare value. It should also be noted that our overall net value per hectare is similar to that obtained by Costanza et al. (1997) and Patterson & Cole (2013), but is notably higher than in the Millennium Ecosystem Assessment (2005), which appears to be the outlier.

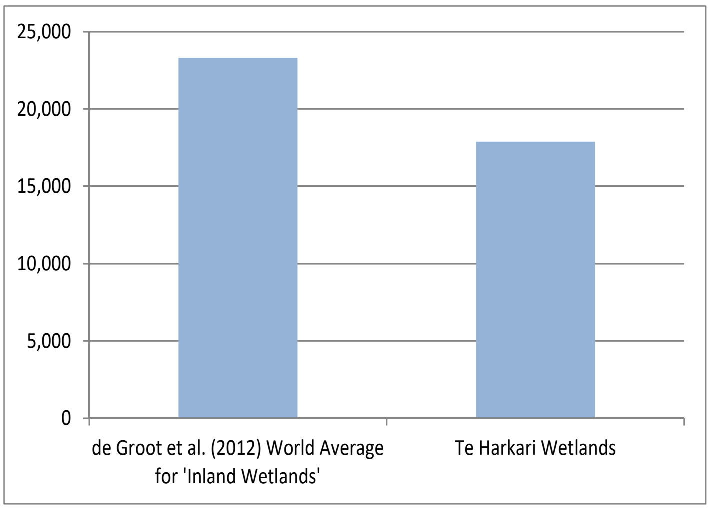


Figure 6: Economic Value of World Average Wetlands versus Te Hākari Wetlands (NZ$_{2015/2016}$ ha/yr)

[7] de Groot et al. (2012) define 'coastal ecosystems' as estuaries, continental shelf areas in seagrass, but exclude wetlands like tidal marsh, mangroves and salt water wetlands.

Table 6: Economic Value per hectare for Different Land-Covers and Land-Uses for the Tahamata Farm (NZ_{2015/2016}$ per hectare per year)

Ecosystem Services	Type of Ecosystem Service	Wetlands Dominated by Vegetation	Surface Water - Wetlands	Surface Water - Other	Forestry	Scrub	Dairy Pasture	Puggy and Poorly Drained: No Stock	Puggy and Poorly Drained: With Stock
Food	Provisioning						958	0	479
Water Provisioning	Provisioning	63					9	9	5
Raw Materials	Provisioning	83			661		57	0	29
Genetic/Medicinal Resources	Provisioning	152							
Climate Regulation	Regulating	749			280	280			
Disturbance Regulation	Regulating	1,605							
Water Storage and Retention	Supporting	5,165	4,042	106					
Waste treatment	Regulating	4,629	2,114	106	277	276	277	277	138
Erosion Control	Supporting	400			390	343	780	357	390
Nutrient Cycling	Supporting	2,630			230	202			
Biological Control	Regulating	1,456			13	12	73	73	37
Gas Regulation	Regulating	733					22	22	11
Refugia	Supporting	3,770							
Cultural - Other	Cultural	3,365	1,709		7	5	7	7	3
Recreation	Cultural	1,018	219		34		6	6	3
Soil Formation	Supporting				32	27	3	1	2
Pollination	Supporting						80	36	40
Primary Production	Supporting	1,887			620		548	0	274
Gross Total (P+C+R+S)		27,705	8,084	211	2,544	1,145	2,821	790	1,411
Net Total (S) = (P+C+R)		13,852	4,042	106	1,272	573	1,411	395	705
Provisioning (P)		297	0	0	661	0	1,025	9	513
Cultural (C)		4,383	1,928	0	41	5	13	13	7
Regulating (R)		9,172	2,114	106	570	567	372	372	186
Supporting (S)		13,852	4,042	106	1,272	573	1,411	395	705

Note:
These values (NZ_{2015/2016}$ per hectare per year) are assumed to apply to the Base Year (2015/16) and the Terminal Year (2045/2046) for all 3 Scenarios

In considering Figure 6, in addition to those factors above that explain the discrepancy between the world average per hectare value and the Te Hākari wetlands per hectare value, is the fact that there is arguably some double-counting in the de Groot et al. (2012) calculations in that they add up a supporting service (nutrient cycling) with the other services, which results in an over-inflated value of the de Groot et al. (2012) estimate.

Value of Ecosystem Services for the Tahamata Farm. The final ecosystem service accounts for the Tahamata Farm for 2015/2016 are outlined in Table 7, expressed in terms of $\$NZ_{2015/2016}$. Overall, the net economic value of ecosystem services for the Tahamata Farm for 2015/2016 is $681,579, of which $328,844 (48.3%) has a commercial value in the sense that it represents the net value per year of products sold from the activities of the Tahamata Farm. The non-commercial value of $352,735 (51.8%) represents ecosystem services that currently have no market price, and the economic value of these ecosystem services are imputed by using the non-market valuation methods outlined in the methodology section (Chapter 2).

According to the Millennium Ecosystem Services assessment framework, the **provisioning, cultural and regulating** ecosystem services all contribute 'directly to human well-being' – as such their relative economic values ($\$NZ_{2015/2016}$) are outlined by Figure 7.

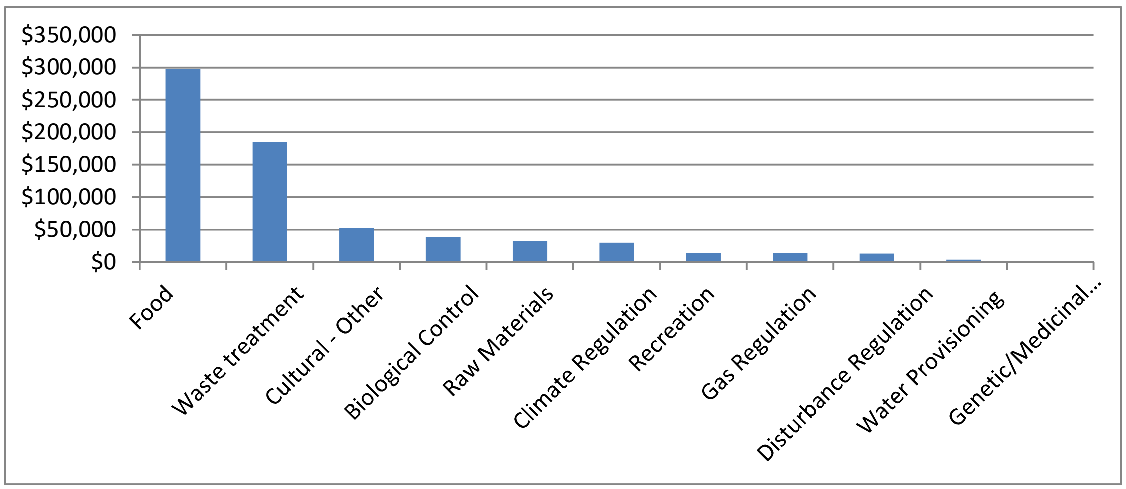


Figure 7: Economic Value ($NZ) of Provisioning, Cultural and Regulating Ecosystem Services* for the Tahamata Farm 2015/2016
(* These are the ecosystem services that 'directly' contribute to human well-being)

Overall, these services are estimated to provide $681,579 of **net value** for Tahamata Farm per year including the Te Hākari wetlands. Not surprisingly, food[8] production has the highest value at $297,096 per annum, given that milk production is the main product of the farm, and that there is a covenant preventing food harvesting from the Te Hākari wetland. 'Waste treatment' is the second largest ecosystem service, providing $184,699 per annum, with pasture soils

[8] For convenience, we have classified all milk production as 'food production' even though not all milk is used to produce food products. By re-classifying some of the milk production to raw materials, to reflect the fact that not all milk is used for food, has no effect on the overall results of this project – for example, the all-important 'net value' indicator remains the same.

Table 7: Economic Value of Ecosystem Services for the Tahamata Farm ($\$NZ_{2015/2016}$)

Ecosystem Services	Type of Ecosystem Service	Wetlands Dominated by Vegetation	Surface Water - Wetlands	Surface Water - Other	Forestry	Scrub	Dairy Pasture	Puggy and Poorly Drained: No Stock	Puggy and Poorly Drained: With Stock	Total
Area Covered (hectares)		8.3	12.8	0.0	21.2	64.4	310.0	35.3	0.0	452.0
Food	Provisioning	0	0	0	0	0	297,096	0	0	297,096
Water Provisioning	Provisioning	519	0	0	0	0	2,919	332	0	3,771
Raw Materials	Provisioning	686	0	0	14,009	0	17,738	0	0	32,433
Genetic/Medicinal Resources	Provisioning	1,260	0	0	0	0	0	0	0	1,260
Climate Regulation	Regulating	6,212	0	0	5,937	18,014	0	0	0	30,163
Disturbance Regulation	Regulating	13,303	0	0	0	0	0	0	0	13,303
Water Storage and Retention	Supporting	42,815	51,628	0	0	0	0	0	0	94,443
Waste treatment	Regulating	38,378	27,004	0	5,870	17,802	85,870	9,775	0	184,699
Erosion Control	Supporting	3,318	0	0	8,265	22,099	241,847	12,606	0	288,136
Nutrient Cycling	Supporting	21,805	0	0	4,872	13,037	0	0	0	39,713
Biological Control	Regulating	12,067	0	0	267	742	22,662	2,580	0	38,318
Gas Regulation	Regulating	6,075	0	0	0	0	6,899	785	0	13,759
Refugia	Supporting	31,250	0	0	0	0	0	0	0	31,250
Cultural - Other	Cultural	27,892	21,832	0	147	350	2,160	246	0	52,626
Recreation	Cultural	8,443	2,792	0	727	0	1,964	224	0	14,150
Soil Formation	Supporting	0	0	0	675	1,772	955	50	0	3,451
Pollination	Supporting	0	0	0	0	0	24,678	1,286	0	25,965
Primary Production	Supporting	15,647	0	0	13,148	0	169,827	0	0	198,622
Gross Total Value(P+C+R+S)		229,671	103,255	0	53,918	73,814	874,616	27,884	0	1,363,158
Net Total Value (S) = (P+C+R)		114,835	51,628	0	26,959	36,907	437,308	13,942	0	681,579
Provisioning (P)		2,466	0	0	14,009	0	317,754	332	0	334,561
Cultural (C)		36,335	24,624	0	874	350	4,124	469	0	66,776
Regulating (R)		76,035	27,004	0	12,075	36,557	115,431	13,140	0	280,242
Supporting (S)		114,835	51,628	0	26,959	36,907	437,308	13,942	0	681,579
Commercial Value		0	0	0	14,009	0	314,835	0	0	328,844
Non-Commercial Value		114,835	51,628	0	12,950	36,907	122,473	13,942	0	352,735

Note:
'Net Total Value' is the most appropriate metric of the 'total' value of ecosystem services, as it avoids 'double-counting' which is the case for 'Gross Total Value' metric.
To emphasize this point the 'Net Total Values' have been underlined.

providing more than half of this service ($95,645) and as well as Te Hākari wetland providing a significant amount of waste treatment services ($65,382 per annum).

The **supporting services** role, as their name would suggest, is to 'support' the above ecosystem services that directly contribute to human well-being – Figure 7 ranks the support services in terms of their economic value.

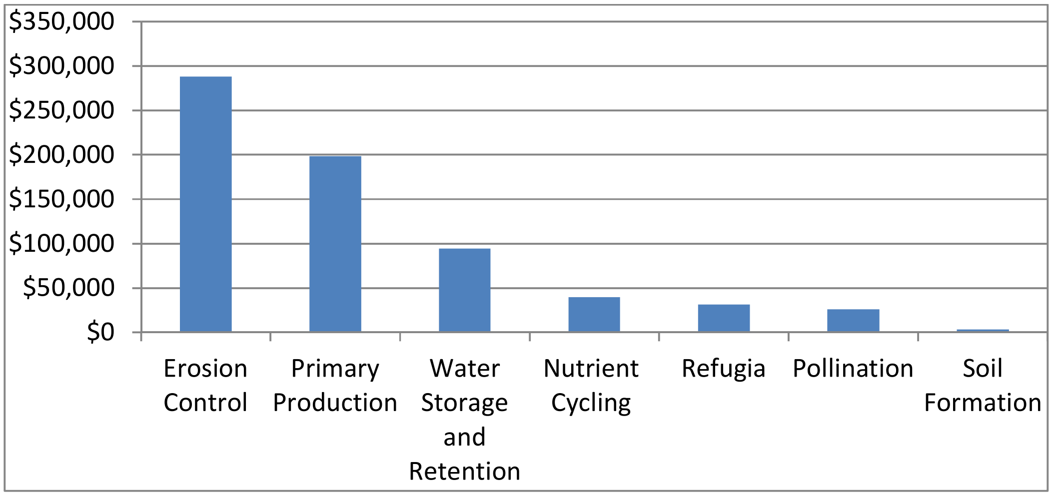


Figure 8: Economic Value ($NZ) of Supporting Services for the Tahamata Farm 2015/2016

By definition, the total value of the supporting services is the sum total of the provisioning, cultural and regulating services, which are equal to the 'net value' produced by ecosystem services on Tahamata farm – estimated to be $681,579 for 2015/2016. Erosion control is the highest supporting service with a value of $288,136 per annum, most of which is provided by 310 ha of land in dairy pasture – without such pasture the sandy soils would be very susceptible to wind and other weather-related hydrological factors that would cause extensive erosion. Primary production is the second most important supporting service, having an estimated value of $198,622 per annum, which its main economic function is ultimately to produce milk for sale. All of the other supporting services (water storage and retention, nutrient cycling, refugia, pollination and soil formation) are important, not only in terms of dairy farming, but also supporting the functioning of the wetlands, forestry land and scrub. In total, these remainder ecosystem services are estimated to have an annual economic value of $194,822.

4. Adaptation Scenarios for the Tahamata Farm from an Ecosystem Services Perspective

Land Cover/Use Changes over the Next 30 Years

With the onset of Climate Change and water inundation on the current Tahamata farmland, there is potential to convert some of the farmland to wetlands, or to further consider other uses of the land. Figure 9 shows the overall picture of the conversion of dairy farm land to wetlands for the three scenarios in the year 2045/2046 ('No Adaption', 'Some Expansion of Wetlands' and 'Full Expansion of Wetlands) and compares this to the base year situation.

As can be seen from Figure 9, for the **'No Adaption' Scenario**, there is no increase in the area of wetlands (it remains at 21.06 hectares) – however under this 'No Adaption', there is ponding of surface water in 35.29 hectares, making it unavailable for dairy farming. Furthermore, an additional 102.07 hectares of dairy land becomes puggy and seasonally waterlogged, which makes dairy farming on this land less productive.

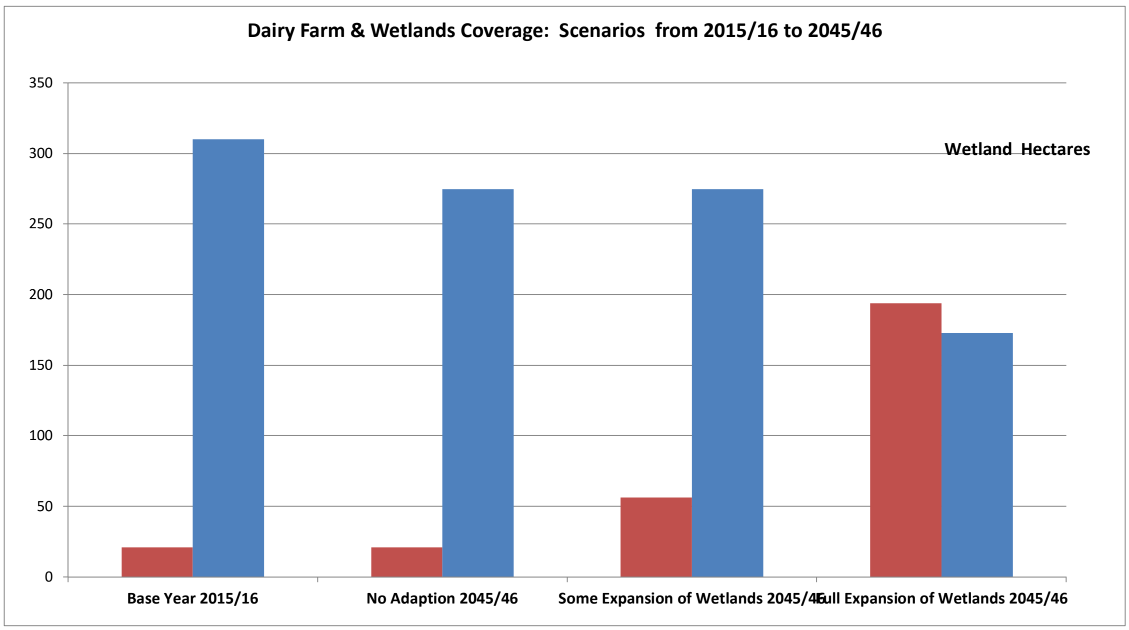


Figure 9: 'Dairy Farm Hectares' versus 'Wetland Hectares' for the Base Year (2015/16) and the Terminal Year for the 3 Scenarios

For the **'Some Expansion of Wetlands' Scenario**, the area of land covered in surface water in the first scenario is actively converted to wetlands, hence an increase in the area of wetlands from 21.06 hectares to 56.36 hectares. The active conversion of this surface water area to wetlands will require significant investment to cover the costs of planting, pest control, fencing engineering works and drainage – the exact costs of this investment is unknown, but based on approximate figures for the establishment of the Te Hākari wetlands in the early 2000's, the cost is likely to be in the order of $200,000. It should be noted that, also under this scenario, 35.29 hectares of land that has become puggy under climate change by 2045/46 is no longer farmed and hence the total area of dairy pasture decreases from 310.0 hectares in 2015/2016 to 274.71 hectares in 2045/46.

For the **'Full Expansion of Wetlands' Scenario**, all of the land that would otherwise be ponded surface water (35.29 hectares) and puggy/poorly drained land (137.36 hectares) will be actively converted to wetlands, extending the wetlands to have a total coverage of 193.71 hectares. Thus, this area of wetlands is now greater than the total area of land under dairy farming, at 172.64 hectares, but notably the dairy farming productivity (kg milksolids/hectare) does increase as there is no dairy farming on marginal puggy and waterlogged land. The resulting farm size of 172.64 hectares is still significantly above the average farm size for the Lower North Island and New Zealand, meaning that the farm remains a viable commercial operation under this scenario, albeit at a lower level of production. It should be noted that this scenario could be characterised as an 'extreme' scenario, as the area of wetland in 2045/2046 increases more than 9 times from the area of wetlands in 2015/2016. This would require a very significant investment (perhaps in the order of $500,000) and probably will require thousands of hours of volunteer time.

Figure 10 presents a more complete picture of the land coverage and land use changes under each scenario and compares this with the base year – essentially characterising the scenario and the base year by 7 land cover/use categories.

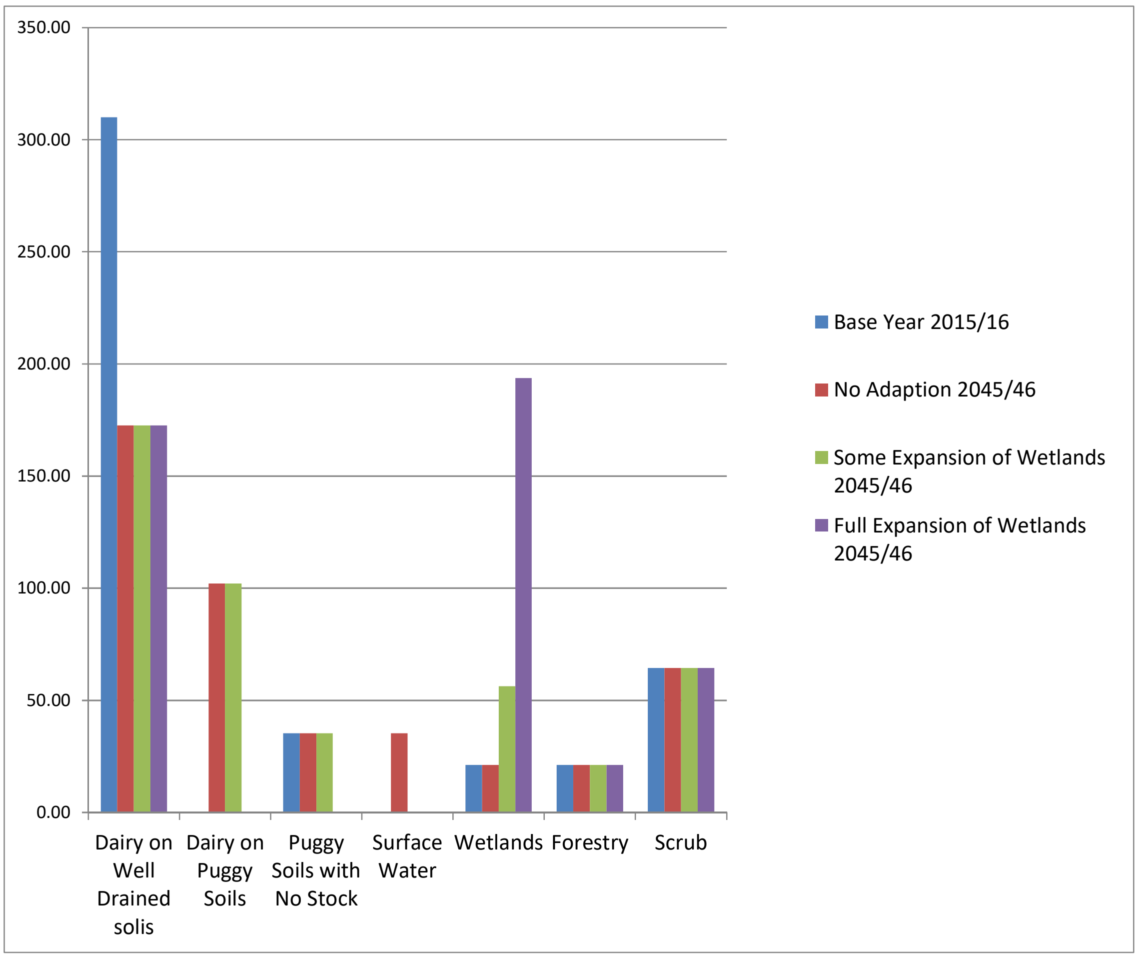


Figure 10: Landcover (hectares) for the Base Year (2015/16) and the Terminal Year (2045/46) for the 3 Scenarios

As well as showing the changes in coverage of wetlands and dairy farm land as described by Figure 9, for each of the scenarios by 2045/2046, Figure 10 provides extra information on the types of soil conditions (drained versus puggy) and how they are used, and describes the forestry and scrub coverage, which incidentally remains constant in the base year (2015/2016) and for the three scenarios (2045/2046).

Milk Solid Payout

The most critical determinant of the profitability of New Zealand dairy farms is the payout for the purchase of milk – or more specifically, the payout for Milk Solids. Importantly, the model used to generate the 3 scenarios to 2025/46 uses the 2015/16 payout that Tahamata received during the 2015/16 year, which was $4.13 per kg of milk solids. Once adjusted for inflation, this is an historically low payout although, as Figure 11 shows, since 1990 the payout has oscillated around an average value slightly under $6 per kilogram of milk solids. Even though this seems to be a reasonably persistent trend since 1990, reliably forecasting commodity prices like milk prices for the terminal year (2045/46) of the scenario is an almost impossible task. This is because it is very difficult to know what the demand will be for cow's milk in 30 years' time, how technology will impact on both supply and demand of milk, and the role government will play in this reasonably protected and sometimes subsidised market. All that said, it should be firstly noted that the scenario model uses the 2015/16 price as the default value, as it is the base year price – users of the model are free to choose any other projected price for 2045/2046, or try a range of prices, to ascertain what impact of those prices will be on the future financial viability of the farm.

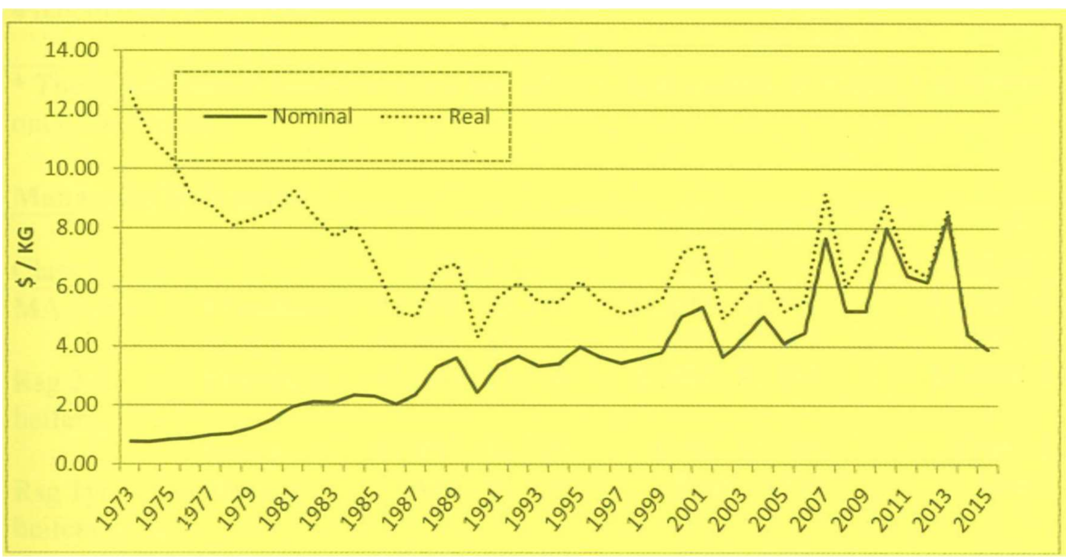


Figure 11: Average Milk Solid Payout for New Zealand from 1973/74 to 2015/16

Notes:
1. The 2015/16 figure is based on a payout forecasted by Fonterra.
2. "Nominal" prices are prices that have not been adjusted for inflation.
3. "Real" prices are prices that have been adjusted for inflation, and are expressed in terms of December 2015 $NZ.
4. This graph is obtained from Lincoln University's "Financial Budget Manual 2016", edited by Askin and Askin (2016).

Secondly, it should also be realised that changing the price of the milk payout will also, to some extent, affect the economic value of the ecosystem services for the Tahamata farm – for example, if the milk price goes up, then implicitly the economic value of the support services that produce milk (mainly primary production) will also increase.

Thirdly, it should be noted that the broad conclusions of the study remain largely unaltered, even with quite a significant increase in milk payout[9].

Scenario 1: No Adaption to Climate Change

Under the first scenario, the farm soil will become puggy due to sea level rise and in some places surface water will accumulate. In this scenario, the farm management will use this land the best they can, which means intermittent grazing in some areas, less intensive grazing in others, and in some places no grazing at all. No additional attempt has been made to 'drain the land' over and above the drainage on the farm as at 2015/2016, or to convert the inundated land to some other economic or ecological use.

Narrative and Science Justification for Scenario 1. The trend for sea level rise around New Zealand has been about 5 mm/yr over the last 30 years, which is significantly larger than the global average of about 3 mm/yr. Large variations in the rate of sea level rise around New Zealand make it even harder to predict when a threshold for the sustainability of some current farming practices will be crossed. However, at this stage, according to Professor Martin Manning as outlined in Smith et al. (2017), assuming a sea level rise at a rate of 200 mm/decade would be a reasonable approach. Projecting out to 2045/46, using this approach we could predict a sea level rise in the vicinity of 600 mm.

Of more relevance in terms of the impact of sea level rise on the farm out to 2045/46, is the change in groundwater levels. Sea level rise can cause a rise in groundwater over low lying land and an increase in the frequency and extent of flooding. Analysis from a Dunedin study (Goldsmith & Hornblow, 2016) indicates that sea level rise will result in ponding of water at the surface but that this does not just occur first on the lowest land, but rather where the water table is currently closest to the surface.

The onset of climate change is expected to increase flood risk. Future floods are likely to be bigger. Modelling work on the Hutt River indicated the potential for a significant increase in flood frequencies over the 21st century under climate change scenarios (Ballinger et al., 2011). However, the magnitude of the change varied considerably depending on the emissions scenario and climate model used. The authors found that, for the Hutt River under a high emissions scenario, flood return periods could reduce to a fifth of current-day values on average. It seems highly likely that with the projected change in climate variables, the Ōhau River will experience larger and more frequent flooding.

The level of uncertainty around the magnitude and pace of sea level rise, frequency of flooding and water table response makes it difficult to predict what this will mean for the Tahamata farm in 2046. However, the soil map can be used as a guide to identify the most vulnerable areas to change in sea level, groundwater levels and increased flooding. For the analysis of the farm in 2046, we have reclassified areas of the farm where the water table is currently less than 30 cm from the surface in winter (puggy and poorly drained dairy pasture – drainage class 1 and 1-2) as surface water. Areas of the farm that have a winter water table at less than 60 cm depth are reclassified in 2045/46 as puggy and poorly drained dairy pasture. The land cover area of wetland/flax and forestry/scrub remains the same in 2045/46 in this 'do nothing' scenario. Based

[9] Phase 2 of this project from 1 August 2017 to 30 January 2019 will produce various scenarios that test the sensitivity of plausible changes to Milk Payout.

on the reclassification of the most vulnerable soils to sea level and water table rise, in 2045/46 surface water (at least in winter) is predicted to cover 48 ha (10.6% of the total farm area). Moderately to well drained dairy pasture is predicted to comprise 51.4% of the farm (232 ha). In 2045/46, the farm area classified as puggy and poorly drained dairy pasture would rise by 30.4%, to 137 hectares.

'Results for 'No Adaption' Scenario. Table 8 provides a comprehensive picture of the economic value of the 18 ecosystem services for the terminal year (2045/2046) for the 'No Adaption' scenario. As can be ascertained from Table 8, the 'No Adaption' scenario shows that by 2045/2046 the total net value per annum of the Tahamata farm decreases $118,046 per annum, falling from $681,579 per annum in 2015/2016 to $563,533 per annum in 2045/2046. This amounts to a decrease of annual net value of 17.3%. The main reason for this decrease in the total net value in the Tahamata farm is the lower production of milk (classified as food production in this analysis), which is due to climate change-induced inundation of water onto the farm causing surface water ponding and some land becoming partly puggy (71 hectares in total) – this decrease in milk production is projected to be $82,732 in 2045/2046, which amounts to a 27.8% decrease in production. Under this scenario of water ponding and some of the land becoming puggy, other ecosystem services also decrease in value, as indicated by Figure 12:

(1) 'erosion control' decreases by $20,182 per annum by 2045/2046 (-10.9%), due to some of the vegetative cover of dairy pasture becoming more waterlogged and hence more susceptible to erosion;

(2) 'primary production' decreases by $47,292 per annum by 2045/2046 (-23.8%), which is essentially due to the decreased value of milk production leading to a decrease in its supporting service of 'primary production';

(3) 'waste treatment' decreases by $20,182 per annum by 2045/2046 (-23.8%), mainly because of the ponding of water making the pasture and soil less effective for processing and filtering faeces, urine, fertiliser run-off and other nutrients.

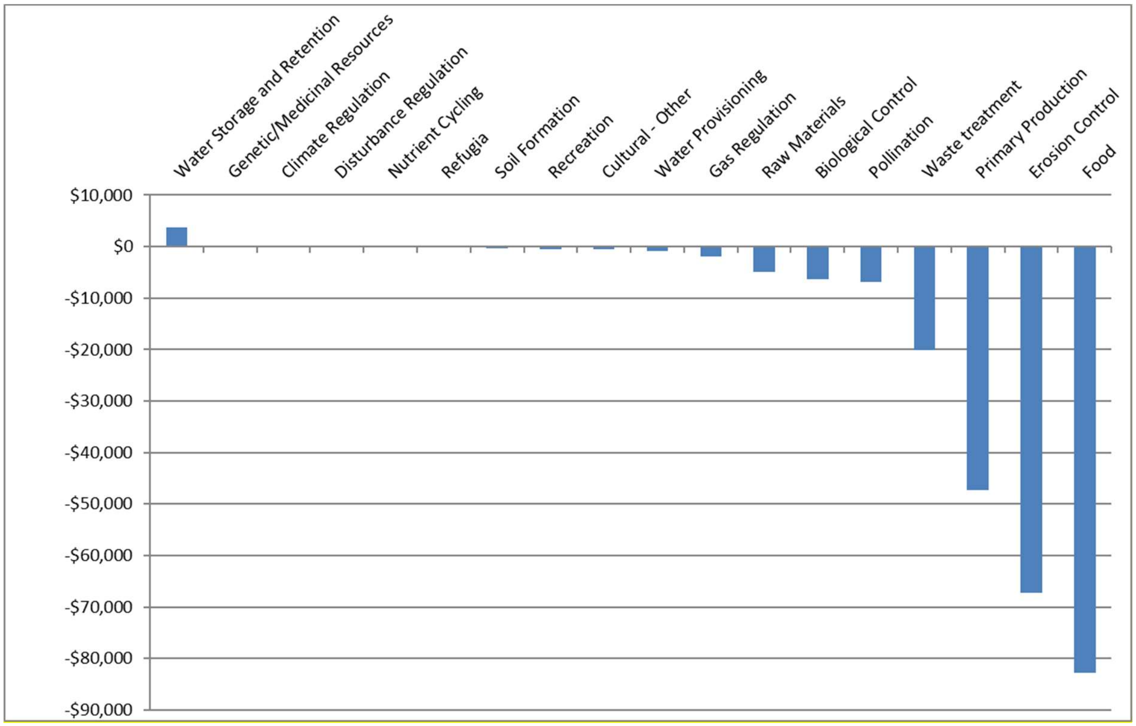


Figure 12: Change in the Economic Value ($$_{2015/2016}$ per year) of the Tahamata Farm from 2015/2016 to 2045/2045, Under the 'No Adaption' Scenario

As can be ascertained from Figure 12, the economic value per annum of eight of the other ecosystem services also decreased under this scenario, with three of the other ecosystem services exhibiting no change. Interestingly, 'water storage and retention' increased slightly (3.9%) from an economic value of $94,443 per annum in 2015/2016 to $98,173 per annum in 2045/2046, attributable to surface water ponding under this scenario; although the majority of the 'water storage and retention' ecosystem service value is still provided by the Te Hākari wetland, which is assumed under this scenario to cover the same area in 2045/2046 as it did in 2015/2016.

It is important to note that the economic output (as measured by contribution to GDP) of the Tahamata farm decreases by $87,671 per annum (-26.6%) from $328,844 in 2015/2016 to $241,173 2045/2046, under this 'No Adaption' scenario. This is essentially due to less pasture being available for grazing due to surface water ponding, and some soils becoming puggy and water inundated in the winter and hence becoming less productive on a $ per hectare basis. The commercial value of the forestry plantation, on an amortised basis, remains unchanged. Although this is a significant drop in the economic value of milk production, the farm still remains profitable and viable, particularly as the milk payout returns to its 'average' value, which is close to the $6 per kilogram (inflation adjusted) of milk solids that has persisted since 1990 – this just means that the level of milk production has decreased, although the farm itself would still be producing more milk than the average 'Lower North Island' farm or average 'New Zealand' farm as recorded in 2015/2016.

Table 8: No Adaption Scenario in 2045/46 -- Economic Value of Ecosystem Services for the Tahamata Farm (\$$NZ_{2015/2016}$)

Ecosystem Services	Type of Ecosystem Service	Wetlands Dominated by Vegetation	Surface Water - Wetlands	Surface Water - Other	Forestry	Scrub	Dairy Pasture	Puggy and Poorly Drained: No Stock	Puggy and Poorly Drained: With Stock	Total	Change in 'Total' from 2015/2016 to 2045/2046
Area Covered (hectares)		8.3	12.8	35.3	21.2	64.4	172.6	35.3	102.1	452.0	0.0
Food	Provisioning	0	0	0	0	0	165,454	0	48,911	214,365	-82,732
Water Provisioning	Provisioning	519	0	0	0	0	1,626	332	481	2,958	-813
Raw Materials	Provisioning	686	0	0	14,009	0	9,878	0	2,920	27,494	-4,940
Genetic/Medicinal Resources	Provisioning	1,260	0	0	0	0	0	0	0	1,260	0
Climate Regulation	Regulating	6,212	0	0	5,937	18,014	0	0	0	30,163	0
Disturbance Regulation	Regulating	13,303	0	0	0	0	0	0	0	13,303	0
Water Storage and Retention	Supporting	42,815	51,628	3,730	0	0	0	0	0	98,173	3,730
Waste treatment	Regulating	38,378	27,004	3,730	5,870	17,802	47,821	9,775	14,137	164,517	-20,182
Erosion Control	Supporting	3,318	0	0	8,265	22,099	134,686	12,606	39,815	220,789	-67,347
Nutrient Cycling	Supporting	21,805	0	0	4,872	13,037	0	0	0	39,713	0
Biological Control	Regulating	12,067	0	0	267	742	12,620	2,580	3,731	32,007	-6,311
Gas Regulation	Regulating	6,075	0	0	0	0	3,842	785	1,136	11,838	-1,921
Refugia	Supporting	31,250	0	0	0	0	0	0	0	31,250	0
Cultural - Other	Cultural	27,892	21,832	0	147	350	1,203	246	356	52,025	-601
Recreation	Cultural	8,443	2,792	0	727	0	1,094	224	323	13,603	-547
Soil Formation	Supporting	0	0	0	675	1,772	532	50	157	3,185	-266
Pollination	Supporting	0	0	0	0	0	13,743	1,286	4,063	19,093	-6,872
Primary Production	Supporting	15,647	0	0	13,148	0	94,577	0	27,958	151,330	-47,292
Gross Total Value(P+C+R+S)		229,671	103,255	7,460	53,918	73,814	487,077	27,884	143,987	1,127,065	-236,093
Net Total Value (S) = (P+C+R)		114,835	51,628	3,730	26,959	36,907	243,538	13,942	71,994	563,533	-118,046
Provisioning (P)		2,466	0	0	14,009	0	176,958	332	52,311	246,077	-88,484
Cultural (C)		36,335	24,624	0	874	350	2,296	469	679	65,628	-1,148
Regulating (R)		76,035	27,004	3,730	12,075	36,557	64,284	13,140	19,003	251,829	-28,414
Supporting (S)		114,835	51,628	3,730	26,959	36,907	243,538	13,942	71,994	563,533	-118,046
Commerical Value		0	0	0	14,009	0	175,332	0	51,831	241,173	-87,671
Non-Commerical Value		114,835	51,628	3,730	12,950	36,907	68,206	13,942	20,163	322,360	-30,375

Note:
'Net Total Value' is the most appropriate metric of the 'total' value of ecosystem services, as it avoids 'double-counting' which is the case for 'Gross Total Value' metric.
It emphasize this point the 'Net Total Values' have been underlined.

Scenario 2: Some Expansion of the Wetlands

Under this scenario, land that was projected to be covered by surface water (35.3 hectares) in 2045/46 in the ‘No Adaption’ scenario is now actively converted to wetlands, bringing the 2045/2046 total area covered by wetlands to 56.4 hectares compared with 21.1 hectares for 2015/16. This would require active planting of native trees and vegetation, pest control, engineering works and so forth. In this way, under this Scenario, areas where the winter water table is currently less than 30 cm below the surface and predicted to have standing water by 2046 (Drainage Class 1 and 1-2) are actively converted to wetlands.

Narrative and Science Justification for Scenario 2. In this scenario of ‘Some Expansion of Wetlands’, the assumptions we make about climate change and its effect on sea level, and the flow on effect it has to the hydrology and drainage of soils in Tahamata, is exactly the same as for the ‘No Adaption’ scenario, as described above. The only difference in this scenario narrative is the management response to climate change in the scenario, which is to take a proactive stance on expanding the wetlands to cover the area that is forecast to be subject to surface water ponding. At this stage in the research programme, we make no assumptions about how this active expansion to the wetlands is to be funded, by whom, how much this would cost, or whether such a venture would have a strong business case in terms of, for example, a cost: benefit analysis, or what institutional, policy and planning arrangements would be required to underpin this expansion of the wetlands. It is suggested at this point, depending on stakeholder responses, that these assumptions could be tested out in Phase 2 of the research programme that runs from 1 August 2017 to 31 January 2019.

Results for ‘Some Expansion of the Wetlands’ Scenario. Table 9 provides a comprehensive picture of the economic value of the 18 ecosystem services, for the terminal year (2045/2046), of the ‘Some Expansion of the Wetlands’ scenario. As can be ascertained from Table 9, the scenario shows that by 2045/2046 the total net value per annum of the Tahamata farm increased by $157,180 per annum, from $681,579 per annum in 2015/2016 to $838,759 per annum in 2045/2046. This amounts to an increase of annual net value of 23.1%. The main reason for this increased annual net value by 2045/2046 is due to the increase in the value of wetlands ecosystem services by $244,852, although there is a drop in the annual net value of the Tahamata farm of $87,671.

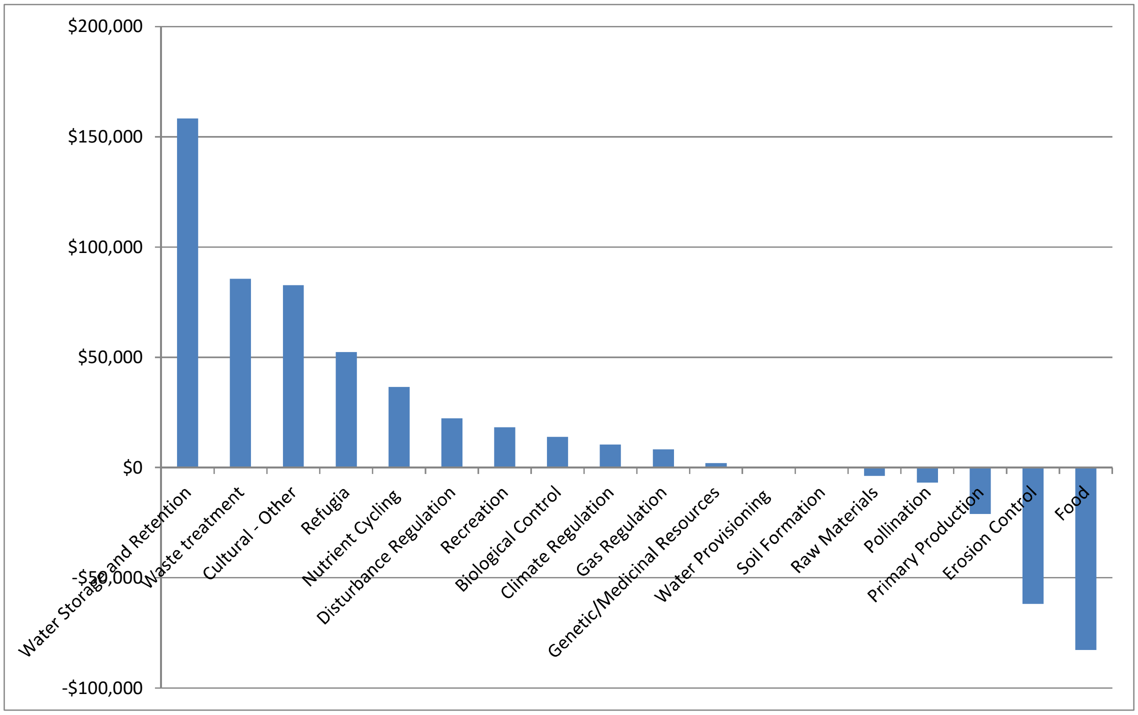


Figure 13: Change in the Economic Value ($$_{2015/2016}$ per year) of the Tahamata Farm from 2015/2016 to 2045/2045, under the 'Some Expansion of the Wetlands' Scenario

Figure 13 shows the very significant increase in the economic value of ecosystem services, from 2015/2016 to 2045/2045, for those ecosystem services that are associated with wetlands:

(1) 'water storage and retention' increased by $158,266 (167.6%) from $94,443 in 2015/2016 to $252,709 in 2045/2045. This is due to the large amount of water stored in that extra 35.3 hectares of wetlands, increasing the total area of wetlands from 21.1 hectares in 2015/2016 to 56.4 hectares in 2045/2046. Given this large increase in the economic value of 'water storage and retention', further research on the hydrological nature of this area, both now and under future climate change regimes, seems warranted in Phase 2 of the project;

(2) 'waste treatment' increased by $85,653 (46.4%) from $184,699 in 2015/2016 to $270,353 in 2045/2046, which again is attributable to the large volume of water available in the newly expanded wetlands;

(3) 'cultural values' such as landscape and wilderness values, aesthetics and cultural values specific to iwi/hapū including spiritual values are also projected to increase by the somewhat nominal amount of $82,654 from 2015/2016 to 2045/2046. Again, this warrants further exploration in Phase 2 of the project, including in consultation with stakeholders regarding whether it is meaningful to undertake an economic evaluation of such values, and if not, to ascertain how such values can be incorporated into the decision-making framework alongside other values that seem to be more amenable to economic valuation. Even if there is disagreement about the applicability of economic valuation to iwi/hapū cultural values, at the very least this study does highlight the fact that these values are potentially large, if we assume that the ways they were measured in the studies recorded in the TEEB database are broadly applicable and valid to the Tahamata case study area;

(4) 'refugia' records the fourth largest projected increase ($52,368/yr) of the ecosystem services with the expansion of the wetlands from 2015/2016 to 2045/2046, which is purely a function of expanding the wetland by 2.68 times its current size. Other ecosystem services that had their economic value increase as a result of expanding the wetlands include, in decreasing order of magnitude: nutrient cycling, disturbance regulation, recreation, biological control, climate regulation, atmospheric gas regulation, and genetic/medicinal resources.

Notably, those ecosystem services mainly associated with dairy farming decreased, as under this scenario there was less land available for dairy farming as it was converted to wetlands (35.3 hectares), and compared with the base year of 2015/2016 a significant amount of land (102.1 hectares) became puggy, which decreases the productivity of this land and its seasonal availability. Accordingly, the following dairy farm-related ecosystem services decreased from 2015/2016 to 2045/2046 by the following amounts: 'food production' (-$82,732/yr), which is exactly the same amount as for the 'No Adaption' scenario; 'erosion control' (-$61,786/yr); 'primary production' (-$21,071/yr); 'pollination' (-$6,872/yr); and 'raw materials' (-$3,790/yr).

The profitability of the Tahamata farm is exactly the same as for the 'no adaption scenario', as exactly the same amount and location of land with dairy farming and forestry operations is used in this 'Expansion of Wetlands' scenario. As for the first scenario, it is important to note that economic output (as measured as contribution to GDP) of the Tahamata farm decreased by $87,671 per annum (-26.6%) from $328,844 in 2015/2016 to $241,173 2045/2046 under the 'No Adaption' scenario. This is essentially due to less pasture being available for grazing due to surface water ponding, and some soils becoming puggy and water inundated in the winter and hence becoming less productive on a $ per hectare basis. Perhaps it could also be speculated that, if the land shown to be under surface water and hence entirely unproductive from a dairy farm perspective, was sold to a third party for development into wetlands, there could be a one-off payment to the Tahamata Incorporation.

Table 9: 'Some Expansion of the Wetlands' Scenario in 2045/46 -- Economic Value of Ecosystem Services for the Tahamata Farm (NZ_{2015/2016}$)

Ecosystem Services	Type of Ecosystem Service	Wetlands Dominated by Vegetation	Surface Water - Wetlands	Surface Water - Other	Forestry	Scrub	Dairy Pasture	Puggy and Poorly Drained: No Stock	Puggy and Poorly Drained: With Stock	Total	Change in 'Total' from 2015/2016 to 2045/2046
Area Covered (hectares)		22.2	34.2	0.0	21.2	64.4	172.6	35.3	102.1	452.0	0.0
Food	Provisioning	0	0	0	0	0	165,454	0	48,911	214,365	-82,732
Water Provisioning	Provisioning	1,390	0	0	0	0	1,626	332	481	3,828	57
Raw Materials	Provisioning	1,836	0	0	14,009	0	9,878	0	2,920	28,644	-3,790
Genetic/Medicinal Resources	Provisioning	3,372	0	0	0	0	0	0	0	3,372	2,112
Climate Regulation	Regulating	16,621	0	0	5,937	18,014	0	0	0	40,573	10,410
Disturbance Regulation	Regulating	35,596	0	0	0	0	0	0	0	35,596	22,293
Water Storage and Retention	Supporting	114,565	138,144	0	0	0	0	0	0	252,709	158,266
Waste treatment	Regulating	102,692	72,256	0	5,870	17,802	47,821	9,775	14,137	270,353	85,654
Erosion Control	Supporting	8,880	0	0	8,265	22,099	134,686	12,606	39,815	226,350	-61,786
Nutrient Cycling	Supporting	58,345	0	0	4,872	13,037	0	0	0	76,253	36,540
Biological Control	Regulating	32,289	0	0	267	742	12,620	2,580	3,731	52,229	13,911
Gas Regulation	Regulating	16,254	0	0	0	0	3,842	785	1,136	22,018	8,258
Refugia	Supporting	83,618	0	0	0	0	0	0	0	83,618	52,368
Cultural - Other	Cultural	74,633	58,417	0	147	350	1,203	246	356	135,351	82,725
Recreation	Cultural	22,592	7,471	0	727	0	1,094	224	323	32,431	18,281
Soil Formation	Supporting	0	0	0	675	1,772	532	50	157	3,185	-266
Pollination	Supporting	0	0	0	0	0	13,743	1,286	4,063	19,093	-6,872
Primary Production	Supporting	41,867	0	0	13,148	0	94,577	0	27,958	177,551	-21,071
Gross Total Value(P+C+R+S)		614,550	276,289	0	53,918	73,814	487,077	27,884	143,987	1,677,519	314,361
Net Total Value (S) = (P+C+R)		307,275	138,144	0	26,959	36,907	243,538	13,942	71,994	838,759	157,180
Provisioning (P)		6,597	0	0	14,009	0	176,958	332	52,311	250,208	-84,352
Cultural (C)		97,225	65,888	0	874	350	2,296	469	679	167,782	101,006
Regulating (R)		203,453	72,256	0	12,075	36,557	64,284	13,140	19,003	420,769	140,527
Supporting (S)		307,275	138,144	0	26,959	36,907	243,538	13,942	71,994	838,759	157,180
Commerical Value		0	0	0	14,009	0	175,332	0	51,831	241,173	-87,671
Non-Commerical Value		307,275	138,144	0	12,950	36,907	68,206	13,942	20,163	597,587	244,852

Note:
'Net Total Value' is the most appropriate metric of the 'total' value of ecosystem services, as it avoids 'double-counting' which is the case for 'Gross Total Value' metric.
To emphasize this point the 'Net Total Values' have been underlined.

Scenario 3: Full Expansion of Wetlands

This scenario goes further than Scenario 2 by actively converting all land to wetlands where the land has now become puggy and is not well drained, as well as areas where there is now persistent surface water. This would be a significant undertaking, extending the existing wetland area in 2015/16 from 21 hectares to 194 hectares. As with the 'Some Expansion of Wetlands' scenario, this would require significant investment in actively planting areas, engineering works and so forth.

Narrative and Science Justification of Scenario 3. In this scenario, like the other two scenarios, the assumptions we make about climate change and its effect on sea level and the flow on effect it has to the hydrology and drainage of soils in Tahamata farm are exactly the same. The only difference in the scenario narrative is the management response to climate change in the scenario, which is to very significantly increase the wetlands so that it covers an area of 193.7 hectares, mostly near the mouth of the Ōhau River, which would expand the wetlands by more than nine times the current coverage of the Te Hākari wetlands, in areas classified as puggy and poorly drained. In addition to the area expanded in the second scenario in these very wet areas (DC 1 and 1-2), the pasture areas predicted to be puggy and poorly drained in 2045/46 under a 600 mm sea level rise (soils that currently have a winter water table less than 60 cm deep) are also actively converted to wetlands. The aspirational goal would be to have greater wetlands that truly had national if not international recognition (e.g., Ramsar) for their intrinsic value as well as being an exemplar of how wetlands can be expanded from land that was previously used for intensive agriculture. Part of the value proposition could be additional economic revenue from creating tourism and recreational opportunities directly associated with the wetlands status. Further commercial value could also be harnessed with little resources for ventures such as fibre processing, although this kind of approach could be in conflict with some of the other ecosystem services values.

Results for 'Full Expansion of the Wetlands' Scenario. Table 10 provides a comprehensive picture of the economic value of the 18 ecosystem services for the terminal year (2045/2046) of the 'Full Expansion of Wetlands' scenario. As can be ascertained from Table 10, the scenario shows that by 2045/2046 the total net value per annum of the Tahamata farm increased by $157,180 per annum, increasing from $681,579 per annum in 2015/2016 to $1,156.736 per annum in 2045/2046. This amounts to an increase of annual net value of 169.7%, which is very significantly more than the increase of annual net value of 23.1% for the 'Some Expansion of Wetlands' scenario.

The profile of the increases and decreases in ecosystem services for the 'Full Expansion of Wetlands' scenario, as outlined in Figure 14, is a more exaggerated form of the 'Some Expansion of Wetlands' scenario – that is, the same increases and decreases in the net annual value of ecosystem services are recorded but just to a larger magnitude. For example, as can be seen from Figure 14, the top four increases in the annual economic value from 2015/2016 to 2045/2046 are: 'water storage and retention' ($774,122/yr); 'waste treatment' ($488,092/yr); 'cultural values' ($406,368/yr); and 'refugia' ('$256,146/yr). In regard to the economic value of these ecosystem services, the same comments apply to this 'Full Expansion of Wetlands' scenario as for the 'Some Expansion of Wetlands' scenario, although these comments can be made more forcibly, given the increased magnitude of the economic value of these ecosystem services.

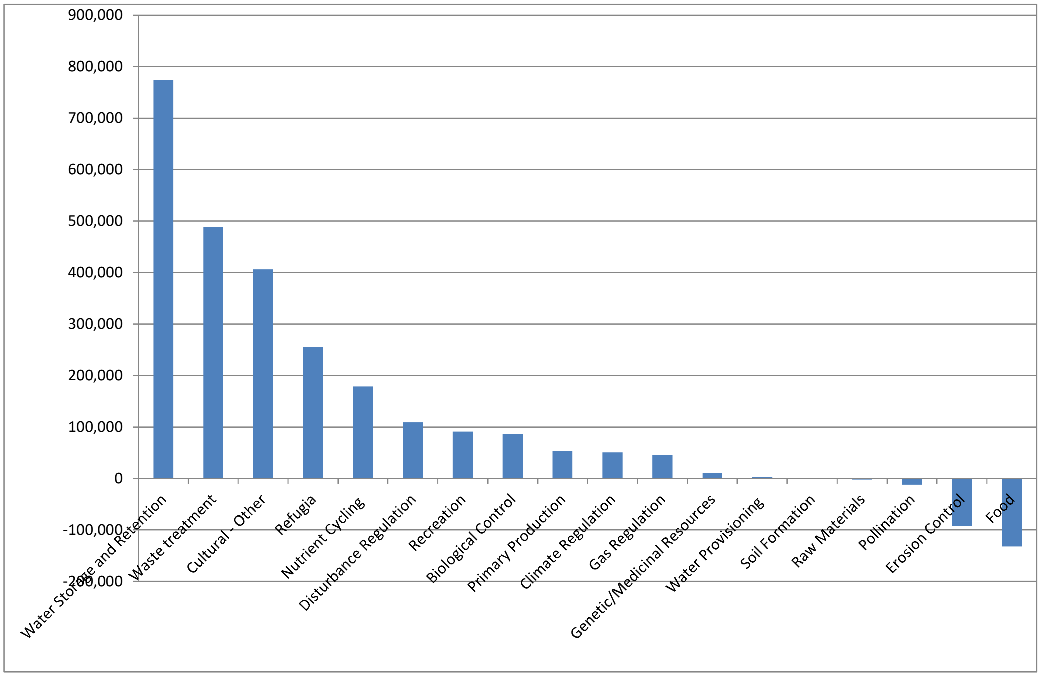


Figure 14: Change in the Economic Value ($$_{2015/2016}$ per year) of the Tahamata Farm from 2015/2016 to 2045/2045, Under the 'Full Expansion of the Wetlands' Scenario

Commercial revenue of the farm is estimated to be $189,342 in 2045/2046, down from $328,844 in 2015/2016. This is reflected in the decrease in the economic value of milk production ('food production' ecosystem service) of $131,642/yr from 2015/2016 to 2045/46, which is 44.3% less milk production over this period. Even more so than the 'Some Expansion of Wetlands' scenario, under this 'Full Expansion of Wetlands' scenario, the challenge for Tahamata Incorporation is whether they can commercially capture some of the economic potential from the very significantly expanded wetlands, including a range of possibilities from land sales to third parties, to harvesting and processing products from the expanded wetlands, all of which would require further investigation in Phase 2 of this research programme.

Table 10: 'Full Expansion of Wetlands' Scenario in 2045/46 -- Economic Value of Ecosystem Services for the Tahamata Farm (\$NZ$_{2015/2016}$)

Ecosystem Services	Type of Ecosystem Service	Wetlands Dominated by Vegetation	Surface Water - Wetlands	Surface Water - Other	Forestry	Scrub	Dairy Pasture	Puggy and Poorly Drained: No Stock	Puggy and Poorly Drained: With Stock	Total	Change in 'Total' from 2015/2016 to 2045/2046
Area Covered (hectares)		76.2	117.5	0.0	21.2	64.4	172.6	0.0	0.0	452.0	0.0
Food	Provisioning	0	0	0	0	0	165,454	0	0	165,454	-131,642
Water Provisioning	Provisioning	4,776	0	0	0	0	1,626	0	0	6,402	2,631
Raw Materials	Provisioning	6,310	0	0	14,009	0	9,878	0	0	30,197	-2,236
Genetic/Medicinal Resources	Provisioning	11,589	0	0	0	0	0	0	0	11,589	10,329
Climate Regulation	Regulating	57,128	0	0	5,937	18,014	0	0	0	81,079	50,916
Disturbance Regulation	Regulating	122,345	0	0	0	0	0	0	0	122,345	109,042
Water Storage and Retention	Supporting	393,761	474,804	0	0	0	0	0	0	868,565	774,122
Waste treatment	Regulating	352,952	248,346	0	5,870	17,802	47,821	0	0	672,792	488,092
Erosion Control	Supporting	30,519	0	0	8,265	22,099	134,686	0	0	195,568	-92,567
Nutrient Cycling	Supporting	200,533	0	0	4,872	13,037	0	0	0	218,441	178,728
Biological Control	Regulating	110,978	0	0	267	742	12,620	0	0	124,607	86,290
Gas Regulation	Regulating	55,866	0	0	0	0	3,842	0	0	59,708	45,949
Refugia	Supporting	287,396	0	0	0	0	0	0	0	287,396	256,146
Cultural - Other	Cultural	256,514	200,781	0	147	350	1,203	0	0	458,995	406,368
Recreation	Cultural	77,649	25,676	0	727	0	1,094	0	0	105,147	90,997
Soil Formation	Supporting	0	0	0	675	1,772	532	0	0	2,978	-473
Pollination	Supporting	0	0	0	0	0	13,743	0	0	13,743	-12,221
Primary Production	Supporting	143,899	0	0	13,148	0	94,577	0	0	251,624	53,002
Gross Total Value(P+C+R+S)		2,112,215	949,607	0	53,918	73,814	487,077	0	0	3,676,631	2,313,473
Net Total Value (S) = (P+C+R)		1,056,108	474,804	0	26,959	36,907	243,538	0	0	1,838,316	1,156,736
Provisioning (P)		22,676	0	0	14,009	0	176,958	0	0	213,643	-120,918
Cultural (C)		334,163	226,458	0	874	350	2,296	0	0	564,142	497,366
Regulating (R)		699,269	248,346	0	12,075	36,557	64,284	0	0	1,060,531	780,289
Supporting (S)		1,056,108	474,804	0	26,959	36,907	243,538	0	0	1,838,316	1,156,736
Commerical Value		0	0	0	14,009	0	175,332	0	0	189,342	-139,502
Non-Commerical Value		1,056,108	474,804	0	12,950	36,907	68,206	0	0	1,648,974	1,296,239

Note:
'Net Total Value' is the most appropriate metric of the 'total' value of ecosystem services, as it avoids 'double-counting' which is the case for 'Gross Total Value' metric.
To emphasize this point the 'Net Total Values' have been underlined.

Comparison of the Scenario Results

Table 11 below summarises the results of the three scenarios. These scenarios are based on exactly the **same climate change projection** and the consequential impact that this has on the Tahamata farm's soil and land. The only difference between the three scenarios is the **management response** to climate change: Scenario 1 assumes no adaption to climate change other than the fact that 35.3 hectares of land becomes unavailable for dairy farming due to the inundation of surface water; Scenario 2 assumes that by 2045/46, 35.3 hectares is proactively converted to wetlands; and Scenario 3 sees a massive conversion of land to wetlands on land that is considered to be impossible to farm due to ponding or an increase in the amount of puggy soils.

Table 11: Economic Value of Tahamata Farm Ecosystem Services for 3 Future Scenarios

Descriptors	Units	Base Year: 2014/15	Scenario 1: No Adaption 2045/46	Scenario 2: Some Expansion of Wetlands 2045/46	Scenario 3 Full Expansion of Wetlands 2045/46
Dairy Farm	Hectares	310.00	274.71	274.71	172.64
Forestry	Hectares	21.19	21.19	21.19	21.19
Wetlands	Hectares	21.06	21.06	56.36	193.71
Net Value	$\$NZ_{2015/16}$	681,579	563,533	838,759	1,838,316
Commercial value of Dairy and Forestry Products	$\$NZ_{2015/16}$	328,844	241,173	241,173	189,342
Non-Commercial Value of Ecosystem Services	$\$NZ_{2015/16}$	352,735	322,360	597,587	1,648,974
Provisioning Ecosystem Services	$\$NZ_{2015/16}$	334,561	246,077	250,208	213,643
Cultural Ecosystem Services	$\$NZ_{2015/16}$	66,776	65,628	167,782	564,142
Regulating Ecosystem Services	$\$NZ_{2015/16}$	280,242	251,829	420,769	1,060,531
Supporting Ecosystem Services	$\$NZ_{2015/16}$	681,579	563,533	838,759	1,838,316
Commercial Value Per Hectare	$\$NZ_{2015/16}$ / hectares (dairy + forestry)	993	815	815	977

Note:
Net Value = Commercial value + Non-Commercial value of Ecosystem Services
Net Value = Provisioning + Cultural + Regulating value of Ecosystem Services
Net Value = Supporting value of Ecosystem Services
Gross Value = Provisioning + Cultural + Regulating + Supporting value of Ecosystem Services
Net Value = Gross Value/2

All of these land use changes result in two opposing trends. The first trend saw a **decrease in the land used for dairy farming** – in the base year of 2015/2016, 310 hectares were used for dairy farming; Scenario 1 and 2 saw this decrease to 274.79 hectares for dairy farming in 2045/2046; and in Scenario 3 the amount of land used for dairy farming decreased to 193.71 hectares, which is a 44% decrease from the base year.

The second and opposing trend saw an **increase in the land converted to wetlands** – in the base year of 2015/2016 and in Scenario 1 ('No Adaption' to climate change), there was 21.06 hectares of wetlands; in Scenario 2, the area of land and wetlands more than doubled to 56.3 hectares by active management; and finally in Scenario 3, the wetlands area increased to 193.71 hectares, which meant there was more land and wetlands than dairy farm. We assume no change throughout the scenarios in the amount of land planted in commercial pine trees (21.19 hectares).

In terms of total ecosystem services economic value, although there was a decrease in the amount of dairy farming and a consequential loss of net commercial revenue, overall there was **an increase in net economic value of the ecosystem services in Scenarios 2 and 3** where new wetlands were purposefully developed – in Scenario 2, the net value of ecosystem services was projected to be $838,759 in 2045/2046 and in Scenario 3 to be $1,838,316. Also in Scenario 1, there was a decrease in commercial revenue for dairy farming, but because there was no development of wetlands, this translated into an overall decrease in the net value of the ecosystem services, dropping from a base year figure of $681,579 of net commercial revenue to $563,533 in 2045/2046[10] .

Due to the scaling back of dairy farming in all of the scenarios due to deterioration of the land environment brought about by climate change, **all 3 scenarios had a decrease in the net commercial revenue** of the Tahamata farm. From the base year of $328,844 net commercial revenue, in 2045/2046 this dropped to $241,174 in Scenarios 1 and 2, and to $189,342 in Scenario 3.

Although it could be tempting to conclude from these data that Scenario 3 is the preferred scenario, this would arguably be a simplistic and premature conclusion for several reasons. Firstly, these scenarios are designed to be 'extreme' so that it becomes more obvious what the trade-offs are between the scenarios. But in the real-world decision-making, it is more likely that there will be a mixture of the scenarios with other land uses and management adaptions not yet considered, and even in the simplest of cases, it is more likely that the adopted regime will be at an intermediate point between these 'extreme' scenarios.

Secondly, although in principle a regime of converting land unsuitable for dairy to wetlands seems to deliver the highest level of ecosystem services value, these scenarios are not suggestive of how this might actually be implemented at a policy level through various instruments including both market and non-market policy instruments, or how this will happen both in terms of legal and institutional frameworks.

Thirdly, as is demonstrated by the table in Appendix B, the equity implications of these scenarios are important in the sense that the gain in some ecosystem service values, particularly some of those associated with wetlands, are very **diffuse and spread across very many stakeholders.** Whilst on the other hand, some of the losses of ecosystem services values impact on a much smaller group of stakeholders – this particularly applies to the loss of wages and salaries experienced by a very small number of people, and hence these **few individuals are bearing the brunt of the economic losses**. The most extreme example of this phenomenon is 'climate regulation', which affects everyone globally, and has a '$ increase in benefit per person ratio' of $0.000007 per 1 person from 2015/2106 to 2045/2016 for Scenario 3, which is an extremely diffuse benefit. Alternatively, 'loss of compensation to employees' in the same scenario affects only three people and hence has a very high '$ loss in benefit per person' of $25,009 per person. These very **disproportionate equity** effects add complication and difficulty to the implementation of any scenario that involves such ratios – and the added difficulty is that, with **'very diffuse' benefits (and costs)**, it is well-known from the evaluation literature that these factors are very difficult to take into account in cost:benefit frameworks, and even more difficult to effectively implement as this requires jurisdiction across a whole complexity of different agencies, many operating at different scales, different legal frameworks and, in the case of climate policy, across many nation states.

[10] These monetary amounts have been adjusted for expected inflation, and hence are expressed in $\$_{2015/2016}$

5. Concluding Remarks

This analysis has shown that the ecosystem services approach can be very usefully harnessed to provide insights into how the Tahamata farm can be managed in the face of climate change-induced effects that make the farm's land less suitable to dairy farming due to a rising water table. The ecosystem services valuation approach clearly showed that actively converting (by means of planting and engineering works) water prone areas to wetlands significantly increases the net economic value produced by the farm each year. Indeed, these ecosystem services benefits outweigh the loss of dairy farm land or productivity caused by soils and land becoming water inundated and puggy as a result of climate change.

Under the three scenarios ('No Adaption' to climate change, 'Some Expansion of Wetlands' and 'Full Expansion of Wetlands'), we found that by 2045/2046 the economic value of dairy production decreased due to the deteriorating condition of water prone soils and areas. In this regard, it is suggested that future research explore the feasibility of options that can at least maintain the 2015/2016 dairy farm production, perhaps whilst also capturing the very significant gains from developing more wetlands. Possibilities that should be analysed in Phase 2 include evaluating the feasibility of draining some of the water prone land, and exploring other options such as evaluating the use of alternative grasses, particularly in areas where the soil conditions may become more saline.

The economic valuation argument seems to support either the partial or full expansion of wetlands in water prone areas of the farm. This conclusion, however, needs to be treated with some caution – firstly, to undertake a proper cost:benefit analysis we require rigorous data on the costs associated with developing new wetlands (e.g., digging, engineering works, plantings, fencing, pest control and labour). Only then can we draw a more strong conclusion about the cost:benefit ratio of wetland development. Secondly, as already pointed out, it is not clear what the implementation pathway would be for developing more wetlands, particularly as many of the benefits of wetlands are 'diffuse', sometimes 'ill-defined' and play out across various scales, including the global scale, all of which make implementation more difficult as we don't tend to have sophisticated and mature institutional frameworks for dealing with such 'diffuse' benefits. All that said, in further research, it is imperative that we identify and discuss operational ways that the very significant 'economic potential' of developing more wetlands can be captured.

On a research level, we developed a reasonably nuanced approach for abstract appropriate of the economic values of ecosystem services from the literature. In this respect, the TEEB database discussed by de Groot et al. (2012) was very useful and, in particular, their multiple regression equation let us summarise data from 224 valuation studies of wetlands and rigorously showed what factors influence these values, which was particularly useful. In adopting such a benefit transfer approach, we also used and further developed both the method and data used in our New Zealand studies (refer to Patterson and Cole, 2013). As in all such studies, there could be improvements to our research methodology and our collection of associated data. Firstly, our spreadsheet model was, generally speaking, based on linear causal relationships and in some areas a more refined approach could be used, based on quantifying non-linear relationships – for example, we assume that the economic benefit of an ecosystem service in terms of $ per hectare remains constant throughout the years of the scenarios, meaning that, if the land area doubled, then the economic benefit of an ecosystem service associated with that land would also double. There is some evidence that the value of wetlands, for example, would not increase in such a linear fashion and instead that there would be diminishing marginal utility with an increase in land area of wetlands. Secondly, although the accounting approach we used has a number of benefits including removing potential double counting, and the care that we took in extrapolating data from the Tahamata farm situation as an improvement on our previous New Zealand studies, there is a need to corroborate the data about biophysical characterisation of Tahamata farm's ecological systems, particularly the wetland systems. Thirdly, more work on the applicability of the nonmarket valuation methods to Tahamata farm would be helpful, particularly in relation to iwi/hapū cultural values, which are particularly difficult to measure using non-market valuation methods and whereby simply translating overseas economic values on 'cultural ecosystem services' seems quite fraught and open to criticism.

It is intended that in Phase 2 of this research programme we will attempt to address the above issues that have stemmed from the research reported in this publication, where appropriate and as resources allow.

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Appendix A: Birdlife Associated with Te Hākari Dune Wetland

Weweia, New Zealand Dabchick [*Poliocephalus rufopectus*]
Kawau, Black Shag [*Phalocrocorax carbo*]
Kawaupaka, Little Shag [*Phalacrocorax sulcirostris*]
White-faced heron [*Ardea novaehollandiae*]
Kōtuku, White Heron [*Egretta alba modesta*]
Little Egret [*Egretta garzetta immaculate*]
Matuku, Australian Brown Bittern [*Botaurus stellaris poiciloptilus*]
Kōtuku Ngutu-Papa, Royal Spoonbill [*Platalea leucorodia regia*].
Black Swan [*Cygnus atratus*]
Canada Goose
Putangitangi, Paradise Shelduck [*Tadorna variegate*]
Mallard duck [*Anas platyrhynchos*]
Grey Duck [*Anas superciliosa*]
Tete, Grey teal [*Anas gracilis*]
Kuruwhengi, New Zealand Shoveller [*Anas rhynchotis variegate*]
Papamango, New Zealand Scaup [*Aythya novaeseelandiae*]
Kahu, Harrier [*Circus approximans*]
California Quail [*Callipepla californica*]
Pheasant [*Phasianus colchicus*]
Puweto, Spotless Crake [*Porzana tabuensis*]
Marsh Crake [*Porzana pusilla*]
Australian Coot [*Fulica atra australis*]
Pukeko [*Porphyrio porphyrio*]

Shrub land

Pipiwharauroa, Shining Cuckoo [*Chrysococcyx lucidus lucidus*]
Ruru, Morepork [*Ninox novaeseelandiae*]
Kōtare, New Zealand Kingfisher [*Halcyon sancta*]
Skylark [*Alauda arvenis*]
Welcome Swallow, [*Hirundo tahitica neoxena*]
Piwakawaka, Fantail
Matata, Grey Warbler [*Bowdleria punctata*]
Song Thrush, [*Turdus philomelos*]
Blackbird
Hedge sparrow, [*Prunella modularis*]

Pihoihoi, New Zealand Pipit [*Anthus novaeseelandiae*]
Tauhou, Silvereye [*Zosterops lateralis*]
Greenfinch [*Chloris chloris*]
Goldfinch [*Carduelis cardeulis*]
Redpol
Chaffinch [*Fringilla coelebs*]
Yellowhammer [*Emberiza citronella*]
Cirl Bunting [*Emberiza cirlus*]
House Sparrow [*Passer domesticus*]
Starling [*Sturnus vulgaris*]
White Backed Magpie [*Gymnorphina tibicen hypoleuca*]

Coastal

Torea, Variable Oystercatcher [*Haematopus unicolor*]
Torea, South Island Pied Oystercatcher [Haematopus ostralegus]
Spur-winged Plover [*Vanellus miles novaehollandiae*]
Tuturiwhatu, Banded Dottere, [Charadrius bicinctus]
Ngutu Parore, Wrybill [*Anarhynchus frontalis*]
Asiatic Whimbrel [*Numenius phaeopus*]
Kuaka, Eastern Bar-tailed Godwit [*Limosa lapponica*]
Greenshank [*Tringa nebularia*]
Poaka, Pied Stilt [Himantopus himantopus]
Karoro, Southern Blackbacked Gull [*Larus dominicanus*]
Taranui, Caspian Tern [*Sterna. Caspia*]
Kahawai, White fronted Tern [*Sterna. Striata*]

Potential

Kereru, New Zealand Pigeon [*Hemiphaga novaeseelandiae*]
Matata, Grey Warbler [*Bowdleria punctata*]
Tui, New Zealand honeyeater
Korimako, Bellbird [*Anthornis melanura*]

Source: Hei Whenua Ora (Smith, 2007)

Appendix B: Table 12 - Indicative Estimates of the Concentration of Gains/Losses ($), Per Person, for each Ecosystem Service, for the 3 Scenarios

Ecosystem Services	**Scale of Direct Benefit/ Loss**	**Reference Population**		**Concentration of Losses and Gains** Loss/Gain in Economic Value Per Person, from 2015/2016 to 2045/2045 (Δ $\$NZ_{2015/2016}$ per person per year)		
		Definition	**Number of Persons**	**Scenario 1: No Adaption to Climate Change**	**Scenario 2: Some Expansion of the Wetlands**	**Scenario 3: Full Expansion of the Wetlands**
Food (Milk) Production	person	Compensation for Employees	3	-15,714	-15,714	-25,003
Food (Milk) Production	person	Return to Shareholders	50	-111	-111	-177
Water Provisioning	person/firm	Employees & Shareholders of the Tahamata Farm	53	-15	1	50
Genetic/Medicinal Resources	national	New Zealand Population (2015)	4,596,000	0	0.0005	0.0022
Climate Regulation	global	World Population	7,500,000,000	0	0.000001	0.000007
Disturbance Regulation	site specific	Number of Visitors and Users of the Tahamata farm and The Hakari Wetlands per year	2,000	0	11	55
Water Storage and Retention	site specific	Number of Visitors and Users of the Tahamata farm and The Hakari Wetlands per year	2,000	2	79	387
Waste Treatment	site specific	Number of Visitors and Users of the Tahamata farm and The Hakari Wetlands per year	2,000	-10	43	244
Erosion Control	local	Population: Horowhenua and Kapiti District Councils (2013)	79,074	-0.85	-0.78	-1.17
Nutrient Cycling	local	Horowhenua and Kapiti (2013)	79,074	0.00	0.46	2.26
Biological Control	local	Horowhenua and Kapiti (2013)	79,074	-0.08	0.18	1.09
Gas Regulation	global	World Population	7,500,000,000	0	0.000001	0.000006
Refugia	regional, some nationally important	Population of the Manawatu-Wanganui and Wellington Regional Councils (2013)	703,701	0	0.07	0.36
Cultural - Other	rohe (iwi tribal area)	Iwi/hapu affiliates in the Horowhenua area - mainly Ngati Raukawa[1]	15,000	-0.04	5.51	27.09
Recreation	site specific	Number of Visitors and Users of the Tahamata farm and The Hakari Wetlands per year	2,000	-0.27	9.14	45.50
Soil Formation	person/firm	Employees & Shareholders of the Tahamata Farm	2,000	-0.13	-0.13	-0.24
Pollination	person/firm	Employees & Shareholders of the Tahamata Farm	2,000	-3.44	-3.44	-6.11
Primary Production	local	Horowhenua and Kapiti (2013)	79,074	-0.60	-0.27	0.67

Notes
1. Only covering iwi/hapu cultural values and hence afillates of local iwi are only counted. Numberof Pakeha benfactors ae more difficult to quantify