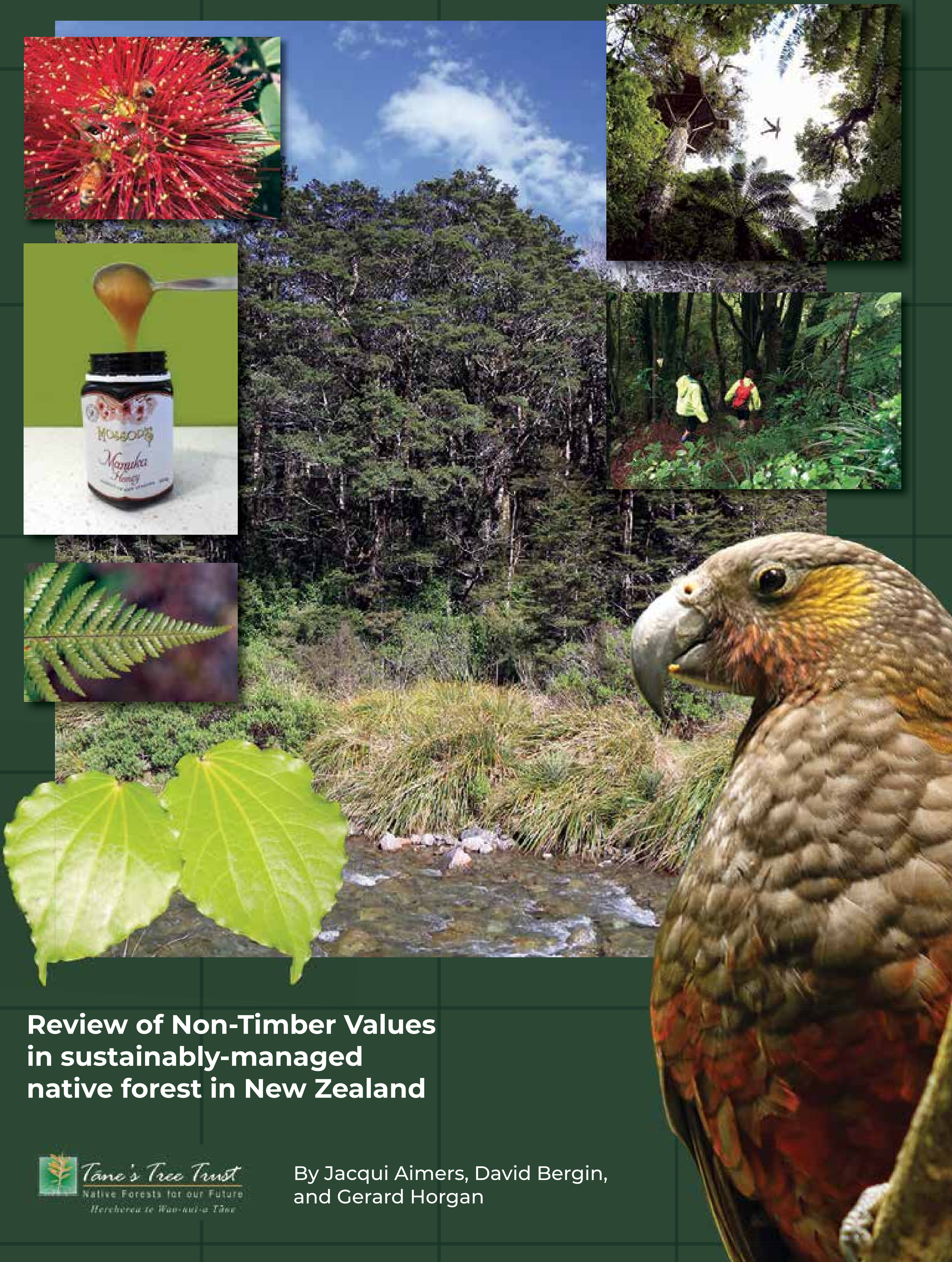
NON-TIMBER VALUES IN NATIVE FOREST



Review of Non-Timber Values in sustainably-managed native forest in New Zealand

By Jacqui Aimers, David Bergin, and Gerard Horgan

Tāne's Tree Trust
Native Forests for our Future
Herehere a te Wao-nui-a-Tāne

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The Tindall Foundation

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Dedication

The authors dedicate this publication to the people doing the extraordinary mahi of restoring and sustainably managing native forest, for the myriad of benefits our ngāhere provides.

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The reasons to love native trees by Ezra Whittaker-Powley, commissioned by Trees That Count, and inspired by this research on non-timber values.

ABSTRACT

Background

Natural ecosystems are important for our survival, providing many services that most of us are not fully aware of until they are damaged or destroyed. There is an imbalance between those benefiting from short-term economic gains and those who suffer the long-term environmental, cultural, and socioeconomic impacts from destruction of natural resources. Prior to human arrival, New Zealand was almost entirely forested below treeline. The current forested area represents over 70% reduction from the pre-human state circa 800 years ago. This large-scale deforestation has been disastrous for our soils, water, and biodiversity. However, there is now increased awareness of the importance (and vulnerability) of New Zealand's natural capital, and ecosystem services have become important in planning and policy matters.

Methods

Current thinking on non-timber values (NTVs) was reviewed. NTVs cover all elements of the ecosystem services concept other than wood products. The focus was on New Zealand's native forests <u>outside of the conservation estate</u>. Literature was examined and synthesised. Knowledge gaps and deficiencies were identified, recommendations were made for further work, and implications for land-use decisions and policy-making were examined.

Results

NTVs were summarised under the following categories: (i) non-timber forest products; (ii) environmental regulating services; and (iii) socioeconomic, cultural, and spiritual values.

There are widely differing methods for quantifying NTVs, often involving subjective judgments with caveats and extrapolation from site-specific examples, resulting in wide margins of error. There is the conundrum of 'valuing the invaluable', i.e., NTVs without direct material benefits, but important, nonetheless. Ideally, NTVs should be determined on a site-specific basis, with stakeholder engagement, and qualitative values included in addition to quantitative NTVs.

New Zealand's economy relies on forests for clean air and water, stable soils, meeting climate change commitments, biodiversity conservation, providing ambient environments for outdoor recreation and tourism, and for being integral to distinctive natural landscapes, spiritual well-being, cultural identity, and international branding as a clean, green country. However, NTVs are currently not easily monetarised, other than carbon sequestration and honey.

Conclusions

Despite identified knowledge gaps, it is apparent that sustainably managed native forest deserves a much higher profile as an economically viable land use. Recognising NTVs as quantifiable assets would encourage native afforestation. Weaving native forest back into our rural and urban landscapes will provide a myriad of ecosystem services that will improve environmental and cultural values, and mitigate the effects of climate change, urbanisation, and intensification of land use. Native forestation should be incentivised as the benefits accrue far beyond the sites where land owners sustainably manage and extend native forest cover.

Aggregated NTVs of native forests are likely to be greater than for exotic plantations – particularly concerning scenic, cultural, and spiritual values, biodiversity, water quality, and protection of erodible steepland, downstream infrastructures and ecosystems. Native forests managed for NTVs alone, or under continuous cover regimes, are likely to have the highest aggregated NTVs, particularly in riparian areas. NTVs are best viewed in a broad context - rather than focussing on a single NTV – the latter could lead to perverse outcomes. However, biodiversity is a pivotal NTV, i.e., efforts to increase biodiversity values will likely concurrently increase most other NTVs.

Keywords: non-timber values; ecosystem services; indigenous forest; native forests; climate change; non-timber forest products; environmental services; cultural and spiritual values.

CONTENTS

1.0 Introduction

This bulletin presents the results of a literature review of non-timber values (NTVs) in native forests, particularly New Zealand's native forests that are actively and sustainably managed, on private and Māori land outside of the conservation estate. The review was initiated by Tāne's Tree Trust as part of the Our Forests Our Future programme, funded by The Tindall Foundation. Tāne's Tree Trust is a not-for-profit, charitable trust focused on promoting the use of New Zealand's indigenous tree species for multiple environmental and cultural benefits, with the option of sustainable production of high-quality timber and other resources where appropriate.

1.1 Definitions and concepts

Scientific nomenclature follows Allan (1961) and Edgar (1971) plus recent taxonomic revisions.

The term NTVs is used rather than 'ecosystem services', as it is a more precise term for the purposes of this review. Essentially, NTVs can be considered a subset of ecosystem services. NTVs are defined as any products or ecosystem services associated with forests, other than timber or wood fibre. Ecosystem services are the benefits that people obtain from ecosystems. In the forestry context, this includes the production of wood and fibre. Ecosystem services are also referred to as 'natural capital' (Costanza et al. 1997), i.e., all aspects of the natural environment that are needed to support life and human activity (Tax Working Group 2019).

A sustainably managed native forest is defined as being primarily composed of indigenous tree species, which can be existing high forest, or a planted or naturally regenerating stand that is actively and sustainably managed for multiple purposes. Note that this includes the entire forest ecosystem in all tiers of the forest and the associated soils. Sustainable management involves a holistic approach where environmental services, recreation, conservation, aesthetic landscape values and cultural values are considered, as well as the option of timber production or utilisation of non-timber forest products, where appropriate.

In this context, the definition of a sustainably managed native forest does not include forests managed as wilderness areas in the conservation estate. This review focuses on the second and third types of native forest described below.

The different types of native forest regimes recognised in this bulletin:

1. Publicly owned parks and reserves on Conservation Land administered by the Department of Conservation, owned in perpetuity by the New Zealand public and protected by Acts of Parliament. (Note that this type of forest regime is not the focus of this review).
2. Privately and Māori-owned permanent native forests - established for conservation, carbon sequestration, catchment protection, or aesthetic or heritage reasons - with no timber harvest intended. This includes covenanted forested areas such as those administered by the QEII Trust.
3. Privately and Māori owned permanent native forests - managed in continuous cover forestry (CCF) regimes (Barton 2008) for multiple purposes. CCF includes near-to-nature practices (as seen in some German, French, and Swiss forests) to supply unique, high-quality, high-value timbers.
4. Plantations, usually single species, established primarily for timber production. Note that this includes a very small proportion of native forest in New Zealand.

The type of forest management influences NTVs, as discussed throughout this review. With the last management method, traditionally there was an expectation of management under a clear-fell regime. However, there is likely to be increasing interest in encouraging succession of single-species plantations to multi-species, multi-aged forest, using CCF principles. In the authors' view, most native forest plantations are likely to be managed under CCF regimes in the future.

Quantifying economic benefits associated with NTVs is important because it allows the wider benefit of forests to be accounted for in economic analyses. However, the concept of a 'value' in this review goes beyond a perception based on traditional economics, where a value is placed only on a product that can be consumed or utilised. In this context, a value pertains to any benefit or service associated with forests, such as the aesthetic value of a forested landscape within a wider scenic vista, which cannot readily be given a monetary value. The assertion is that, just because a particular value cannot be easily quantified in monetary terms, it is not automatically inferior.

1.2 Overall goal and objectives

This review provides a synthesis of information on NTVs associated with forests in New Zealand and discusses the opportunities and challenges for quantifying these values; and the implications. Particular reference is made to native forests that are actively and sustainably managed, and are either planted or naturally regenerating in indigenous species.

To meet this overall goal, the key objectives of this work were to:

1. Review the literature on NTVs; identifying the various types of NTVs and providing a summary for each NTV.
2. Determine the relevance of the NTVs to sustainably managed native forests.
3. Ascertain whether these NTVs can be monetarised, or whether there is the potential to do so; alternatively, identify other mechanisms for valuing NTVs.
4. Review methodology and tools for identifying and valuing NTVs, with a focus on tools that have been utilised or have the potential to be utilised within the New Zealand context of native forest on private or iwi land.
5. Synthesise the information on NTVs and identify weaknesses and deficiencies in the collective knowledge. Subsequently, make overall conclusions and recommendations for further work.
6. Discuss the implications for economic analyses, land use decisions and policy-making in New Zealand.

2.0 Methodology

Classification of types of NTVs in this review largely follows the Millennium Ecosystem Assessment (2005), Lindhjem (2006), and Yao et al. (2017).

Key publications were identified in the extensive literature collections of the authors and their colleagues, and through online literature searches. Relevant references were also identified from citations in key papers. Online search tools were utilised, particularly ResearchGate and ScienceDirect. In addition to this, searches based on key words were undertaken in key journals, particularly the New Zealand Journal of Forestry Science and the New Zealand Journal of Forestry. Searches also included publicly available reports from government, research, and non-government organisations.

Key words included (but were not confined to) “ecosystem services”, “non-timber values”, “non-timber forest products”, “secondary forest products” (and specific, identified forest products), and many other specific key words related to each type of NTV, in conjunction with key words including “forest”, “forestry”, “native forest” or “indigenous forest”.

Different types of NTVs were identified and information was collated under each type of NTV. The focus was NTVs directly associated with, or potentially associated with, native forests in New Zealand. An assessment was made over whether a monetarised value could be applied, or potentially applied to the identified NTV, or whether other methods of measurement were more appropriate.

Methodology and tools for determining ecosystem services were also reviewed with a focus on tools that have been utilised or have the potential to be utilised within the New Zealand context. Gaps in knowledge were identified and conclusions and recommendations were made based on the synthesised information on NTVs - including implications for economic analyses, land-use decisions and policy-making.

3.0 Background

3.1 New Zealand's forests

Prior to human arrival, New Zealand was almost entirely forested below the treeline. The current forested area represents a more than 70% reduction from the pre-human state circa 800 years ago (Allen et al. 2013; Steer 2014; Forbes et al. 2020). Forest cover was first reduced by Māori, who burnt forest and cleared land for cultivation and settlement (Allen et al. 2013). Deforestation accelerated with the arrival of European settlers, with the rapid development of land suitable for agriculture, particularly in lowland areas. This led to wide-scale ecosystem degradation and habitat loss (Thorpe 1998; Steer 2014; Walker et al. 2018; Forbes et al. 2020). Much of the remaining natural forest in New Zealand is restricted to upland regions, with intact lowland podocarp-hardwood forest now scarce in many regions (Parliamentary Commissioner for the Environment (PCE) 2002; Ministry for Primary Industries (MPI) 2015; Hall 2016; Forbes et al. 2020).

Concern began in the 1860s and 1870s over the destruction of native forest, declining native bird numbers, and the need for regulated forest management (Roberts et al. 2015). The State Forest Service was established in 1919 (later renamed New Zealand Forest Service) with a vision for sustained-yield forestry of native trees supported by exotic plantations. Over the following decade and a half, there was widespread planting of fast-growing exotic forestry species, particularly radiata pine *(Pinus radiata)* (Nathan 2015). Soil conservation programmes began in the 1940s and 1950s due to concerns over erosion and sedimentation of waterways, particularly where steeplands had been deforested. This resulted in the first programmes of tree planting on erosion-prone land.

The conservation movement gained momentum and political recognition in the 1960s and 1970s. It became clear that many New Zealanders viewed native forests as far more valuable than the value of their timber alone. The Maruia Declaration was signed in 1976, demanding a halt to all logging of native forest on public land (Roberts et al. 2015). In 1987, the Forest Service was dis-established; the Forestry Corporation was established with the role of managing all Crown-owned production forests (which initially included some native forest), and the Department of Conservation was established to manage conservation land and wildlife (Nathan 2015).

In 1991, the New Zealand Forest Accord was signed by representatives from environmental groups and the forestry industry. It recognised "the important heritage values of New Zealand's remaining indigenous forests and the need for their protection and conservation". It also recognised the importance of commercial plantation forests (of exotic or indigenous species) for renewable fibre and energy, as an alternative to the depletion of natural forests.

In a paper delivered at a forestry conference in 1998, it was stated that "the value of New Zealand's indigenous forest should not just be measured in terms of its market value, but its contribution to the economy of New Zealand as a whole" (p. 26, Thorpe 1998). This was further elaborated by Steer (2014, p. 39): "… the real value of New Zealand's indigenous forest is not financial, but lies in non-consumptive uses, such as soil and water enhancement, amenity provisions, spiritual and visual values and perhaps, most importantly, biodiversity conservation".

The New Zealand Climate Change Accord was signed in 2007, recognising that "carbon sequestration by forests is a key mechanism to offset greenhouse gas emissions and should be utilised to help New Zealand's transition to a carbon-neutral economy" (New Zealand Forest Owners Association (NZFOA) 2007). There were also strong statements that government policies "should avoid perverse outcomes such as the loss of indigenous forests …" and "promote the retention and expansion of indigenous forests and replanting and expansion of plantation forests and associated use of wood products to recognise their positive climate change benefits."

Today nearly 39% of New Zealand's land area is in forest cover, with over 29% in natural forest of indigenous species (NZFOA 2017, 2019). Note that there are varying figures for the extent of native forest as some observers split, while others combine, the categories of native forest and shrubland (or scrubland), though the latter is often regenerating native forest.

About 76% of New Zealand's native forest is publicly owned and protected under the management of the Department of Conservation. The amount of land set aside for conservation is high by international standards; however, much of this is high elevation, steep hill country. There are recognised issues including the limited resourcing of the Department of Conservation and under-representation of lowland natural ecosystems in the conservation estate (Thorpe 1998; PCE 2002; Steer 2014; OECD 2017a).

In New Zealand, there is a clear distinction between plantation forestry, which is based almost entirely on exotic species, and natural forests of indigenous species (Steer 2014, MPI 2015; Goulding 2017). Much of the plantation resource is owned by international forestry corporations, but farm-based forestry is also important, and so is iwi ownership, particularly in the central North Island (MPI 2015). Most of the former exotic state forests are reverting to iwi ownership and the cultural values of forests are becoming increasingly important (Steward 2017).

There is a strong dichotomy in land management in New Zealand between conservation and production, and indigenous and exotic ecosystems (PCE 2002). This is particularly evident in forestry and limits the realisation of the wider value of native forests in our rural working landscapes and urban areas, and their importance for biodiversity and human well-being.

Most of the native forest in the conservation estate is contained in tracts larger than 500 ha. About 20% of New Zealand's native forests are in private ownership or owned by Māori entities, and most of this consists of smaller forest fragments (Steer 2014; MPI 2015; MPI 2017a; Nixon et al. 2017). About a third of the privately-owned native forest is regarded as suitable for sustainable harvesting (MPI 2017a). Timbers from native species are ideal for high-quality furniture and finishing products (Bergin and Gea 2007; Steer 2014). Less than 0.1% of natural forest is harvested per year, largely on private land, under strictly sustainable forest management permits and plans (OECD 2017a). Only single trees and small coupes can be felled for timber (MPI 2015).

Only a very small part of the plantation resource is comprised of native forest species. Surveys of native plantations undertaken by the Forest Research Institute in the 1980s (Pardy et al. 1992) and by Tāne's Tree Trust in 2010 (Bergin and Kimberley 2012) assessed over 100 planted stands of native trees ranging from 10 to 100 years of age. Planted stands were typically small in area. Estimates of the total area of indigenous plantations range from 100 to 2500 hectares (MPI 2015). The largest areas were established by the former New Zealand Forest Service and were primarily kauri *(Agathis australis)*, rimu *(Dacrydium cupressinum)* and tōtara *(Podocarpus totara)* often as inter-planted lines amongst regenerating shrubland. Most of these historical plantings are on land that is now managed by the Department of Conservation, so are unlikely to be harvested (MPI 2015).

In recent years, there has been a conservative estimate of approximately 10 million native trees planted annually (Bergin and Gea 2007; NZPPI 2019). Significant increases are anticipated due to government initiatives such as the One Billion Trees programme (Te Uru Rākau 2018, 2019a) and the Climate Change Commission's recommendation for a significant scaling up of native forest establishment to help New Zealand meet international climate change commitments (Climate

Change Commission 2021). Previously, plantings have been relatively small-scale and established for a mix of purposes such as riparian planting to improve water quality, planting to stabilise erosion-prone land, and restoring native forestry within landscapes dominated by agriculture. Native trees are only occasionally planted with the option of a long-term timber resource.

New Zealand currently imports large amounts of specialty timbers each year, some of which comes from non-sustainable sources (Devoe and Olson 2001; PCE 2002; May and O'Loughlin 2005; Steer 2014; MPI 2015; Goulding 2017). New Zealand imported NZ$99 million worth of sawn hardwoods and softwoods in 2016, and NZ$107 million worth in 2017 (MPI 2021a). A large amount of wooden furniture was also imported. There are published discussions questioning why New Zealand is not producing more of its own specialty timbers, including timber from native species (Devoe and Olson 2001; May and O'Loughlin 2005; Steer 2014; Goulding 2017). For example, sustainably grown tōtara would be an excellent substitute for imported western red cedar *(Thuja plicata)* in many applications (May and O'Loughlin 2005).

Today, the real value of New Zealand's natural forests is seen in a much wider context than timber production alone, with its role in biodiversity conservation regarded as particularly important (Thorpe 1998; Steer 2014; Roberts et al. 2015). Most of New Zealand's flora and fauna are endemic and many species are highly unique due to a long period of geographic isolation (OECD 2017a; Walker et al. 2018). However, species extinction rates of native fauna are among the highest in the world, largely due to loss of natural habitat in many regions and the introduction of pests (Brown et al. 2015; MPI 2015; OECD 2017a; Walker et al. 2018).

The economic value of forests in New Zealand is significant (Nixon et al. 2017; Vivid Economics 2017). Nearly 7% of New Zealand's land area is currently planted in production forest, with 89.9% in radiata pine and 6.1% in Douglas-fir (*Pseudotsuga menziesii*). New Zealand's forestry export value in the year to June 2019 was $6.93 billion, with a total contribution to GDP of $3.55 billion (from forestry and downstream activity) (NZFOA 2019). The role of forests in multiple other functions and their wider value to society was initially often overlooked (Payn and Clinton 2005) but is now becoming better recognised (MPI 2015; Hall 2016; PCE 2016; Nixon et al. 2017; Yao et al. 2017).

Forests are also important for international trade and tourism (Nixon et al. 2017). New Zealand has an international reputation as a 'green' country, both as a tourist destination and as a producer of natural and safe food (Kaefer 2014; OECD 2017a). But this 'clean, green' image has been criticised. In 2017, an environmental performance report for New Zealand released by the OECD (Organisation for Economic Co-operation and Development, an inter-governmental economic organisation with 35 member countries) found that New Zealand's growth model, based largely on exploiting natural resources, was approaching its environmental limits (OECD 2017a; OECD 2017b):

> "New Zealand's natural environment provides tremendous benefits on several levels. Easy access to pristine wilderness and good air quality heighten quality of life for New Zealanders, while the spectacular landscapes attract millions of visitors every year. Apart from the economic benefits of tourism, the natural environment provides the basis for the country's large exports of dairy, meat, wool, fruit, vegetables, fish, and wood.
>
> But New Zealand's growth model is approaching its environmental limits. Greenhouse gas (GHG) emissions are increasing. Pollution of freshwater is spreading over a wider area. And the country's biodiversity is under threat" (p. 3, OECD 2017b).

There is a growing focus in the forestry industry on sustainable development and the wise stewardship of natural resources, buoyed in part by consumer pressure and public opinion. Currently, about 68% of the New Zealand plantation resource is under environmental certification by the Forest Stewardship Council (FSC) (NZFOA 2020).

FSC is an international organisation promoting environmentally appropriate, socially beneficial and economically viable management of forests (FSC New Zealand 2017). FSC certification provides a third-party guarantee that the products come from forests that have been managed following FSC principles, i.e., sustainably managed. New Zealand also participates in the Montreal Process, which provides a framework for international reporting on progress towards sustainable forest ecosystem management for both planted and natural forests (MPI 2015). Involvement in FSC certification and the Montreal Process has influenced industry and government opinions about forests and demonstrates recognition of the wider value of forests beyond timber production.

There are calls for farmers to be part of the solution by planting trees or encouraging forest regeneration (PCE 2016). However, there is already an active farm forestry ethos. The New Zealand Farm Forestry Association was formed in 1957 and has 27 branches throughout New Zealand (New Zealand Farm Forestry Association 2019). The New Zealand Landcare Trust was established in 1996 to assist farmers and community groups to improve the sustainability of land and waterways, with tree planting a major component (New Zealand Landcare Trust 2021). Both organisations have had a positive impact on forestation rates, with native and exotic species, and recognition of the wider value of forests among land-owners. Also, for 40 years the Queen Elizabeth II National Trust has been helping private land-owners to permanently protect native forest via open space covenants (QEII National Trust 2021).

In Manaaki Whenua's 2019 Survey of Rural Decision Makers, non-foresters were asked for their reasons for planting trees in the near future (Stahlmann-Brown 2019). The most popular reasons were aesthetic-landscape values, habitat-biodiversity, animal welfare, water quality, and personal well-being/spiritual/cultural values - all of which currently do not have a direct monetary value. Other reasons included erosion control, kaitiakitanga, resilience to climate change, wood products, and carbon sequestration.

Carbon sequestration in forests is an important mechanism for helping New Zealand meet its climate change targets (NZFOA 2007; Hall 2016, 2017; NZFOA 2020). New Zealand's gross greenhouse gas (GHG) emissions per capita, and per GDP, are among the highest in the OECD and continue to steadily rise (OECD 2017a; NZFOA 2020). Net emission removals, largely through forestry, have decreased in recent years due to maturing of the commercial plantation resource and deforestation. The increase in net emissions between 2004 and 2007 was largely due to deforestation prior to the introduction of the New Zealand Emissions Trading Scheme (ETS) (Ministry for the Environment 2016). In 2018, 23.4 Mt CO_2-e was removed from the atmosphere by the forestry sector, compared with 31.5 Mt CO_2-e in 1990 (NZFOA 2020).

The ETS was established in 2008, to reduce net GHG emissions and meet international targets for climate change (OECD 2017a). Initially, it was envisaged the ETS would encompass all sectors, including forestry and agriculture. However, the ETS was amended in 2009, with emissions from agriculture initially exempted from any obligation, a decision that has been openly criticised (PCE 2016; OECD 2017a). Agricultural greenhouse gases form about half of New Zealand's emissions (Ministry for the Environment 2016; OECD 2017a). The forestry sector currently sequesters about 30% of gross emissions (Ministry for the Environment 2016).

Despite recognition of forestry's important role in carbon sequestration (NZFOA 2007; MPI 2015), there was significant deforestation in many parts of New Zealand in the decade 2004 to 2014 (Hall 2016; Ministry for the Environment 2016; Ministry for the Environment & Stats NZ 2017; NZFOA 2017, 2019; Nixon et al. 2017). This was largely due to land-use conversion from plantation forestry to pastoral agriculture, particularly dairy farming (Manley 2015; PCE 2015; Nixon et al. 2017; OECD

2017a). It was driven in part by forestry land-owners anticipating deforestation liabilities under the ETS (prior to 2008) and the perceived lack of profitability of forestry compared with other land uses (Manley 2015; MPI 2015; Hall 2016; Ministry for the Environment 2016; PCE 2016; OECD 2017a). Deforestation was predicted to continue unless there were greater incentives for forestry (Manley 2015; Hall 2016).

The NZ ETS was initially linked to overseas carbon markets. Cheaper international units pushed New Zealand's carbon prices down and this probably contributed to deforestation (MPI 2017b). The ETS was amended to exclude international units from mid-2015 onwards. This, along with phasing out of the one-for-two deal, has helped New Zealand's carbon prices rebound (MPI 2017b).

The New Zealand government ratified the Paris Agreement in October 2016 and committed to reducing GHG emissions by 30% below 2005 levels by 2030. The report 'Our Forest Future', commissioned by Pure Advantage, identified a trend of net forest loss and called for 1.3 million hectares of new forest to be planted to get back on track regarding reduction in net greenhouse gas emissions (Hall 2016). A report by Vivid Economics (2017) put forward three potential strategies for emissions reductions, each scenario including substantial new forest planting.

Strong, stable carbon prices provide an incentive for forestation (Ministry for the Environment 2016; Vivid Economics 2017). Government-funded forestation programmes also continue to provide incentives (MPI 2017b; Te Uru Rākau 2019a). The New Zealand government's One Billion Trees Programme set a goal to plant one billion trees in the decade 2018 to 2028. This is one of many initiatives funded by the Provincial Growth Fund, aimed at enhancing regional economic development opportunities, creating sustainable employment, and helping meet New Zealand's climate change targets (Te Uru Rākau 2018, 2019a).

The One Billion Trees Programme signified that the New Zealand Government recognises the wider value of forests. The aim was to incentivise the planting of a broad range of tree species for multiple objectives, such as carbon sequestration, honey production, improving soil stability, improving water quality, restoring lowland native forest, enhancing indigenous biodiversity, boosting employment outcomes in marginalised communities, and increasing resilience to a changing climate through integration of trees into landscapes (Te Uru Rākau 2018). The programme has committed to funding two-thirds of plantings in native (as opposed to exotic) species (Te Uru Rākau 2020). At the time of writing, nearly 70% of trees funded by One Billion Trees are indigenous (Te Uru Rākau 2021). Protecting soil, water quality and other natural resources are key aims for the programme.

The Climate Change Commission recognises the value of land use change to permanent native forests, in its advice on the direction of policy necessary for New Zealand to meet international climate change commitments (Climate Change Commission 2021). The Commission acknowledges that this will simultaneously address multiple other environmental issues, providing substantial co-benefits for the environment and associated communities. The importance of co-benefits was also emphasised in a World Economic Forum report on "Nature and Net Zero' (2021).

3.2 Non-timber values and ecosystem services

Natural ecosystems sustain over half of the global economy – ensuring food security, supporting water cycles, protecting communities from floods and fires, and assisting with climate change mitigation (by absorbing carbon dioxide) and adaptation (by increasing resilience) (World Economic Forum 2021). However, most people are not fully aware of these benefits.

The concept of ecosystem services was created to illustrate the benefits that natural ecosystems generate for society and to raise awareness of their importance and vulnerability (Costanza et al.

1997; Millennium Ecosystem Assessment 2005). When estimates of economic losses associated with depletion of natural assets are factored into measurements of the total wealth of nations, they significantly change the balance sheet in economies that are dependent on natural resources, i.e., this results in a loss in net savings (Millennium Ecosystem Assessment 2005).

The term ‘NTVs’ (non-timber values) is used in this review rather than ‘ecosystem services’ as it is a more precise term for the purposes of this work. NTVs are a subset of forest ecosystem services, i.e., ecosystem services associated with forests, other than timber and pulp products. Note that there are natural ecosystems and managed (human-modified) ecosystems, which both have ecosystem services important to human well-being (Dymond et al. 2014).

The concept of ecosystem services was first introduced in the 1950s but only gained wider recognition more recently. Robert Costanza and his colleagues were the first to comprehensively attempt to estimate the economic values of ecosystem services (Costanza et al. 1997). They did so on a global scale, in what is now regarded as a pivotal research paper: *The Value of the World's Ecosystem Services and Natural Capital*:

> “We estimated the current economic value of 17 ecosystem services for 16 biomes, based on a synthesis of published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of $16 - 54 trillion/yr., with an average of $33 trillion/yr. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global GNP is around $18 trillion/yr” (p. 254, Costanza et al. 1997; note that the values are in US dollars).

Costanza *et al.* (1997) were candid about the shortcomings of their research. The following year, they were compelled to reply to critics who questioned the value of the work:

> “Why would one want to measure the aggregate value of ecosystem services, whether at local, regional, national or global scales? This is a reasonable and necessary exercise to the extent that human welfare depends on whether these services improve or deteriorate. We may have more houses, but if that means we have fewer trees and less viable forests, something is seriously wrong with an accounting system that only adds up houses and presumes that this is a full measure of welfare change” (p. 68, Costanza et al. 1998).

In the New Zealand context, in 2002, a pivotal publication by the Parliamentary Commissioner for the Environment (PCE) discussed the development of ecosystem service markets to support future roles for native plants on private land (PCE 2002).

The concept of ecosystem services subsequently gained acceptance and momentum. The Millennium Ecosystem Assessment (MEA) programme was established by the United Nations in 2001. In 2005, the MEA programme published a widely accepted definition of ecosystem services: "the benefits people obtain from ecosystems" (p. 40, Millennium Ecosystem Assessment 2005). Over 1,360 international experts assessed the consequences of ecosystem change for human well-being and provided a scientific basis for action. They considered 10 key ecosystems in the world, with forests identified as providing the largest number of ecosystem services. Approximately 60% of the ecosystem services evaluated worldwide were found to be degraded or used unsustainably.

Some practitioners argue that there are ecosystem services that should not be valued by short-term perceptions of instrumental or utilitarian value; rather, their value should be determined by ethical and moral principles. Patterson and Cole (2013) acknowledge this argument in their estimation of the total economic value of New Zealand’s land-based ecosystems and their services (see below). However, they contend that only when the non-market values of ecosystems are accounted for, will decision-makers grasp the importance of natural capital relative to traditional economic indicators (such as GDP) and factor this into land use and resource management decisions. Brown *et al.* (2015) argue that environmentally sustainable economies are essential for lasting prosperity.

Costanza et al. (2014) published a revision of their earlier research with an updated estimate of the global value of ecosystem services of between US$125 and US$145 trillion per year. They noted a significant reduction of ecosystem services due to land-use change in the 17 years since the first publication on global ecosystem services (Costanza et al. 1997).

In the New Zealand context, Barton (2008) in his pivotal publication – a handbook for continuous cover forest management – makes the following comments:

> "There is good evidence suggesting that forests managed under continuous cover produce higher values for carbon sequestration, landscape, biodiversity, soil, and water than do clear-cut forests or farmland. Apart from carbon there have only been minimal attempts to value these factors or consider how such valuation might provide a benefit to the owner; there is good reason to undertake research in this area" (p. 35, Barton 2008).

Also, in the New Zealand context, van Meeuwen-Dijkgraaf et al. (2010) contend that ecosystems are inherently complex and economic valuations are challenging, but the value of ecosystem services is likely to be huge, even for small, defined ecosystems. Probably the best collective information on ecosystem services in New Zealand is found in a book edited by Dymond (2013). It was the first collation of assessments of ecosystem services at national and regional scales for New Zealand, with 36 chapters written by 118 authors.

In terms of NTVs, another useful source of information is New Zealand's third national report under the Montreal Process (MPI 2015). Although it is not reporting on ecosystem services, per se; it reports on progress towards achieving sustainable forest ecosystem management for both planted and natural forests, and this includes extensive information on ecosystem services provided by forests. Also, Hall (2016) compiled information from studies on ecosystem services of plantations and natural forests in New Zealand (Table 1, Chapter 4 of Our Forest Future).

Four commonly described categories of ecosystem services are described below in the context of forest ecosystems (Millennium Ecosystem Assessment 2005; Nixon et al. 2017; Yao et al. 2017):

- **Provisioning services:** extraction of materials such as wood, fibre, energy, and chemicals for pharmaceutical and industrial uses; also, understory crops, honey and freshwater.
- **Regulating (environmental) services:** stabilisation of soils, reduction in erosion and sedimentation; moderation of water flow and microclimates; retention of carbon and nutrients, preventing discharge into atmosphere and water; habitat provision and protection of biodiversity; hazard regulation, particularly in modulating the effects of extreme events such as floods and fires. Sometimes referred to as environmental values.
- **Social and cultural services:** ambient environments for recreation, tourism, natural and historic heritage; general amenity; conservation of species; spiritual and cultural well-being.
- **Supporting services:** basic bio-physical and chemical functions of nutrient and water recycling, and soil formation, which underpin all other ecosystem services.

Yao et al. (2017) provide a diagram and explanation on how the categories of ecosystem services overlap, and how they link with components of human well-being, with particular regard to forestry. The provisioning category includes wood and fibre as well as non-timber forest products. Also, there are overlaps between all categories, e.g., habitat provision is under the regulating (environmental) services category, and species conservation is under the social and cultural services category, as conservation of native species is important to cultural identity.

According to a New Zealand Institute of Economic Research (NZIER) report, the concept of ecosystem services provides a useful framework to explain the relationship between natural resources, their biophysical functions, and their contribution of services to human well-being (Nixon et al. 2017). It also provides a systematic way of ensuring that economic strategy, land-use decisions and policy include the natural capital of ecosystems.

The NZIER report estimated in economic terms the wider benefits of forestry in comparison with agriculture. Plantation forestry created an estimated NZ$31 million of environmental benefits annually, while dairying created an estimated annual loss of NZ$18 million due to environmental damage (Nixon et al. 2017). The report recommended that the wider role of forestry be recognised through satellite accounts, i.e., rearranging existing data and introducing new information or data (such as social and environmental values) to properly reflect the industry's importance.

The NZIER report used site-specific examples extrapolated to overall national figures. A drawback of this approach is that there can be marked differences between sites; however, it provides a starting point for determining monetary values for environmental services. The authors note that too few studies have been undertaken in New Zealand to reliably infer generic values across the country (Nixon et al. 2017). And it is also problematic translating overseas values into New Zealand contexts. These conclusions are similar to those of Patterson and Cole (2013).

Note that there are other approaches to measuring ecosystem services. Roberts et al. (2015) utilised Max-Neef's (1991) approach in their comprehensive report 'The nature of wellbeing', which focuses on how nature's ecosystem services contribute to the well-being of New Zealand and its people. This approach involves nine fundamental human needs: subsistence, protection, affection, leisure understanding, participation, creation, identity and freedom. Like many of the earlier studies of ecosystem services in New Zealand, Roberts et al. (2015) focus on the first four of these human needs: subsistence, protection, affection and leisure values. The authors also discuss the lack of consensus among practitioners measuring ecosystem services, particularly non-market ecosystem values, and the lack of acceptance of a single, universally applied framework.

Despite general acknowledgement of the importance of natural capital, until recently NTVs have largely not been factored into the economic value of forests. This is partly because of the difficulty in tracking and quantifying the myriad of products and services associated with forests, which is partly due to the lack of universally accepted frameworks for measuring non-market services. It is also because of the lack of a holistic, long-term, sustainable focus regarding the exploitation of natural resources in modern times. Instead, a focus on short-term cash flow has often prevailed over traditional viewpoints of the wider value of resources (Gluckman 2017).

According to the Tax Working Group (2019), the well-being of New Zealanders is critically dependent on the state of our natural environment and the health of our ecosystems. Their report states that a broader perspective would "acknowledge natural capital as a profound and non-substitutable basis for the economy" and "natural capital is productive in its own right; even 'unused' or 'vacant' land, for example, produces a stream of ecosystem services that underpin human existence". Indeed, economic progress should not be defined solely by GDP growth, but consider the multiple values of nature for a good quality of life, while not exceeding biophysical and social limits (Pörtner et al. 2021).

3.3 Measuring ecosystem services

The market value of timber or fibre in forests is relatively easy to estimate but non-market ecosystem services (which include most NTVs) are more difficult to measure and are usually not factored into the economic value of forests. However, valuation of non-market services is now recognised as an essential tool in planning and policy-making in New Zealand and worldwide (Yao and Kaval 2007;

van Meeuwen-Dijkgraaf et al. 2010; MPI 2015; Walsh et al. 2017; Nixon et al. 2017). Government agencies in New Zealand are increasingly recognising the need to accurately assess natural capital, and to develop valuation methods that can measure non-market goods and services (MPI 2015).

The importance of non-market ecosystem services is also being recognised by commercial enterprises and community organisations throughout New Zealand (MPI 2015). As the public becomes more familiar with this type of assessment, environmental and cultural values are likely to play a larger role in negotiations on resource management issues (van Meeuwen-Dijkgraaf et al. 2010; MPI 2015). Communication of research findings is raising political and community awareness of these issues, particularly in the context of land use, soil and water management (MPI 2015).

The difficulty lies in how non-market ecosystem services can be accurately determined. There are many different approaches and methods. In some cases, quantitative biophysical data is readily available for helping quantify environmental services, such as soil characteristics including soil erodibility, and water quality data that has been systematically recorded in New Zealand for many years (MPI 2015; PCE 2016; Gluckman 2017) as well as the documented costs associated with cleaning up freshwater bodies (Ministry for the Environment 2017; Nixon et al. 2017). There are also indicative average values that can be applied, such as the 'look-up tables' for carbon sequestration (MPI 2015; PCE 2016; Walsh et al. 2017; MPI 2017c) although the look-up tables have been criticised for under-representing the carbon sequestration of native forests (Kimberley 2021).

Councils, government agencies and key industry groups are utilising quantitative biophysical data and exploring methodologies for valuing the benefits of ecosystems and identifying the impact of environmental pressures and land-use changes on natural resources (MPI 2015).

Social and cultural services are more difficult to quantify, as much of this is subjective and intrinsically difficult to measure, but nonetheless, very important. The importance of non-market NTVs has been widely recognised in Scandinavia for several decades. Lindhjem (2006) reviewed 20 years of literature on determining NTVs in Norway, Sweden and Finland, based on stated preference methodologies, particularly, willingness to pay. Yao and Kaval (2007) analysed all available studies, published from 1974 to 2005, on valuation of non-market ecosystem services in New Zealand. There was an increase in the number of studies, specifically those requested by government agencies, following the passage of the New Zealand Resource Management Act of 1991. Overall, the highest valued commodity was biodiversity services.

Roberts et al. (2015) describe New Zealand's long history of non-market valuation, starting with the measurement of values associated with recreational angling and backcountry tramping experience in the 1970s.

Good practice protocols for the economic valuation of non-market forest goods and services are summarised in a book edited by Riera and Signorello (2016). It was developed by Action E45, which involves institutions from 20 European and two non-European countries (New Zealand and Tunisia), aiming to facilitate a better and more consistent reporting and application of non-market valuation projects. The following categories were identified for determining non-market services:

- **Stated preference methods**, which use market-research methods of direct questioning particularly contingent valuation and choice experiments. This includes 'willingness to pay' or 'accept compensation', i.e., people's willingness to pay for securing (or giving up) an ecosystem service. Value determination is typically undertaken via a survey. Advice is provided on how to write, conduct and analyse surveys in Riera and Signorello (2016). Choice modelling' and 'contingent valuation' methods have been used to value biodiversity conservation, water quality enhancement and recreational values (Nixon et al. 2017).

- **Revealed preference methods,** such as the hedonic pricing approach and travel costs method, which can be used to estimate forest ecosystem services such as air quality, outdoor recreation, cultural values and landscape quality. These methods are dependent on the availability of data reporting on people's actual choices, e.g., premium prices attributable to proximity to desirable environmental features such as parks or forests (Nixon et al. 2017).
- **Benefit transfer approaches, market surrogates or cost-based estimates,** e.g., forestry's contribution to water flow management could be estimated as the avoided costs of damage from reduced flood frequency and severity (Nixon et al. 2017). These methods can be used when there is a lack of time or money for a primary valuation study. However, they are dependent on data availability and may involve subjective judgments, proxies and extrapolation, which may result in wide margins of error. Advice is provided in Riera and Signorello (2016) on how to obtain good estimates, including examining scientific soundness and the relevance of comparative studies.

A comprehensive list of ecosystem functions and services supplied by New Zealand ecosystems was provided by van Meeuwen-Dijkgraaf et al. (2010) in their study of protected areas and ecological corridors in the Kaimai-Tauranga catchment, Bay of Plenty, New Zealand. Very few New Zealand studies had been undertaken at that time and ecosystem services were, therefore, estimated by applying values obtained from the overseas model developed by Costanza et al. (1997) to New Zealand land cover classes in the study area. The most valuable NTVs listed for forest biomes were climate regulation, erosion control, nutrient cycling, waste treatment and recreation. Potential errors, limitations and caveats are listed in their report; which the authors believe would have likely led to an underestimation of ecosystem services.

An approximate, indicative economic value of $NZ195 million/yr was estimated for total ecosystem services for the catchment, about 5% of the sub-region's GDP (van Meeuwen-Dijkgraaf et al. 2010). Native forest (the biome with the largest area) provided 66.6% of this estimated value at NZ$130 million, or NZ$2,495/ha/yr. In comparison, Kaval (2004) estimated the value of native forest ecosystem services in the Waikato region at NZ$1,618/ha/yr. This would equate to NZ$80 million/yr if applied to the Kaimai-Tauranga catchment.

Patterson and Cole (2013) assessed the total economic value of New Zealand's land-based ecosystems and the services they provide. This involved measuring use values (provisioning, cultural, regulating, and supporting) and non-use values (option, existence, and bequest) based largely on the framework of the Millennium Ecosystem Assessment (2005). They estimated that in 2012, New Zealand's land-based ecosystem services contributed NZ$57 billion to human welfare (equivalent to 27% of New Zealand's GDP). The authors openly stated the limitations of this project, i.e., a lack of specific New Zealand data except for provisioning services, problems with translating world data to a New Zealand context (a wide range of overseas studies were used to estimate non-market values), and issues relating to the methodological and philosophical assumptions underlying the approach. Therefore, the authors acknowledge the provisional and approximate nature of their estimations of non-market services.

Erosion control of forests was valued at NZ$2092 million, second only to production of forestry raw materials (Patterson and Cole 2013). The authors viewed native forests as having a critically important role in maintaining soils and preventing sediment loss on steep, unstable land. Other important forest ecosystem services included climate regulation (carbon sequestration), valued at NZ$1,503 million, and waste treatment (recovery of mobile nutrients and breakdown of excess nutrients and compounds, e.g., animal effluent and agricultural chemicals) valued at NZ$1,486 million. Nutrient cycling was also identified as an important supporting service.

It is beyond the scope of this review to evaluate the many tools available internationally for measuring ecosystem services. However, a comparative assessment of tools for identifying and quantifying ecosystem services was undertaken by Bagstad et al. (2013). They reviewed 17 ecosystem services tools against eight evaluative criteria but concluded that "most tools are currently too resource-intense for routine use in public- and private-sector decision making" (p. 27, Bagstad et al. 2013).

Tools that have been utilised, or have the potential to be utilised in the New Zealand context, are discussed below, along with relevant case studies.

Carswell et al. (2013) assessed ecosystem services provided by St James Conservation Area, in North Canterbury, based on the Millennium Ecosystem Assessment (2005). St James Station was purchased in 2008 by the Nature Heritage Fund, signalling a transition of the largest privately owned farm (78,000 ha) in New Zealand, to St James Conservation Area for the benefit of ecosystem services. St James could be viewed as a model system, relevant to other large areas of 'marginal' farmlands in New Zealand, i.e., pastoral farmland on steep land with erodible soils and low economic returns from grazing (Carswell et al. 2013).

The majority of ecosystem services at St James were estimated spatially in a GIS environment. Maps were produced showing the spatial distribution of surface water supply, erosion control, carbon sequestration, and biodiversity benefit. OVERSEER® was used for the nitrogen leaching model. Soil erosion rates were calculated using the NZeem® erosion model (Dymond et al. 2010; cited in Carswell et al. 2013). Carbon sequestration was estimated using mapped forest cover classes and determining sequestration rates of plant communities reverting to forest. A quantitative framework was applied for assessing biodiversity benefit through management intervention using the Vital Sites and Actions (VSA) model. Recreational services were not quantified although the authors discussed possible approaches for assessing the monetary value of recreation and cultural services, including contingent valuation ('willingness to pay' surveys) or possibly deliberative monetary valuation (involving focus groups).

Changes in ecosystem services likely to occur in the future at St James were discussed, as well as how an ecosystem services framework could best benefit conservation. Climate regulation, erosion control, clean water provision, and recreation services were expected to increase over time. Habitat provision and biodiversity were expected to be maintained. Water yield was expected to decrease. The authors concluded that the superior water yield of pasture cover, compared with shrubland or forest, represents a major trade-off between biodiversity and water provision, if regeneration of native forest was encouraged (Carswell et al. 2013).

Herzig et al. (2013) described a Land-Use Management Support System (LUMASS) and demonstrated the impact of spatial configuration of land use on ecosystem services in two case studies in New Zealand. LUMASS is open-source software built on a range of cross-platform, open-source libraries for geospatial data processing and visualisation (Landcare Research 2018a). Herzig et al. (2013) argue that if landscapes vary spatially in climate, soils, slope, and susceptibility to erosion, then ecosystem services will vary depending on the location of the land use within the landscape. This information can be used to support land-use decision making.

Using various modelling scenarios, Herzig et al. (2013) demonstrated how land-use change can increase the values of some ecosystem services while decreasing the values of other services. They subsequently demonstrated, using LUMASS, how the pattern of land-use can be reconfigured to concurrently improve multiple ecosystem services while maintaining agricultural production; even if there are multiple, possibly conflicting, objectives and constraints.

One of the case studies, based in the central North Island, involved plantation forest, dairying, and pastoral sheep and beef farming (Herzig et al. 2013). The area had undergone land-use change, with dairy farming increasing in area by 12% from 2003 to 2008, with a corresponding decrease in plantation forest area. The authors used LUMASS to model optimisation of the land-use pattern to concurrently minimise nitrate leaching and soil erosion. The potential for nitrate leaching varies spatially, largely depending on soil properties such as water-holding capacity. A map of potential nitrate leaching in the central North Island was compared with the actual land-use distribution.

The results showed that the current landscape configuration was suboptimal and a shift from dairying to forestry was needed for minimisation of nitrate leaching and soil erosion, particularly in the northern part of the study area, which has a high potential for nitrate leaching (Herzig et al. 2013).

Ausseil et al. (2013) assessed various tools for measuring ecosystem services at a catchment scale in New Zealand. They considered ecosystem services affected by natural factors, such as soil and climate, and anthropogenic factors, such as land use and land management practice - reflecting dominant land-use and land-cover types in New Zealand. They developed spatial models for the following ecosystem services: 1) regulation of climate, 2) control of soil erosion, 3) regulation of water flow (quantity), 4) provision of clean water (quality), 5) provision of food and fibre, and 6) provision of natural habitat for indigenous species. The five managed ecosystems considered were dairy, sheep, beef and deer farms, and planted forests.

Soil loss was estimated using the NZeem® erosion model, which was calibrated from sediment discharges measured in New Zealand rivers. Nitrogen leaching was estimated using OVERSEER®, a nutrient budget tool that takes farm management, soil and climate variables as inputs, and subsequently produces annual nutrient budgets. Carbon sequestration was estimated using the process-based model CenW (Carbon, Energy, Nutrient, Water). A benefit function was used to assess the contribution of natural habitats to conservation goals (Dymond et al. 2008). The proportion of natural land cover remaining in a land environment was weighted by a condition index.

These models can serve as tools for decision-makers, as they allow assessment of the effects of land-use change scenarios on multiple ecosystem services (Ausseil et al. 2013). This was demonstrated by an assessment of ecosystem services in a simulation of hill-country afforestation in a Manawatū catchment, in New Zealand, where erosion and sedimentation of waterways are serious problems. The simulation involved 500 farms being afforested with radiata pine where there was a high proportion of highly erodible land, i.e., about 32,000 hectares of pastoral farmland (5% of the total catchment). The results showed that climate regulation and erosion control increased significantly, while water quality and wood provision increased slightly. There was a small reduction in water yield, and wool and meat production were slightly lowered. This scenario could be used as an incentive for farmers to retire marginal land from production (Ausseil et al. 2013).

Peh et al. (2013) developed a Toolkit for Ecosystem Service Site-based Assessment (TESSA). This easily applied tool was developed in the United Kingdom but is globally applicable and can be used at the local level by non-specialists for rapidly quantifying a range of ecosystem services. It is particularly designed for determining ecosystem services at sites where biodiversity conservation is important. The authors recommend the use of existing data in TESSA, where appropriate, and collection of field data at relatively low cost and effort, where needed.

To date, ecosystem service research has been dominated by a monetary interpretation of value, to give ecosystems more weight in policy decisions and management strategies (Scholte et al. 2015). However, there have been criticisms of this approach, and the use of non-monetary methods for the valuation of all ecosystem services has gained momentum. The social (or the socio-cultural) approach to valuation (not to be confused with socio-cultural values or services, per se) is a more holistic approach based on values that society attributes to each ecosystem service, rather than on monetary values (Martin-Lopez et al. 2012; Scholte et al. 2015). Examples of social valuation were reviewed by Scholte et al. (2015) and Felipe-Lucia et al. (2015).

Felipe-Lucia et al. (2015) argue that using qualitative methods with a social approach in assessing ecosystem services enables a more comprehensive understanding of interactions between humans and ecosystems. They proposed a framework for social valuation of ecosystem services, as opposed to relying solely on economic (monetary) valuation methods. The framework enables comparison across studies and supports decision-making in land planning and management. The authors emphasise the importance of including a good representation of stakeholders from all social ranges, particularly local residents most likely to be impacted by changes in ecosystem services. They contend that fair social participation in decision-making, via ecosystem services assessments, will benefit human well-being. They recommend a two stage-approach - first identifying the ecosystem services that stakeholders consider valuable, and secondly, ranking their preferences (i.e., the value) for each ecosystem service. They also recommend that the provision of services across past, present, and future ecosystem services scenarios should be considered.

Scholte et al. (2015) evaluated methodologies for socio-cultural valuations. The most frequently utilised method was survey questionnaires, which the authors recommend as a robust technique for gathering large amounts of data that can be quantitatively analysed. However, the costs involved tend to be high, as the valuation of ecosystem services is often too complex to allow for self-administered questionnaires, i.e., via post or e-mail. Also, questionnaires only capture info from those interested in contributing. Focus groups were another popular approach although the authors cautioned about vocal group members dominating group opinions.

Scholte et al. (2015) recommend a pluralistic approach, presenting a framework for combining socio-cultural valuation methods alongside monetary valuations and ecological assessments. They argue that a solely monetary approach neglects social perspectives on the importance of ecosystems for human well-being. And monetary valuation focuses on ecosystem services that can be easily evaluated through market-based methods, while less tangible services such as aesthetic or inspirational services are frequently dismissed as hidden externalities. They state that the crux of socio-cultural valuation is to include the values identified by all relevant stakeholders, not just experts and/or policymakers. They also emphasised the importance of delineating (mapping) the spatial boundaries and relating socio-cultural values to landscape features.

The social-cultural approach is likely to have relevance in New Zealand, particularly in identifying and evaluating ecosystem services important to tangata whenua. Lyver et al. (2017a, b) identified community-based indicators and metrics from a te ao Māori perspective for monitoring forest health and community well-being, based on interview narratives through a series of workshops. They contend that alignment of community-based indicators with scientific-based measures would enrich and deepen knowledge and have more relevance for indigenous communities, as described below, in the section on socioeconomic, cultural and spiritual services.

Tools and frameworks largely based on monetary valuations have been used to quantify and analyse forest ecosystem services in New Zealand (Yao et al. 2016, 2017). A spatial economic tool called the Forest Investment Framework (FIF) is being developed by Scion to enable the assessment of key ecosystem services provided by plantation forests in New Zealand (Yao et al. 2016, 2017). As well as estimating the income from timber, the framework can also estimate indicative values of carbon sequestration credits and avoided sedimentation of waterways. Avoided erosion benefits were quantified using the New Zealand Empirical Erosion Model (NZeem®) (Dymond et al. 2010) to estimate the reduction in sediment loss due to land stabilisation. Yao et al. (2017) included several case studies where the FIF has been applied.

One of the case studies involved estimation of the wider benefits provided by the Wenita Forest Estate, the largest planted forest in Otago (Yao et al. 2017). The primary aim of Wenita is to produce timber, however, carbon sequestration was found to contribute the greatest proportion to the total value of the forest (54%), followed by timber (41%), then avoided erosion (5%). The small value for avoided erosion was expected as most of the forest estate is in low-erosion areas. The fourth quantified ecosystem service was recreational hunting for pigs. A price-based valuation technique was used to quantify this, based on an estimation of the value of the game meat. Further ecosystem services were identified by Yao et al. (2017) for incorporation into the FIF, including water quality, water yield, recreation, and biodiversity conservation.

In another example, an ecosystem services analysis was undertaken for different afforestation scenarios in erosion-prone, pastoral hill country in New Zealand (Walsh et al. 2017). This involved both a broad analysis at the national level and a more detailed analysis of the erosion-prone Manawatū catchment in the lower North Island. Scenarios included planting exotic pine plantations and encouraging native forest regeneration.

A range of quantitative geographic, biological, and economic models were integrated, and several qualitative assessments were undertaken. The New Zealand Forest and Agriculture Regional Model (NZ-FARM) was used to incorporate data from economic and land-use databases and biophysical models. NZ-FARM tracks environmental outputs such as greenhouse gas emissions, forest carbon sequestration, water use, and nutrient losses. It is designed to help decision-makers assess the potential economic and environmental impacts of policy on regional land use (Landcare Research 2018). The results of the analyses are described in various sections throughout this review.

Another useful tool has been developed at Stanford University, as part of the Natural Capital Project. InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a suite of free, open-source software models used to map and value ecosystem services and inform decisions about natural resource management (Stanford University 2019; Sharp et al. 2021). InVEST can help answer queries such as: how a proposed forestry management plan could affect ecosystem services; what parts of a catchment could provide the greatest carbon sequestration, biodiversity, or tourism values; or where would reforestation achieve the greatest downstream water quality benefits while minimising the impacts on water yield?

A web-based survey was used to query forestry stakeholders about the importance they place on ecosystem services provided by New Zealand's plantation forests, particularly forest soils (Coker et al. 2019). This is an example of the socio-cultural approach to ecosystem services analysis. There were 145 responses suitable for analysis. Across all respondents, very high importance was placed on the ability of soils to support sustainable production, which was more highly valued than maximising short-term production. Māori stakeholders placed greater importance than non-Māori on forest ecosystem resilience, provenance, kaitiakitanga (stewardship of resources), water quality, and harvest of food or medicines from forests. Coker et al. (2019) demonstrated that there were inherent cultural differences in how stakeholders value forest ecosystem services that soils support - and cultural views must be understood and integrated to reflect the needs of all stakeholders.

4.0 Review of NTVs in New Zealand's sustainably managed native forests

'Ka ora te whenua, ka ora te tāngata - When the land is well we are well' - Māori proverb.

In a pivotal report published in 2002 - *Weaving Resilience into our Working Lands: future roles for native plants on private land* - the Parliamentary Commissioner for the Environment (PCE) noted that there had been inadequate exploration of potential benefits provided by native plants in our working lands, including ecological sustainability in production systems and potential possibilities in future systems (PCE 2002). Since the PCE report was written in 2002, there has been considerable research on specific benefits provided by native forest, but this is contained within narrow disciplines.

This review pulls together and integrates information on the wider values associated with native forest. A synthesis of relevant literature is provided under the following categories of NTVs:

(i) **Non-timber forest products (NTFPs) and other provisioning services;**

(ii) **Environmental regulating services;**

(iii) **Socioeconomic, cultural and spiritual services**.

In addition to the three categories above, **supporting services** are acknowledged as an important underlying component of all NTVs. Supporting services are defined as the bio-physical and chemical functions associated with the nutrient and water cycles, photosynthesis, and soil formation (Costanza et al. 1997; Millennium Ecosystem Assessment 2005).

These supporting services are not discussed as a separate category in this review, but it is acknowledged that these vital functions underpin all NTVs, particularly environmental regulating services such as carbon sequestration, hydrological services, nutrient regulation and water quality. There is little information available in the literature quantifying supporting services associated with native forests in New Zealand, but there is a substantial amount of information on other types of ecosystem services or NTVs.

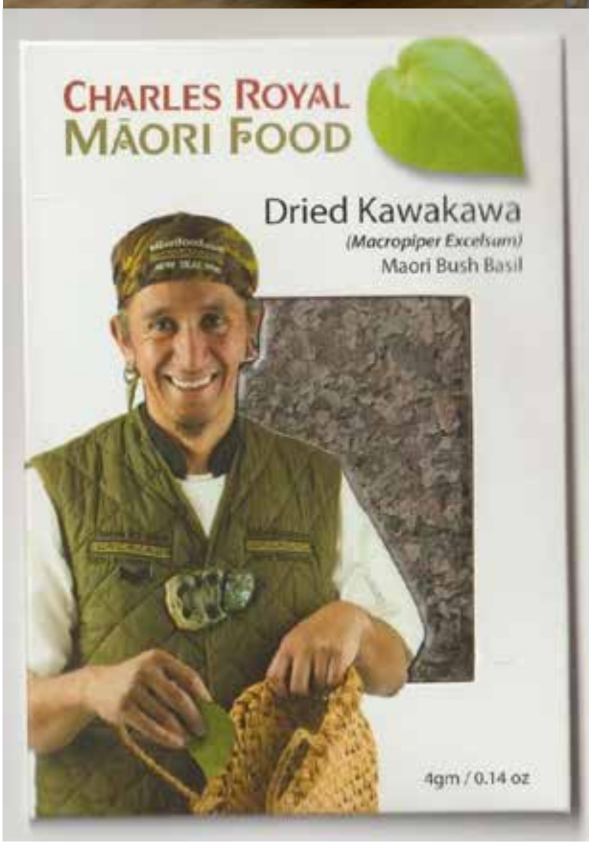
Note that there are overlaps and linkages between all categories of NTVs. Care needs to be taken to not 'double count' when quantifying the values of overlapping NTVs.

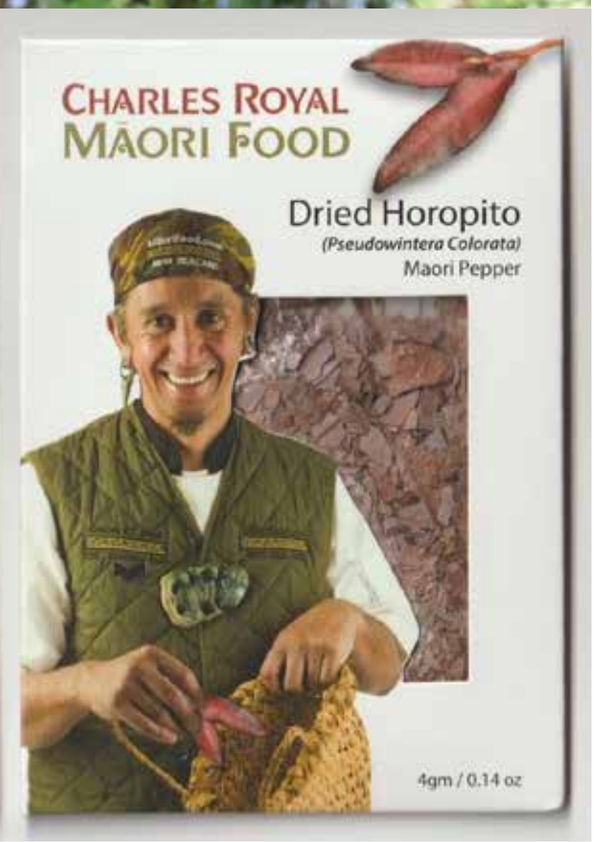
NTVs are best viewed in a broad socio-economic and environmental context, rather than focussing on a single NTV to the neglect (or even at the expense) of all others. Whereas efforts to increase one specific type of NTV could result in simultaneous increases in other NTVs, there could be potential trade-offs where an increase in one NTV could lead to a decrease in other NTVs. Potentially, a narrow focus on increasing a single NTV, without consideration of the broader context, could lead to unintended perverse outcomes for other NTVs.

Non-timber forest products and other provisioning services


pure nature
Manuka Organic
Essential Oil
Leptospermum Scoparium


KAWAKAWA
skin balm
love your skin
100% natural skincare, handmade with love
www.honestskincare.co.nz
honest skincare
80ml


CHARLES ROYAL
MĀORI FOOD
Dried Kawakawa
(Macropiper Excelsum)
Maori Bush Basil
4gm / 0.14 oz


CHARLES ROYAL
MĀORI FOOD
Dried Horopito
(Pseudowintera Colorata)
Maori Pepper
4gm / 0.14 oz

4.1 Non-timber forest products (NTFPs) and other provisioning services

Non-timber forest products (NTFPs) are also known as secondary forest products. They are non-timber provisioning services, i.e., useful materials obtained from forests that do not require the harvesting of entire trees.

For hundreds of years, Māori harvested plants from forests for natural healing (rongoā), and they also foraged for food and fibre (Dodd and Ritchie 2007; Harmsworth and Awatere 2013; MPI 2015; Roberts et al. 2015). However, loss of connection to the land has resulted in a loss of cultural knowledge systems and a decreased use of goods foraged from forests (Walker et al 2021).

Recognition of the importance of NTFPs has recently increased due to the COVID-19 pandemic shaping consumer trends with an increased focus on overall health and wellness, connections to nature and self-sufficiency. There has been increased demand for mānuka honey (MPI 2021b), which is likely to have flow-on effects to other natural pharmaceutical products.

Important NTFPs in native forests are described below. Unfortunately, apart from the honey, sphagnum moss and mānuka oil industries, there is limited information available on existing and potential economic values for most NTFPs because these industries are not well developed in New Zealand (MPI 2015). While most of these industries are small-scale, they are important for supporting local economic activity, they are often culturally important, and they help provide food for local communities and fibre for traditional crafts (MPI 2015).

NTFPs in New Zealand's native forests include:

- honey production and other bee products;
- medicinal plants for traditional healing (rongoā) collected from the forest;
- bioactive compounds for chemicals and pharmaceuticals;
- plants used for traditional purposes, e.g., harakeke or flax (*Phormium tenax*);
- growing crops under forest canopies;
- sphagnum moss;
- genetic resources of indigenous forest species, which current (or future) developments in knowledge and biotechnology have revealed (or could reveal) to be valuable.
- wild game and fur products, and food foraged from native forests; and
- Animal fodder.

4.1.1 Honey production and other bee products

Apiculture in New Zealand strongly relies on native forest as native flowering species provide pollen and nectar for honey bees (*Apis mellifera* L.) (Butz Huryn 1995; MPI 2015). Native forest species important for honey production include mānuka, kānuka, rātā *(Metrosideros* spp.*)*, tāwari *(Ixerba brexiodes)*, kamahi *(Weinmannia racemosa)*, hinau *(Elaeocarpus dentatus)*, tī kōuka or cabbage tree, (*Cordyline australis)*, pohuehue *(Muehlenbeckia spp.)* and rewarewa *(Knightia excelsa)* (Allen et al. 2013). Monofloral honey has been developed for mānuka, southern rātā *(Metrosideros umbellata)*, tāwari, rewarewa, and kamahi (MPI 2015; Airborne Honey 2019). A distinct type of honey is derived from honeydew from beech forests (Crozier 1981; Allen et al. 2013). Honeydew is also used to make mead.

New Zealand is the world's second-largest honey exporter (MPI 2017b). Honey exports have grown strongly over the past decade and record export prices have been driven by the market success of mānuka honey (MPI 2015, Morrison 2016; McPherson 2016; MPI 2017b; MPI 2020).

Mānuka honey contains natural compounds with anti-microbial and wound healing properties that enable it to be used in medical dressings and for treating burns (MPI 2015; McPherson 2016). Mānuka honey with high levels of the Unique Mānuka Factor (UMF) is particularly valuable as it has higher levels of bioactive compounds associated with medicinal benefits (Stephens 2006; Lee 2017).

Exports were valued at $348 million in 2017/18 (MPI 2017b; MPI 2019). More recently, honey exports bucked the general effects of the COVID-19 pandemic on global consumer demand, with exports exceeding earlier forecasts to reach $425 million for the year ended June 2020, based largely on mānuka honey (MPI 2021b). However, since the mānuka honey definition was implemented in early 2018, demand and average prices for multi-floral mānuka and non-mānuka honey have been declining (MPI 2020).

The average export price per kilo in 2019 was $54 for mono-floral mānuka (with much higher prices paid for premium product), $31.10 for multi-floral mānuka, and $20.62 for non-mānuka honey (MPI 2021b). However, while the average export price for mono-floral mānuka honey is expected to remain around $55 per kilo in 2021, the price for multi-floral mānuka honey is expected to drop below $30, and the price for non-mānuka honey is expected to drop below $20 per kilogram (MPI 2020).

The industry has been steadily moving away from wild-grown mānuka to establishing mānuka plantations for the more consistent production of high-UMF honey. Breeding programmes have been developed for cultivars with high methylglyoxal levels (McPherson 2016; Lee 2017). A government and industry primary growth partnership is funding research and development, aiming to increase the annual value of New Zealand's mānuka honey industry to NZ$1.2 billion by 2028 (Morrison 2016). High methylglyoxal levels in mānuka are associated with high-UMF honey, but there is considerable variation in the methylglyoxal levels in mānuka from different geographic sources (Stephens 2006).

Growing mānuka plantations for mānuka honey has become a viable alternative land use on marginal pastoral land in New Zealand (McPherson 2016; Lee 2017). It has a low environmental footprint and is a good land-use option in environmentally sensitive catchments, where land is highly erodible or there are water quality issues associated with pastoral farming. However, not all sites are ideal for mānuka honey production and at least 20 hectares of mānuka, preferably over 50 ha, are needed (McPherson 2016).

Economic returns compare favourably with other land use options (Lee 2017). Land-owners can obtain a share of the returns from beekeepers (usually around 30%), or undertake the beekeeping themselves for higher returns (McPherson 2016; Lee 2017). At the time of publication, net cash returns for mānuka honey for land-owners from well managed mānuka plantations were around $1,000 per hectare by year-7, with a productive life of about 20 years for honey production (Te Puni Kōkiri 2021).

However, many factors affect financial returns. Mānuka honey production is inherently variable, largely due to competition from other flowering species and variation in climate, which can lead to a poor flowering season for mānuka or low levels of bee foraging (McPherson 2016). Another factor is the potential risk imposed by the recent incursion of myrtle rust *(Austropuccinia psidii)*, which could potentially infect mānuka (MPI 2017b).

Foliage can also be harvested from mānuka plantations for oil extraction, as described below. This can be a revenue stream complementary to mānuka honey. However, the best genetic strains of mānuka for high-UMF honey production may not be the best genetic strains for oil production (Stephens 2006). It is also possible to gain carbon credits for mānuka plantations (Lee 2017).

The beneficial properties of kānuka honey are also becoming increasingly recognised. It has anti-inflammatory effects and high antibacterial activities against a wide range of bacteria (Braithwaite et al. 2015) and possible anti-viral activity (Semprini et al. 2019). Kānuka honey is purported to be an effective topical treatment for several skin conditions, although there is currently limited clinical evidence except for the effective treatment of rosacea (Braithwaite et al. 2015) and cold sores (Semprini et al. 2019).

As well as honey, industries have developed around propolis and beeswax, and sales of live bees (*Apis mellifera* L.), colonies and hives (MPI 2015; MPI 2019). Propolis is created by bees from the natural resin produced by some tree species, but it is unclear how important native tree species are for propolis production. It has been used for hundreds of years for its health properties; and is marketed as a dietary supplement and used in balms, throat lozenges and other natural health products (MPI 2019). Beekeepers can get approximately $380 a kilo for pure propolis (Ecrotek 2021). The amount of propolis that can be collected in a season from a hive varies from 50 g, up to 1 kg or more if a collection mat and correct procedures are used.

The importance of native forests to pollination services is discussed below in the section on environmental services.

4.1.2 Native forest plants used for rongoā, pharmaceuticals and natural remedies

There has been a recent resurgence in rongoā (Dodd and Ritchie 2007; Jones 2007). Forest species known to have healing properties include harakeke or flax, kawakawa (pepper tree *Piper excelsum* subsp. *excelsum*), rata, koromiko (*Hebe* spp.), karamu (large-leaved *Coprosma* spp.), makomako (wineberry *Aristotelia serrata)*, mānuka, kānuka, tī kōuka, kumarahou (gum-diggers soap *Pomaderris kumeraho),* and kowhai *(Sophora* spp*.)* (Dodd and Ritchie 2007; MPI 2015; Jones 2007).

The use of native plant species for medicinal, natural health remedies and skincare products has attracted increasing interest from the research community and health sector (MPI 2015). Commercial ventures have developed around nutritional supplements, antibacterial oils and health remedies (e.g., Phytomed Medicinal Herbs NZ 2017). Some companies have a strong export focus (MPI 2015). Māori have been significantly involved in these business and research initiatives, frequently drawing on customary knowledge (MPI 2015; Roberts et al. 2015).

Extracts from native plants are increasingly being used for skin care, medicinal and natural health products (Dodd and Ritchie 2007; MPI 2015). The gel extracted from harakeke is used in cosmetic products. Kumarahou has a long history of use and is still being used in shower gel and shampoo. Totarol, an extract derived from the timber of tōtara (*Podocarpus* spp.) is added to products for its anti-microbial effect (Bosworth 2016) including being used as a preservative for cosmetics (Dodd and Ritchie 2007). Kānuka and mānuka leaves produce oils with valued bioactive compounds (Saunders 2017). The species are morphologically similar but chemically quite different. Mānuka oil has better anti-bacterial properties, while kānuka oil is more effective against some fungi. The oils are steam distilled from harvested branchlets.

Mānuka oil production can complement income from honey production, although different varieties tend to be better for oil production versus honey production (Stephens 2006).

The mānuka oil industry is mostly based in the East Cape, where local strains produce mānuka oil with the highest potency (Te Puni Kōkiri 2021). Until recently most of New Zealand's mānuka oil production came from wild-harvested mānuka, but with its growing demand, mānuka plantations are now being established on hill country farms. Several companies are distilling and selling mānuka oil in New Zealand. Most are focused on the domestic market, but two companies have larger-scale production for exporting.

The economics of growing mānuka for oil extraction were expounded by Pizzirani et al. (2019) with 1 kg of essential oil assumed to be worth $325, approximately 3.5 kg of essential oil produced for every tonne of mānuka branch material distilled, and 544 tonnes of branch material harvested per hectare over a 15-year rotation. According to Te Puni Kōkiri (2021), mānuka foliage from the North Island's East Coast, Coromandel and Great Barrier Island can produce 3 to 5 litres of oil per tonne of foliage. In 2021, wholesale prices were approximately $500 to $600 per kg for generic mānuka oil, and oil production costs are around $400 to 450 per kg. However, these values vary depending on oil properties and operational costs (Te Puni Kōkiri 2021).

Kawakawa is of high cultural value to Māori, it is closely related to the Fijian kava plant (*Piper methysticum*), and has long been recognised for its medicinal properties (Jones 2007; Awatere et al. 2018). There are active constituents linked with medicinal properties that can be extracted when kawakawa is dried. These include volatile oil (45 to 70% in essential oils and 1.6 to 2.5% in the dry herb - mostly myristicin) and mixed cadinenes (12.2% essential oils and 0.43% in dry herb). It has antimicrobial and analgesic properties, helps reduce inflammation, and is antidyspectic and antispasmotic, therefore, aids digestive complaints. The economics of planting, managing, harvesting and selling kawakawa have been investigated by Awatere et al. (2018) and are summarised below in the subsection on forest understory crops.

There are potentially other pharmaceutical benefits that could be obtained from other native plants, which are yet to be discovered.

4.1.3 Native forest plants used for (non-timber) traditional crafts

For hundreds of years, Māori have used plant materials for weaving and feathers of indigenous birds for traditional purposes (Waitangi Tribunal 2011; MPI 2015). No data are available regarding the extent of these traditional uses of forest products - in a national context they are limited, but regarded as culturally important (MPI 2015). These cultural values are discussed below, under the section on cultural values associated with native forests.

Four of the six natural fibres used by Māori for traditional crafts come from native forests, forest margins and wetland complexes - including harakeke, tī kōuka, tōī or mountain cabbage tree (*Cordyline indivisa*), and kiekie (*Freycinetia banksia*) (Waitangi Tribunal 2011). Natural fibres have traditionally been used for tukutuku panels, mats, ropes, fishing nets, kete (bags), mats, hats, headbands, snares and traps, cloaks, belts and rain capes. Of these, harakeke is regarded as the most important for traditional crafts (Waitangi Tribunal 2011).

A flax industry (based largely on harakeke) was developed by European settlers in New Zealand (Swarbrick 2007). Flax mills were built from the 1860s onwards, creating a thriving industry until the overseas demand declined. The last flax mill was closed in 1985.

4.1.4 Forest understory crops

Secondary crops of edible mycorrhizal fungi (truffles) and ginseng *(Panax* species*)* are being developed on a small scale in some production forests in New Zealand (MPI 2015). However, growing crops of exotic species, such as ginseng, may not be appropriate in native forest as it may compromise some of the other NTVs, particularly aesthetic and cultural values.

Another possibility would be to enrich native forest plantations with native species, grown for culinary and medicinal purposes, such as the edible fern fronds of pikopiko or hen and chicken fern

(Asplenium bulbiferum), horopito or Māori pepper tree *(Pseudowintera colorata)*, kawakawa, and harakeke (to produce New Zealand flax seed oil). Kawakawa is of high cultural value to Māori and has medicinal properties, as described above. In some parts of New Zealand, it naturally grows in abundance under native and exotic forest, particularly on forest edges and in light gaps.

Kawakawa has been identified as a potential forest understory crop for a niche market and the economics of the industry have been investigated (Awatere et al. 2018). Prices of dried kawakawa typically range between NZ$75 and NZ$300 per kg. Revenue is highly variable due to the currently small market size, and it is reported to commonly dip below the break-even point. Kawakawa harvesting is estimated to be unprofitable at revenues of NZ$75/kg or less for dried leaves (Awatere et al. 2018).

4.1.5 Sphagnum moss

Sphagnum moss is important for the Westland economy (MPI 2015). It is naturally found in wetland areas. Harvested areas normally return to a stable condition in 3 to 5 years (Orchard 1994; MPI 2015). Sphagnum is mainly exported to Asia, where it is used for orchid production and similar applications (Orchard 1994). The annual value of exports during the 1990s ranged from NZ$13 million to NZ$18 million, but this fell back substantially over the following decade (Plant & Food Research 2013). Exports were NZ$5.1 to 5.2 million in 2015-2016 (Plant & Food Research 2016). Synthetic alternatives and competition from sphagnum production in other countries are thought to be contributing factors to reduced demand for sphagnum.

4.1.6 Genetic resources and germplasm conservation

An often overlooked NTV is the genetic resources of our indigenous forest species, which are under threat worldwide due to human activity. These genetic resources are valuable to human well-being and current and future developments in knowledge. Examples include species important to rongoā and natural pharmaceuticals, mentioned above - including genetic provenances of mānuka important for high-UMF honey production, and genetic provenances of kānuka and mānuka that provide oil with high levels of bioactive compounds (Stephens 2006; Saunders 2017).

Roberts et al. (2015) mention the value of preserving an endangered species and also the potential loss of genetic material that future developments in knowledge could reveal to be valuable, e.g., for medicine. Meurk et al. (2013) note that remnants of native vegetation are important as they can be valuable genetic resources. The Millennium Ecosystems Assessment (2005) project notes the importance of genetic resources for breeding and biotechnology.

New Zealand’s native forests are highly unique with a high proportion of endemic species, due to New Zealand’s long history of geographic isolation (MPI 2015; OECD 2017a; Walker et al. 2018). New Zealand also has a high rate of extinction of indigenous species, as described earlier. Genetic resources in native forests can be maintained by protecting existing natural ecosystems and by encouraging the natural regeneration of native forests, or by planting new native forests – these are all important strategies for preserving germplasm of species at risk and their associated ecological communities.

This is particularly important where a species has a limited distribution or has been significantly depleted species over much of its natural range, e.g., kauri, kahikatea (*Dacrycarpus dacrydioides*), and pōhutukawa (*Metrosideros excelsa*). It is important for not only the main forest species concerned, but also for the indigenous flora and fauna associated with these unique ecosystems. The need to maintain New Zealand’s genetic diversity has come into sharper focus with the recent developments in kauri dieback and the arrival of myrtle rust threatening some of our most high-profile native tree species, and increasing concern about wide-scale loss of natural habitat and biodiversity.

Kahikatea is New Zealand's tallest native tree, and it was once dominant on fertile lowlands in wetter regions throughout New Zealand. This land was particularly sought after for agriculture and urban development. Kahikatea is now common only in South Westland; elsewhere, it is largely restricted to small remnants of old-growth forest and regenerating stands (often unfenced and degenerating) scattered across New Zealand's productive landscapes. For example, only about 1.4% of the kahikatea-dominant forests of the Waikato and Piako Plains remain, and they are scattered, vulnerable fragments (Smale et al. 2005). These stands are vulnerable and could easily be lost, yet they are often the sole reservoirs of indigenous biodiversity remaining within their region and are an important part of the unique genetic variation of a once widespread species.

Kauri was a dominant tree species in the lowland forests of northern New Zealand at the time of European settlement. Due to excessive timber extraction and burning to clear land during the 19th and early 20th centuries, natural stands of kauri are now largely restricted to publicly-owned reserve land (MPI 2015). Kauri is under increased threat as the pathogen causing kauri dieback is now present over most of its limited natural range (MPI 2015; Balm 2017). Kauri dieback was first observed on Great Barrier Island in the early 1970s (Gadgil 1974). The disease is caused by a previously unknown species named *Phytophthora agathidicida,* also referred to as PTA (Balm 2017).

There is serious concern about the loss of genetic variability within the kauri species, and indeed, the loss of the iconic species altogether, and the flow-on effects for kauri-dominated ecosystems that support flora and fauna not found elsewhere (MPI 2015).

Germplasm conservation can include planting genetic archives in locations away from the natural area of distribution of a species, i.e., ex situ germplasm conservation (Eriksson et al. 1993). This is a particularly good strategy when a species is under threat in its natural range, due to factors such as environmental pressures, or incursion of a serious pathogen. New Zealand has several native forest species that have limited distributions and are currently under threat, including the iconic kauri.

However, there are biological, aesthetic and cultural concerns about planting species away from their natural range. Regardless, in the face of potential extinction, drastic action is warranted. And it can be argued that there has been widespread planting (and subsequent naturalisation) of native species outside their natural range since the arrival of humans in New Zealand. Karaka (*Corynocarpus laevigatus*) was thought to have been brought to New Zealand by the ancestors of Māori and became naturalised after being deliberately planted near Māori settlements (Best 1929). Another example is the naturalisation of pōhutukawa from a century of planting well south of its natural range throughout the Wellington region.

Despite its current limited natural range of kauri (north of latitude 38 °S), it grows well throughout much of New Zealand, on sheltered, fertile, free-draining sites (Bergin and Steward 2004; Steward and Beveridge 2010; Balm 2017). Kauri was widespread in New Zealand until the Pleistocene epoch (400,000 – 14,000 years BP). Climatic changes associated with glaciation probably caused its retreat to the northern half of the North Island (Reed 1953; Barton 1983; Halkett and Sale 1986, cited in Steward and Beveridge 2010). Kauri resins have been identified in fossilised material found in Tertiary lignite deposits in southern parts of the South Island (Evans 1937, cited in Steward and Beveridge 2010; Reed 1953).

Ex-situ germplasm conservation is particularly appropriate in an era of climate change because many indigenous species will become (or already are) stressed within the normal limits of their natural distribution (Eriksson et al. 1993; Staudinger et al. 2012). Trees that are stressed due to changes in their normal ambient climate are more susceptible to pathogens and pests. Also, a warmer climate means that pathogens and pests from subtropical and tropical regions are more likely to become established in New Zealand, which could negatively affect native biodiversity (see Staudinger et al. 2012). This is particularly concerning when the species has a limited natural range.

Other native species could also benefit from germplasm conservation in stands planted outside of their natural distribution, including native species vulnerable to myrtle rust *(Austropuccinia psidii)*. This wind-borne pathogen attacks species in the myrtle family, including *Metrosideros* species, kānuka and mānuka. Myrtle rust was first discovered in several New Zealand regions in May 2017 (MPI 2017b). It will have a variable impact across the 27 native Myrtaceae species in New Zealand. The most susceptible native myrtle is ramarama *(Lophomyrtus bullata)* which is used widely in large-scale plantings. Relatively high levels of infection have also been found in the iconic Metrosideros species - pohutukawa and rata, and in swamp maire *(Syzygium maire)* (Biosecurity New Zealand 2018).

The Ministry for Primary Industries (MPI) and the Department of Conservation (DOC) attempted to contain and control the disease, but it rapidly spread and is predicted to continue to spread through much of New Zealand. The focus has shifted to finding ways to manage the disease in the longer term, including scientific research to find ways to mitigate its impact (Biosecurity New Zealand 2018).

We can learn lessons from Australia, where myrtle rust was first detected in 2010 and has subsequently caused the localised extinction of some myrtle species and had a significant impact on native plant communities (Carnegie and Pegg 2018). Wider-scale species extinction is a distinct possibility as the pathogen continues to spread in Australia, and more recently, in New Zealand. We need to do all we can to prevent this from happening.

Manaaki Whenua Landcare Research scientists have identified areas, known as 'refugia', where Myrtaceae may be able to ride out the threat of myrtle rust. They compared how the habitat range of each species overlaps with the likely range of myrtle rust. They have found some species have adequate refugia, such as southern rata, while several species have little or no areas of refugia, such as ramarama and swamp maire (Landcare Research 2020).

Seed banking is another action being taken to ensure the long-term future of our myrtle species. Seed has been collected throughout New Zealand from our native myrtles as an insurance policy - preserving the genetics of our myrtle species in the event of myrtle rust spreading throughout New Zealand and possibly causing extinctions (Department of Conservation 2020).

However, vulnerable swamp maire has proved recalcitrant (conventional seed storage methods fail, and seed remains viable for only a short time). There is a deep concern for the future of this highly unique, endemic species (Dr Jacqueline Bond, pers. comm.).

Another concern is the loss of unique genetic variation due to the use of commercial strains. For instance, mānuka is a highly complex species with considerable genetic variation (Stephens 2006; McPherson 2016). As described above, high-UMF mānuka honey is highly sought after and has a higher economic value. If local strains of mānuka are not ideal, planting stock from genetic strains selected for high-UMF honey production are recommended for establishing mānuka plantations (McPherson 2016; Lee 2017). Unfortunately, bringing in different genetic strains of mānuka could have an impact on the genetic integrity of the local mānuka strains through intraspecific genetic introgression.

With any native plant species, care needs to be taken to avoid planting either different provenances or commercially-bred strains near natural vegetation of high conservation value that contains the same species - due to the risk of genetic introgression or 'genetic pollution' undermining the unique inherited characteristics of the natural population. It is also important in ecological restoration to utilise plants grown from seeds, wherever possible, as opposed to vegetatively propagated material, as this maximises genetic diversity and resilience of populations in response to pathogens.

4.1.7 Wild foods, freshwater fisheries, hunting and trapping of wild game

Wild foods are associated with both provisioning and cultural ecosystem services. Provisioning services are described here, and the cultural component is described later in this review. King et al. (2013) provide a comprehensive list of wild foods in New Zealand. Lyver et al. (2017a, b) describe how the rivers and native forests around Ruatahuna, Te Urewera, have historically provided the local community with valued food sources; and increasingly restricted access and availability of native species have resulted in exotic species becoming more important sources of fur (e.g., possum) and meat (e.g., red deer, *Cervus elaphus*, and feral pig, *Sus scrofa*).

Recently there has been a renewal of interest in native herbs, edible ferns, fruits and berries traditionally eaten by Māori (Dodd and Ritchie 2007; Royal and Kaka-Scott 2013; King et al. 2013). This includes pikopiko (young unfurling fern fronds), roots of bracken fern (rārahu, *Pteris esculentum*) horopito, kawakawa, pūhā (*Sonchus kirkii*), kowhitiwhiti or watercress *(Nasturtium officinale)*, the succulent tips of kareao (also known as pirita, or supplejack, *Ripogonum scandens*), and harakeke seed for the production of New Zealand flaxseed oil, which has a high nutritional value. Tender new shoots of nikau palm (*Rhopalostylis sapida*), and all types of cabbage tree (*Cordyline* spp.) can be eaten raw or cooked, but this can destroy the plant and should only be harvested very judiciously. Collecting berries from some species of native trees and shrubs, such as kahikatea, kotukutuku or tree fuchsia *(Fuchsia excorticata)*, and kohia (native passionfruit, *Passiflora tetrandra*) has been a customary activity (Crowe 2004; MPI 2015).

Huhu grubs are a traditional Māori delicacy that has become popular at wild food festivals. They are the larva of the huhu beetle *(Prionoplus reticularis)* and are typically found in rotting logs. Also, shavings and sawdust from mānuka and kānuka have become popular for smoking food, giving it a distinct flavour (Dodd and Ritchie 2007).

Various native fungi were utilised by Māori. Harore (bush mushrooms, *Armillaria novae-zelandiae*) are edible, fungal fruiting bodies found on fallen wood such as tawa and tawai, or at the base of dead trees. Tūhoe continue to collect and eat harore in Te Urewera. Three species of native New Zealand mushrooms, recommended by iwi for their pleasant taste and potential for large-scale cultivation, are currently being investigated by researchers at Manaaki Whenua for their nutritional value and potential for commercial cultivation (Manaaki Whenua Landcare Research 2020).

In a study of NTVs of forests in northern Sweden, Mattsson and Li (1993) estimated the value of traditional non-timber forest products (berries and mushrooms) via mail surveys, using the contingent valuation method (willingness to pay). On-site consumptive use of non-timber forest products was more valuable to rural people. In contrast, on-site non-consumptive use (hiking, camping, etc.) was more valuable to visiting urban people.

Note that all native species found on conservation land in New Zealand, including any plant material, are protected by law and permission is required before anything can be taken. Also, for any forest foraging on private land, permission must be sought from the land-owner. And there are regulations regarding fishing and hunting that must be complied with.

Wild food harvests should increase with an increase in forest cover, particularly with native afforestation (Walsh et al. 2017). This includes freshwater fisheries. Native forests have a significant role in protecting riparian zones and maintaining water quality, as described below. Trout and eel habitat (particularly for the native freshwater eel or tuna, *Anguilla* spp.) should improve with better water quality leading to greater fish abundance and catch (Walsh et al. 2017).

Whitebait is the generic term for the juvenile form of five fish species from the Galaxiidae family (MPI 2015). Māori traditionally caught whitebait, and whitebait fritters have become one of New Zealand's favourite delicacies (MPI 2015). Whitebait can be found in many of New Zealand's major rivers and streams, but they have declined in areas where there is extensive pastureland. Intact forested catchments, which have better water quality (see the section on environmental services below), provide the primary habitat for whitebait. One of the best-known areas for whitebait is South Westland, where most of the streams have their sources within natural rain forest in the conservation estate (MPI 2015).

Kōura are native freshwater crayfish (*Paranephrops* species). There are two species, and both are threatened and in 'gradual decline' (Terra Nature 2017). They are a highly-valued delicacy for Māori. There is no commercial catch of koura because no person is permitted to sell or trade koura under the Freshwater Fish Farming Regulations 1983. However, permits for commercial koura farming have been issued. Kōura reach their highest densities in native forest streams. At times of heavy flooding, forested streams with a stable riparian habitat provide a better refuge for kōura than pastoral streams (NIWA 2017). Their presence is an indication of clean water (Terra Nature 2017).

These wild foods and traditional Māori foods are being increasingly used in contemporary New Zealand fine cuisine, helping to create a distinct New Zealand food identity (Royal and Kaka-Scott 2013; Tourism New Zealand 2017). The growing profile of indigenous cuisine has created new markets for wild foods, but the value of this market is unknown. The Wildfoods Festival held for the last 30 years in Hokitika on the West Coast has become hugely popular for cuisine and fashion featuring a wide range of animals hunted and fished often from native forest areas.

Hunting and trapping in New Zealand's forests are not big industries, but they provide important secondary forestry products for many rural families, are important for outdoor recreation, and support small business enterprises throughout New Zealand (MPI 2015). Wild pigs, goats and deer are hunted for meat, and possums are hunted and trapped primarily for their fur. All these species were introduced to New Zealand, and they pose a significant threat to New Zealand's indigenous flora and fauna (Thorpe 1998; MPI 2015). Recreational and commercial hunting of these pests assists in their control (MPI 2015).

The Australian brushtail possum (*Trichosurus vulpecula*) is an introduced pest that causes significant damage to New Zealand's native flora and bird-life, and considerable resources are spent on its control (Thorpe 1998; Warburton 2008; MPI 2015). Possums are trapped or shot for fur and pelts, which also helps with pest control. The number of possums harvested varies considerably from year to year in line with the variable market for pelts and fur (MPI 2015). The trade in possum skins saw progressive growth in the early to mid-2000s, with exports increasing from NZ$0.5 million in 2002 to NZ$2.3 million in 2008, but dropped dramatically during the global economic crisis and were slow to recover (MPI 2015).

There has been renewed interest in possum fur due to the development of a unique fibre blend (MPI 2015). Possum fibre has exceptional thermal properties and is blended with merino wool to create a lightweight, high-quality yarn (MPI 2015). In 2010, the merino–possum yarn and associated fashion sector were estimated to be worth NZ$100 million per annum, with significant potential for growth (Adams 2010). However, there is controversy associated with the industry due to possums being pests and also bad press over hunting and trapping for fur (Adams 2010; New Zealand Fur Council 2014; MPI 2015). Despite this, the ultra-soft merino-possum fur blend has become increasingly popular, and the prices for plucked possum fur reached up to $145/kg in 2019. The market has recently dipped due to the COVID-19 pandemic and the return for plucked possum fur was about $90/kg in 2020 and 2021 (O'Hara 2020; EcoFX 2021).

A small trade in fur skins continues and there is interest in possum meat for pet food, although this is limited by the presence of tuberculosis in possum populations in some regions (MPI 2015).

Commercial and recreational hunters have sourced game meat from New Zealand's forests for over a century (MPI 2015). Commercial hunters harvested 10,000 to 30,000 feral deer per annum during the 1990s, but the industry subsequently declined due to a fall in venison prices. Commercial hunting remains at relatively low levels as a niche industry. Recreational hunting remains a significant activity, often requiring hunting permits, especially on public (Department of Conservation) land and restricted hunting periods (MPI 2015). Guided hunting expeditions create tourism revenue, as described later in this review.

Yao et al. (2017) estimated wider benefits (ecosystem services) provided by Wenita Forest Estate, the largest planted forest in Otago, including recreational hunting. Pig hunting is a popular activity in the forest and a price-based valuation technique was used to quantify this, based on an estimation of the value of the game meat (Yao and Harrison 2016; Yao et al., 2017).

Pig hunters collected about 1,792 pigs in 2014 and 1,361 pigs in 2015 from the Wenita Forest Estate (Yao et al., 2017). Assuming the following: (i) each pig yielded an average of 20 kg of usable game meat for home consumption; (ii) each kilogram of meat has a value of about NZ$7 based on the current price of a pork chop at about NZ$10 – 15/kg; and (iii) the hunter's meat processing cost was about NZ$3 – 8/kg; then the total meat value provided by the forest estate to hunters was NZ$250,880 and NZ$190,540 in 2014 and 2015, respectively. Assuming that about 15,000 ha of the estate are classified as a pig hunting area, the value of pig hunting (based on meat value) was about NZ$15/ha/year (Yao et al., 2017).

4.1.8 Animal fodder

Many native plants are suitable for animal fodder, including harakeke, koromiko, houhere or lacebark (*Hoheria* spp.), karamu (*Coprosma robusta*), wineberry, and kanono (*Coprosma grandifolia)* (Dodd and Ritchie 2007). Some have health benefits for stock, particularly harakeke, which is reported to have anti-parasitic properties and is a fodder preferred by cattle (Dodd and Ritchie 2007).

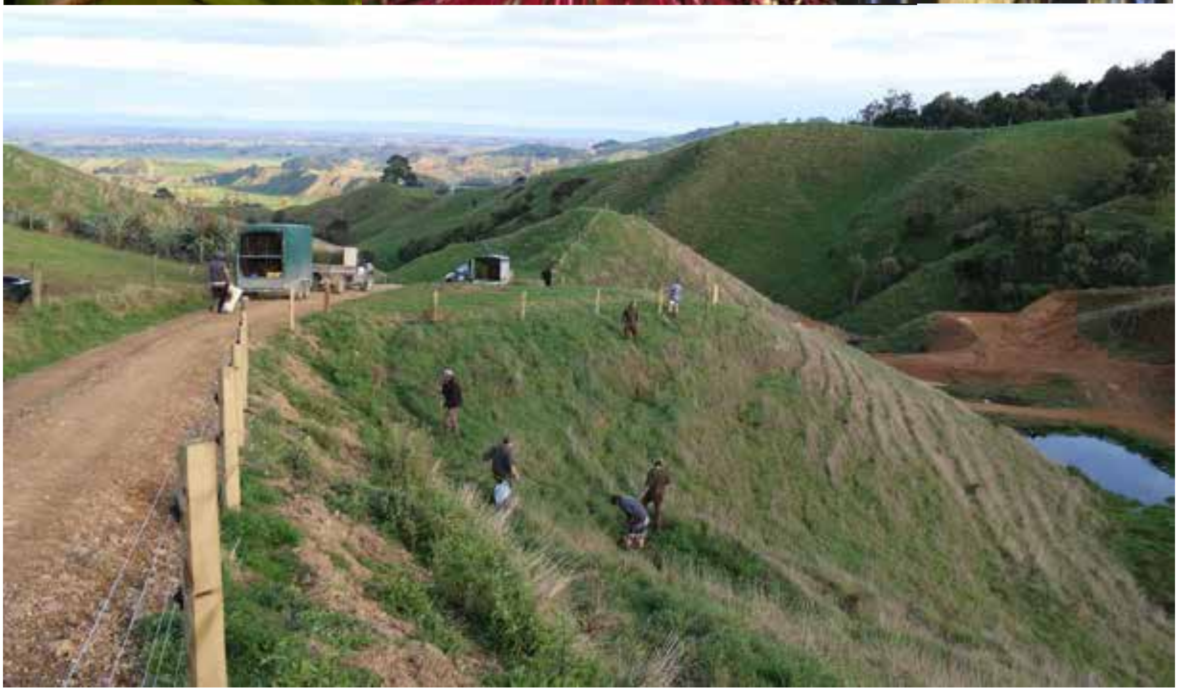
It is recommended that native plants are only used judiciously and sustainably for animal fodder. Note that all native species found on conservation land, including any plant material, are protected by law.


Environmental regulating services







4.2 Environmental regulating services

The New Zealand economy relies heavily on forests, natural and planted, for environmental services (Yao et al. 2013; MPI 2015; Hall 2016; NZFOA 2017, 2019; MPI 2017b; Nixon et al. 2017; OECD 2017a; Walsh et al. 2017; Yao et al. 2017). However, these environmental services are usually not included in the economic value of forests (Payn and Clinton 2005; MPI 2015; Nixon et al. 2017).

Our land-use intensity has increased significantly in recent decades, particularly intensification of agriculture (Hall 2016; Julian et al. 2017; OECD 2017a; Nixon et al. 2017; Gluckman 2017). With this intensification, increasingly more is being required of environmental services from natural and planted forests (Dymond 2013; MPI 2015; Nixon et al. 2017; Yao et al. 2017) including:

- sequestration of atmospheric carbon;
- provision of habitat and biodiversity values;
- urban forests and air quality, green infrastructure, and moderation of local climate;
- stabilisation of soils, reduction of erosion and sedimentation, moderation of water flows and protection of downstream ecosystems and infrastructures;
- coastal buffers;
- water yield;
- nutrient regulation and water quality, i.e., absorption and retention of excess nutrients from intensive agriculture, which would otherwise be discharged into the water;
- maintenance of the health and clarity of waterways;
- pollination services;
- green firebreaks and fire risk reduction; and
- green infrastructure and flood protection.

All forests provide environmental services of differing types and to differing degrees (MPI 2015). However, environmental services in commercial plantation forests are largely only secondary benefits from broader forest management, with production of timber and wood fibre (pulp) products being the primary objective (MPI 2015).

Environmental services in New Zealand are widely regarded as ‘free-of-charge’, or a ‘gift of nature’ (MPI 2015). They are not easily monetarised other than carbon forestry, and to a limited extent, nitrogen capping in two catchments (discussed below). An OECD report on New Zealand’s environmental performance recommended broadening the use of economic instruments to provide incentives for conservation on private land, and for land management measures that reduce water pollution (OECD 2017a).

The role of environmental services is now emerging as an important planning and policy issue in New Zealand (MPI 2015). There is a growing call for the recognition of environmental services associated with forestry, with some commentators proposing that they should be treated as quantifiable assets (Payn and Clinton 2005; MPI 2015; Nixon et al. 2017; Yao et al. 2017). This would result in greater positive returns beyond timber values alone, and encourage more forestry plantings and retention and protection of existing forests.

In 2017, a New Zealand Institute of Economic Research (NZIER) report described the economic and environmental value of plantation forestry compared with dairy farming. Based on provisional estimates, the report noted that plantation forestry created approximately NZ$31 million of environmental benefits annually, while dairying created approximately -NZ$18 million in environmental damage annually (Nixon et al. 2017). The NZIER report estimated economic values by using site-specific examples and extrapolating these to overall national figures. This approach can be criticised as there are marked differences between sites, but it provides a starting point for determining monetary values for environmental services.

Environmental services are described below, with a focus on sustainably managed native forests. This includes the entire forest ecosystem with every species in all tiers of the forest and associated forest soils. Environmental services are interlinked. Speden (2008) described how conservation of natural areas protects natural capital, i.e., investment in protection of biodiversity in its natural habitat concurrently protects other environmental services, including carbon sequestration, maintenance of water quality, protection of erodible soils and catchments – all of which benefits New Zealand's economy and human well-being. Various types of native forest play important roles in erosion control and soil conservation in vulnerable hill country, riparian zones, and coastal buffers. These ecosystem services are increasingly important in an era of climate change, with rising sea levels and increased frequency of severe weather events (Ministry for Environment and Stats NZ 2017).

Note that habitat provision and biodiversity values are reviewed below in the section on environmental services, while ecotourism and conservation of species are reviewed in the section on cultural services, as per the categorisation by Yao et al. (2017).

4.2.1 Carbon sequestration

The environmental service most easily quantified economically is carbon forestry under New Zealand's Emission Trading Scheme (ETS). Expansion of our forest resources has been identified as a major means of meeting climate change commitments (Ausseil et al. 2013; Hall 2016; MPI 2017b; Mason and Morgenroth 2017; NZFOA 2017; Nixon et al. 2017; OECD 2017a; Walsh et al. 2017). Approximately one-third of anthropogenic emissions since pre-industrial times is believed to have come from land use change, mainly deforestation (IPCC 2013). The flip side is that restoring forests can remove large quantities of carbon dioxide from the atmosphere through photosynthesis. Carbon sequestration will eventually slow down and can cease once the forest is fully mature, but if the forest remains intact, the carbon will remain stored within its trees (Kimberley 2021).

The establishment of the ETS was the first example of a nation-wide economic valuation of an ecosystem service in New Zealand (Monge et al. 2015). The ETS was established in 2008 to reduce greenhouse (GHG) emissions and meet international targets for climate change (OECD 2017a). It imposes a cost on businesses for their emissions and provides incentives for emissions reductions and removals (e.g., through carbon forestry) (MPI 2017b; OECD 2017a; Walsh et al. 2017). The New Zealand Government previously provided two incentives for increasing forested area for carbon sequestration - the Permanent Forest Sink Initiative (PFSI) and the ETS carbon credits system. However, the PFSI was discontinued and replaced with a new permanent post-1989 forest activity introduced into the ETS (MPI 2021d).

The carbon accumulated by trees can only be counted in the ETS if the trees form a 'carbon forest'. A carbon forest must be a minimum of 30 m wide and cover 1 ha, with the crowns of the trees covering more than 30% of each hectare, and the trees must have the potential to grow to a height of at least 5 m (PCE 2016). Native forest and regenerating vegetation that existed prior to 1989 are not included, yet they represent the largest biomass carbon pool in New Zealand. However, these carbon stocks are at risk of being lost through degradation due to browsing by pest animals (e.g., deer, possums) which requires active management and mitigation strategies (Ausseil et al. 2013). Unfenced forest in rural areas is also at risk from grazing by livestock.

There is significant scope in New Zealand for establishing large-scale carbon sequestration forests to provide a low-cost option for offsetting GHG emissions (Vivid Economics 2012; Hall 2016; Mason and Morgenroth 2017; Nixon et al. 2017; PCE 2016; Climate Change Commission 2021). The One

Billion Trees Programme, which provided grants to incentivise forest establishment, signified the New Zealand government's recognition of the wider value of forests, including carbon sequestration (Te Uru Rākau 2018). A strong, stable price for carbon provides incentives for forestation, including retiring marginal land for natural forest regeneration (Ausseil et al. 2013; Ministry for the Environment 2016; PCE 2016; Vivid Economics 2017; Walsh et al. 2017).

The Climate Change Commission recognised the importance of land use change to permanent native forests, in its advice on the direction of policy necessary for New Zealand to meet international climate change commitments (Climate Change Commission 2021). This would also simultaneously address multiple other environmental issues, providing substantial co-benefits for the environment and associated communities. The Commission recognised that the current sector infrastructure and policy settings heavily favour the planting of radiata pine over other species, and increasing carbon prices would incentivise establishment of permanent exotic carbon forests rather than native forests.

In their assessment of the total economic value of New Zealand's land-based ecosystems and the services they provide, Patterson and Cole (2013) valued climate regulation (carbon sequestration), by forests (native forests and exotic plantations) at NZ$1,503 million in 2012. This was when the price of carbon was relatively high and stable. During the initial years of the scheme, a carbon price of around NZ$20.00 was being traded (per New Zealand unit tonne of carbon dioxide equivalent). However, there was volatility and an overall decline in the price of carbon units from 2012 to 2014. In 2014, the price of a New Zealand unit largely stayed under NZ$5.00 (see Figure 1a).

Figure 1a: Indicative Carbon Prices New Zealand Units (NZUs) 1 January 2013 to 7 January 2020 (Carbon Forest Services Ltd 2020)

Initially, it was envisaged the ETS would encompass all sectors. However, it was amended in 2009 with emissions from agriculture initially exempted from any obligation, a decision openly criticised (PCE 2016; OECD 2017a). The ETS was also initially linked to overseas carbon markets. Cheaper international units pushed New Zealand carbon prices down and probably contributed to deforestation (MPI 2017b). The ETS was amended to exclude international units from mid-2015 onwards. This, along with the decision to phase out the one-for-two deal, helped New Zealand carbon prices rebound (MPI 2017b). The 'one-for-two' scheme was introduced by the government in the depth of the Global Financial Crisis to minimise the economic impact of addressing climate change. Organisations that emitted carbon, such as petrol companies, only needed to pay for half the value of their emissions via purchases of carbon credits that typically came from forestry organisations.

The price of carbon dramatically improved in 2016 after the first ETS amendments (MPI 2017b, Nixon et al. 2017). The price stayed above NZ$20 throughout 2018 and 2019 (Figure 1a). Further review of the ETS improved incentives for forestry (MPI 2017b, 2021e) leading to higher, stable carbon prices, which have stayed above NZ$30 from mid-2020 to mid-2021 (Figure 1b).

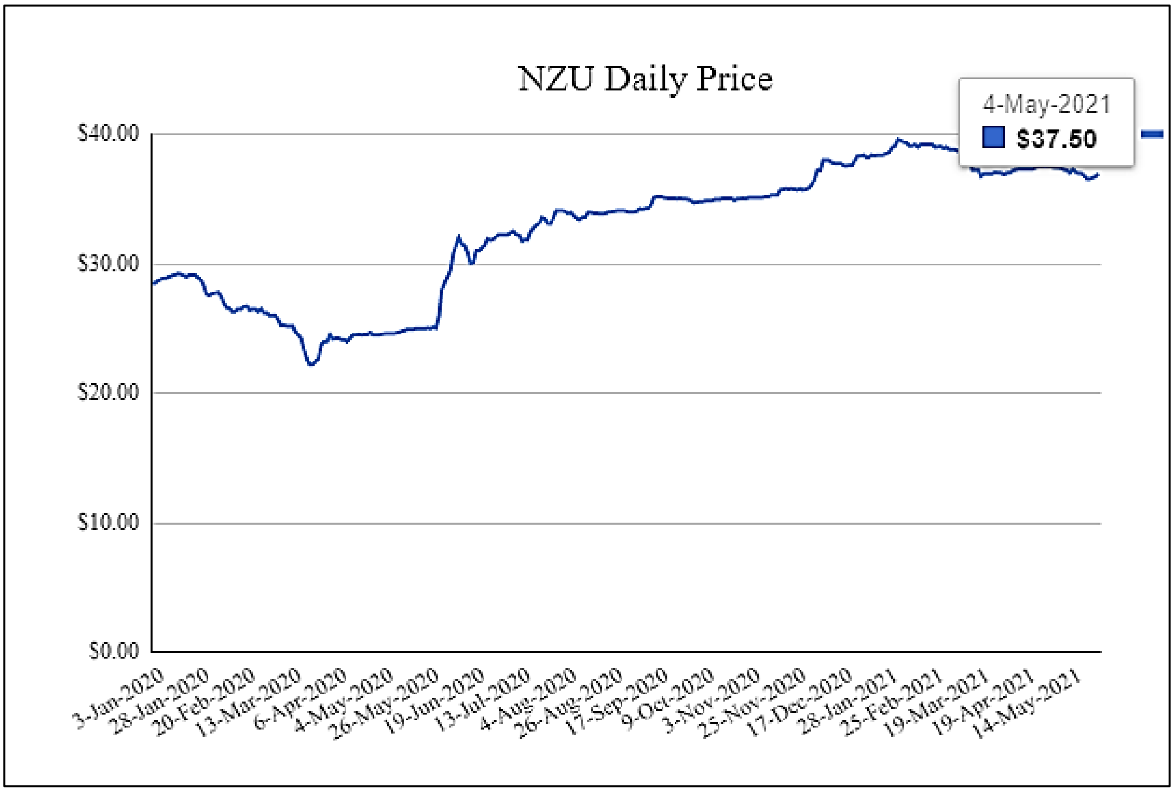


Figure 1b: Indicative Carbon Prices in New Zealand Units (NZUs) 3 January 2020 to 28 May 2021 (Carbon Forest Services Ltd 2021)

Carbon sequestration varies with the type of forest and stage of development. Carswell et al. (2013) assessed carbon sequestration and other ecosystem services provided by an area being transitioned from a large farming operation in North Canterbury - to St James Conservation Area, for the benefit of ecosystem services, as described above. Carbon sequestration was estimated using mapped forest cover classes and determining sequestration rates of ecosystems reverting to native forest, utilising a time series of multi-spectral aerial imagery from 2002 to 2009, in combination with site visits and sample plots. Rates of sequestration were predicted to increase during the early stages of succession (as trees become established and tree density increases), remain high for approximately 50 – 100 years, and then gradually decline as the forest reaches maturity. Much of the cover in St James was determined to be within the early stages of the sequestration curve (Carswell et al. 2013).

Figure 2 (from p. 67, PCE 2016) shows the rate of carbon dioxide accumulation in a regenerating podocarp-hardwood forest over 100 years, based on the ETS look-up table for native forests (MPI 2017c). The accumulation rate slows after 40 years as pioneer species (e.g., mānuka and kānuka) die off and the initially slow-growing later successional species emerge. After 50 years of growth, one hectare of regenerating native forest will have accumulated about 320 tonnes of carbon dioxide.

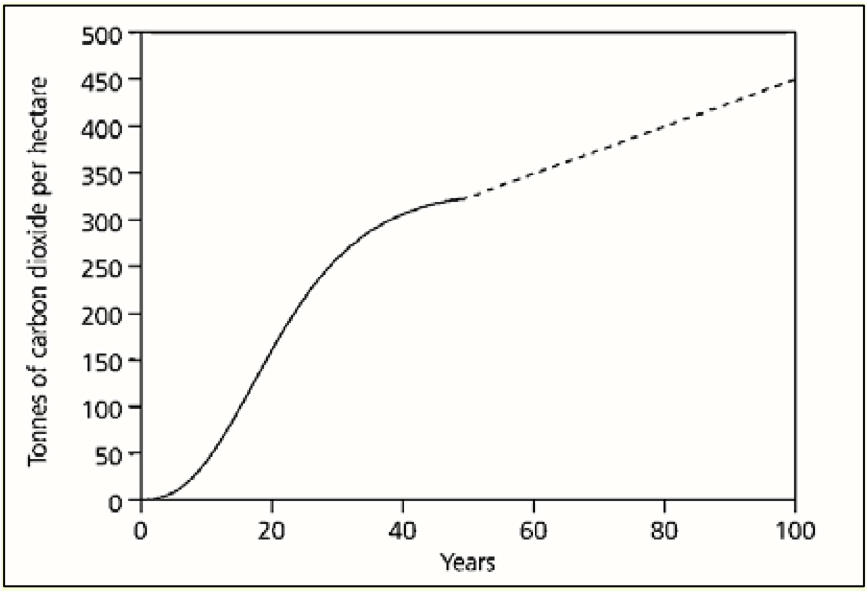


Figure 2: CO_2 accumulation in regenerating podocarp forest
(from Figure 9.2, p. 67, PCE 2016)

However, the look-up tables have been criticised for under-representing the carbon sequestration of planted native forests (Kimberley 2021) as discussed below.

There is a different scenario if radiata-pine plantations are used for carbon storage (Figure 3 and Table 1, below, from the Parliamentary Commissioner for the Environment report, PCE 2016). Although the faster initial growth and the average tree density (and therefore the sequestered carbon) of exotic forests are generally more than that observed in indigenous forests, exotic plantations are periodically harvested (Walsh et al. 2017). The scenario in Figure 3 (from p. 70, PCE 2016) assumes that the radiata pine is harvested at about 28 years and then replanted. Radiata pine's rapid growth makes it very efficient at removing carbon dioxide from the atmosphere over its rotation period. The discarded branches (slash) and roots left behind after harvest will decay, releasing carbon dioxide back into the air. However, most of the harvested stem is utilised for paper and timber products, effectively storing carbon for the lifetime of the product.

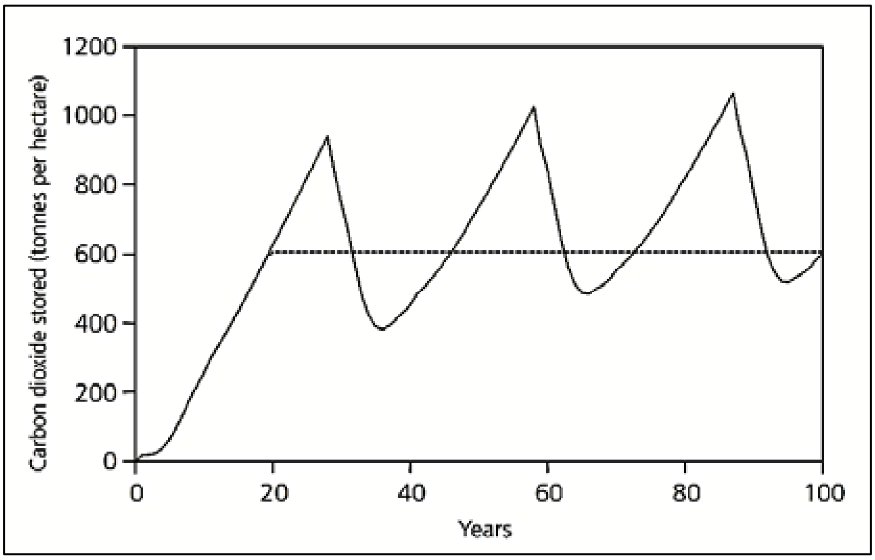


Figure 3: The amount of CO_2 accumulated by establishing a hectare of radiata-pine forest and replanting it after each harvest (from Figure 9.5, p. 70, PCE 2016)

Figure 3 (from PCE 2016) shows the amount of carbon dioxide accumulated by establishing 1 ha of radiata-pine and replanting it after each harvest. The dotted line shows the average amount of carbon stored in a forest over a hundred years, i.e., 31 tonnes per hectare per year for the first 20 years. To retain the storage of 600 tonnes of carbon dioxide in each hectare, the rotations would have to continue indefinitely, or an equivalent new area would need to be planted with pines (PCE 2016).

Data in Table 1 (from Tables 9.1 and 9.2, PCE 2016) shows the areas of forest needed to offset biological emissions from sheep, beef, and dairy farms when considering (i) regenerating podocarp-hardwood forest, and (ii) a radiata-pine plantation. The second column shows the methane and nitrous oxide emitted annually by livestock expressed in the equivalent amount of carbon dioxide (CO_2-eq). The third column shows the area of regenerating native forest needed to offset these emissions every year for 50 years, assuming there is no harvesting for timber. If a radiata-pine forest is to continue offsetting biological emissions, the planted area would have to periodically increase. The fourth column of Table 1 shows the new area that needs to be planted in pine every 20 years to continue to offset biological emissions (PCE 2016).

Table 1: Hectares of forest needed to offset biological emissions from livestock:
(i) area of regenerating native forest needed; and
(ii) new radiata-pine plantation that needs to be added every 20 years

Type of Livestock	Tonne of CO_2-eq per year from 100 animals	(i) Hectares of regenerating native forest needed to offset biological emissions	(ii) Hectares of new pine plantation that need to be added every 20 years to offset biological emissions
Sheep	38	6	1.2
Beef	179	28	5.7
Dairy	273	42	8.7

From Tables 9.1 (p. 68) and 9.2 (p. 71) Parliamentary Commissioner for the Environment report (PCE 2016)

Note that plantation forests of other forestry species would follow a similar pattern to that shown for radiata-pine in Figure 3, if they are managed under a clear-fell regime. However, there would be differences in the growth curve (and carbon sequestration) for each species, and differences in rotation lengths.

If native forests are managed under a continuous cover regime (Barton 2008), with only a small amount of timber harvested periodically under a sustainable forestry management (SFM) plan, then the curve for the amount of carbon dioxide accumulated would be much more similar to Figure 2 than Figure 3. Small gaps created in the forest by the harvest of single trees or small groups of trees would encourage the release of previously shaded and suppressed saplings, thus encouraging further sequestration of carbon dioxide in the forest. Indeed, Barton (2008) contends that the capacity for carbon sequestration is likely to be higher in a mature coniferous forest managed under a continuous cover regime (due to its multi-tiered, multi-aged structure) than in a clear-fell plantation regime.

Forest growers with more than 100 ha are required to use the Field Measurement Approach for determining carbon sequestration (MPI 2021c) whereas small forest owners can use the look-up tables (MPI 2017c).

However, it is questionable how reliable the look-up tables are for planted native forest as they are based on data from regenerating shrublands (MPI 2017c), which have less carbon storage capacity than taller forests (Kimberley 2021). According to the look-up tables, the carbon dioxide removal rate averaged over the 50 years from planting is 25 tonnes for radiata pine forest, 19 tonnes for Douglas-fir, and 13 tonnes for other exotic softwoods. However, the rate given for native forest is only 6.5 tonnes.

Tāne's Tree Trust has estimated the carbon sequestered based on their database of planted native trees and shrubs, which represents the most comprehensive set of measurements available (Kimberley et al. 2014; Kimberley 2021). Although native species initially have slower growth rates, they can compete with exotic species in carbon sequestration over the longer term, and even in the medium term. Carbon sequestration rates for planted native species are highly variable, depending on stand age, stocking, site productivity and level of maintenance after planting. Mean annual increment (CO_2 sequestration divided by stand age) for stands over 30-years-old, range from 6 to 20 t/ha/yr and average 13t/ha/yr (Kimberley et al. 2014).

Predicted carbon sequestration rates on average sites for several native tree species, a mixed-species planting of shrubs, and a typical radiata-pine stand are shown below in Figure 4 (updated from Kimberley et al. 2014). Clearly, none of the native tree species can compare in early carbon sequestration rates with fast-growing radiata-pine. However, beyond about 20 years in stand age, the fastest growing native species (such as kauri, red beech *(Nothofagus fusca)* and black beech *(Nothofagus solandri)*), can approach exotic species in terms of annual increment.

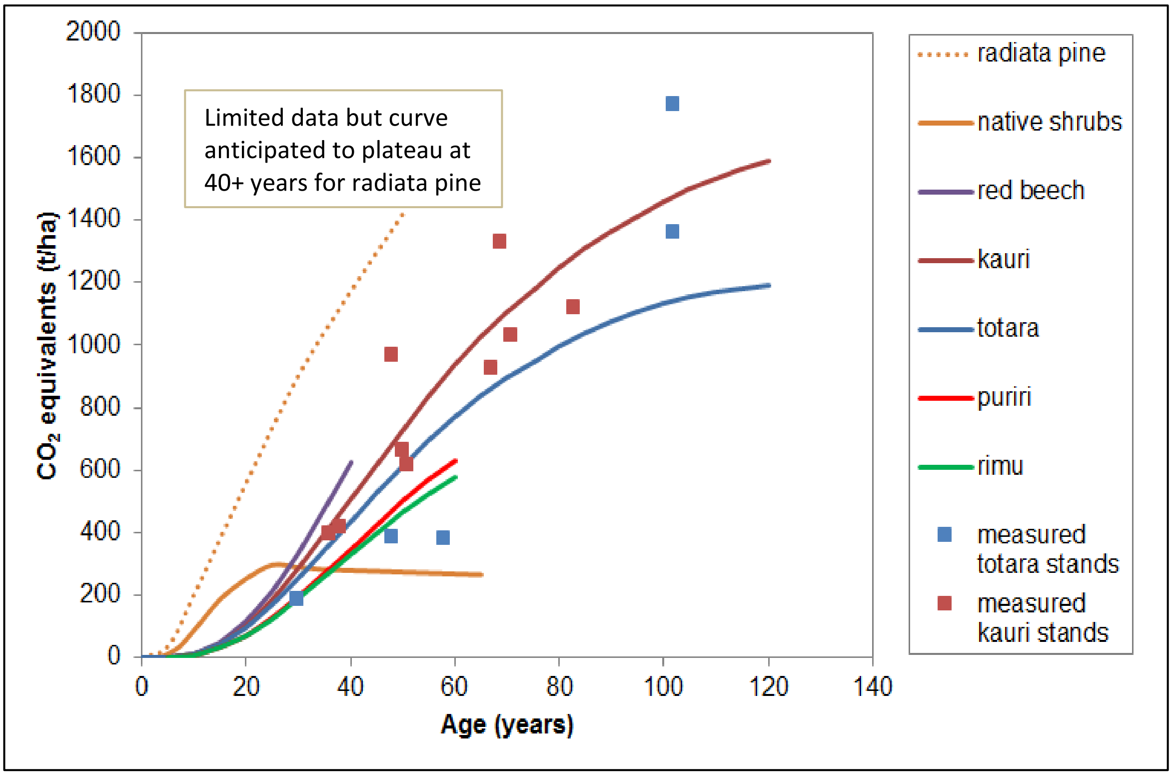


Figure 4: Carbon sequestration rates on average sites for several native tree species, a mixed-species planting of native shrubs, and a typical radiata-pine stand

A clear-fell regime of radiata pine will sequester on average 600 tonnes of carbon per hectare within 20 years of planting (Figure 3). Based on data from look-up tables, native forest that is naturally regenerating will take over 100 years to sequester 600 tonnes of carbon (Figure 2) compared to 50 years for planted native forest (Figure 4). However, mixed-species plantings of native shrubs and small trees can initially have much higher carbon sequestration rates than late-successional native tree species, which approaches that of fast-growing exotic tree species, but they typically plateau at ages 20 to 30 years (Figure 4).

These native shrub species are commonly used in reforestation programmes on open sites aimed at mimicking early successional processes in naturally regenerating shrubland (Kimberley et al. 2014). Although they provide little additional carbon sequestration beyond 20 to 30 years, this coincides with the period of accelerated growth in native tree species, which are often late-successional and typically have a slow early establishment phase, dependent on the initial shelter of the shrub species. Kimberley et al. (2014) concluded that establishing fast-growing native shrub species on open sites has the advantage of not only providing shelter for native tree species, but also provides a substantial boost to carbon sequestration in the first two decades after planting. However, the mixed shrub-tree plantings need to be carefully managed to avoid suppression of the later-successional tree species.

Note that planted native stands are often small-scale, poorly managed, and on less productive land. However, (Kimberley 2021) provides three examples demonstrating that native conifer species such as totara, kauri and kahikatea can have carbon removal rates comparable to those of Douglas-fir:

(i) A grove of planted totara in Northland, which is over 102 years old - the oldest stand included in the database, with an average carbon removal rate of 15.6 tonnes.
(ii) A 2-ha stand of kauri planted in Taranaki in the 1940s, with an average carbon removal rate since planting of 18.9 tonnes;
(iii) A grove of kahikatea planted in Hawke's Bay in 1980, with an average carbon removal rate since planting of 21.1 tonnes.

Ultimately, all forest (exotic or native) will reach a maximum carrying capacity for carbon. The carbon sequestration rate in radiata-pine stands is likely to start tailing off from about age 40 - 50 years because it is very light dependent, leading to mortality as smaller trees are suppressed (Ian Barton, personal communication). However, there is limited data for older radiata-pine stands in New Zealand to confirm this because radiata pine is normally harvested before age 35. Carbon sequestration in most native forests is likely to continue to increase over a much longer time period before it tails off. However, there is limited data from native forest stands over the age of 100 years to confirm this.

Tāne's Tree Trust has used its databases to develop a carbon calculator for planted native trees. This was launched on the Trust website for users to calculate carbon sequestration from their planted stands (Tāne's Tree Trust 2019b). It allows people to work out how many trees they will need to plant to offset their carbon emissions.

A large amount of marginal agricultural land has the potential to revert to shrubland and native forest (PCE 2016). Many hill-country farmers struggle to control regenerating scrub and keep marginal land in pasture. It is estimated that at least 1 million hectares of marginal farmland could be left to regenerate back into native forest, which would offset about 17% of the biological methane and nitrous oxide currently emitted by the agricultural sector each year for 50 years (PCE 2016). Fencing erodible, erosion-prone hill country and allowing it to regenerate would have the added benefit of preventing erosion and sedimentation, and enhance biodiversity conservation, as described below.

An ecosystem services analysis was undertaken for different afforestation scenarios in erosion-prone, pastoral hill country in New Zealand (Walsh et al. 2017). As described earlier, this involved both a broad analysis at the national level, plus a more detailed analysis in the erosion-prone Manawatū catchment in the lower North Island. The scenarios included planting exotic pine plantations and encouraging native forest regeneration. With carbon prices steadily increasing at the time, the report concluded that afforestation programmes could represent the most economically and environmentally viable land use for some of New Zealand's erosion-prone pastoral hill country (Walsh et al. 2017).

Mason and Morgenroth (2017) modelled reforestation with various types of forestry (six different combinations of species and silvicultural regimes) on highly erodible land in New Zealand, and explored the potential to achieve international climate change commitments through increasing the forest estate. The authors were open about the limitations of their work and recommended further analysis, particularly the refinement of rates of carbon sequestration on diverse land types. Their simulations suggest that an extensive planting programme on highly erodible land would lead to New Zealand becoming completely neutral for greenhouse gas emissions. They recommended a 'plant and leave' regime of radiata-pine (because of its very fast initial growth), with an understory of late-successional native forest species that they assumed would subsequently take over. They also recommended the planting of native tree species in a successional understorey if there is a lack of good local seed sources of native forest species to allow for natural regeneration (Mason and Morgenroth 2017).

Forbes et al. (2019) investigated the long-term potential of non-harvest radiata pine as a facilitative nurse for native forest restoration. They found that radiata-pine understories naturally become dominated by shade-tolerant, native species on some sites, if seed sources are nearby, providing an opportunity for restoration of native forest in New Zealand's production landscapes. However, intervention may be necessary to accelerate secondary native forest succession. And 'plant and leave' radiata pine is seen by many in rural communities as a controversial and undesirable land use, as exemplified by the '50 shades of green' lobby group.

Unfortunately, there are barriers to participating in carbon forestry. Hughes and Molloy (2017) criticised the bureaucracy of the ETS, which discourages small-scale forest owners from joining the scheme. The authors obtained information from submissions to an ETS review. They believe that the disproportionately high cost of participation and compliance, poor systems and processes, and penalties on participants for errors, create disincentives for small-scale forest owners. The recent review of the ETS addressed some of these concerns (MPI 2021e).

Tāne's Tree Trust commissioned a report by Motu Economic and Public Policy Research to assist those interested in carbon forestry with native forest plantings (Tuahine 2018). The report identified what is legally required of a forest owner to earn carbon credits and where it may be possible to reduce some of the transaction costs associated with native species-based carbon forestry (Tāne's Tree Trust 2017; Tuahine 2018).

Calculation of the carbon stocks of the forest can be complex and is determined by the size of the forest, the type of forestry, the planting periods and the harvesting timetable (if timber production is envisaged) (Hughes and Molloy 2017; Tuahine 2018). The Motu report sets out some scenarios for small-forest owners to indicate how carbon stocks are calculated. As stated above, for larger forests, participants must use a 'field management approach'. According to Tuahine (2018), all of the native forest species surveyed have higher total carbon stocks in comparison to the default look-up table, suggesting that participants who can use the field management approach could earn significantly more carbon units. However, the cost of the field management approach is likely to be prohibitive for small forest areas.

Another issue is that the ETS does not include carbon sequestration associated with shelterbelts and riparian setbacks, which according to Burrows et al. (2018) could be considerable. The Climate Change Commission also recognises this in its advice to Government:

> "The additional carbon removed by small areas of vegetation on farms and in urban green spaces is not currently recognised in target accounting, though it is in *New Zealand's Greenhouse Gas Inventory*. However, ongoing technology developments may make it more

possible to robustly estimate emissions from these areas in future" (p. 322, Climate Change Commission 2021).

Also, current models based on tree growth may underestimate carbon sequestration in native forests. Investigations by Steinkamp et al. (2017) indicate that native forest on the west coast of the South Island may be a bigger carbon sink than is evident in current models. This is based on data from a regional atmospheric inversion method used to determine the spatial and temporal distribution of carbon dioxide sinks and sources across New Zealand. However, this research is preliminary, i.e., more work is needed to confirm this.

In the context of carbon markets and high carbon prices, there are also risks of bio-perversity. This is where negative biodiversity and environmental outcomes arise due to a narrow focus on single environmental problems without consideration of the broader context, which Lindenmayer et al. (2012) discuss in the context of carbon sequestration solutions. The authors contend that a narrow focus on carbon sequestration could potentially create negative outcomes if protection and enhancement of other values such as biodiversity are not considered. This is further expounded in a report by the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) and the IPCC (Intergovernmental Panel on Climate Change), which examines the synergies and trade-offs between biodiversity protection and climate change mitigation and adaptation (Pörtner et al. 2021).

There have been calls for the ETS Permanent Forest Category to be limited predominantly to native forests (e.g., Hall and Lindsay 2021), and the Climate Change Commission notes that in its consultation process, some submissions stated that only native forest should be permitted to register as permanent forests (p. 321, Climate Change Commission 2021).

At the time of writing, there are limited incentives for land-owners to transition less productive farmland to native forest – this was highlighted in submissions to the Climate Change Commission, including submissions from farmers (Climate Change Commission 2021). The Commission acknowledges the capacity of native forests to sequester large amounts of carbon in the long term but recognises that it takes a longer time and higher costs to establish native forests. In their 2021 advice to Government, the Commission states that "work is urgently needed to develop the incentives for native forests so they can remove sufficient carbon as Aotearoa gets closer to its 2050 target of zero emissions" (p. 314, Climate Change Commission 2021).

It is interesting to note that areas of native forest regarded as having the highest total carbon stocks (live and dead stems) also tend to have the greatest richness of native bird species and the greatest dominance of native plants over non-native plants (Bellingham et al. 2014). However, habitat provision is not as easily monetarised as carbon sequestration, as described below.

4.2.2 Habitat provision and biodiversity values

Native forests have a critical role in habitat provision and biodiversity conservation in New Zealand. In this context, biological diversity, or biodiversity, describes "the richness, diversity and variability among all living organisms and ecosystems" (PCE 2002).

Most New Zealanders particularly value, and increasingly identify with, our indigenous flora and fauna, as opposed to exotic species (Meurk et al. 2013). Yet New Zealand's species extinction rates are among the highest in the world (OECD 2017a; Walker et al. 2018; Ministry for the Environment & Stats NZ 2019). More than half of amphibians, and roughly a third of mammals, birds, fish and reptiles are threatened, and many native plants are at risk, including the iconic kauri.

The main threats are - habitat loss, fragmentation and degradation, invasive plant species, introduced predators and pests, and new incursions of pathogens (Lee et al. 2005; MacLeod et al. 2012; OECD 2017a; Walker et al. 2018; Ministry for the Environment & Stats NZ 2019). The fundamental cause of the ongoing decline in indigenous biodiversity throughout New Zealand is the continued loss and degradation of indigenous ecosystems and habitats, where there are conflicts with other land uses (Walker et al. 2018).

The amount of public land set aside for conservation in New Zealand is high by international standards (OECD 2017a). However, not all ecosystem types are well represented, particularly lowland forest, wetland-forest complexes, and coastal forest ecosystems (PCE 2002; Ministry for the Environment 2007). Also, there is a problem with under-resourcing of the Department of Conservation (Thorpe 1998; Steer 2014; OECD 2017a) and concern that indigenous biodiversity on private land is declining (Brown et al. 2015). This is probably partly due to limited incentives for land-owners to maintain biodiversity and ecosystem services on their land (Brown et al. 2015; OECD 2017a). Much of the privately-owned native forest is contained in small, isolated fragments, some of which are unfenced and grazed (MPI 2015).

Brown et al. (2015) state that there is a compelling argument for compensating the efforts of land-owners who safeguard biodiversity in the wider public interest, which is the flip side of the 'polluter-pays' principle. Although farmers and horticulturalists may benefit from pollination services and birds reducing the number of pests, in many cases they are unlikely to benefit financially from restoring habitat for native species on their own land.

Rural land-owners have considerable interest in biodiversity values. In Manaaki Whenua's 2019 Survey of Rural Decision Makers, non-foresters were asked for their reasons for planting trees in the near future (Stahlmann-Brown 2019). 'Habitat-biodiversity' was one of the most popular reasons.

An important question is how different types of forests and forestry management practices influence habitat value and biodiversity. There is not a great amount of empirical data on this. However, it is well recognised that native forests support a greater biodiversity of indigenous fauna and flora than any other type of forest, particularly if the native forest is permanent or managed in a continuous-cover regime rather than a clear-fell regime (Pawson et al. 2010; Steward et al. 2014; MPI 2015; Young and Norton 2017). In a recent study of different afforestation scenarios, biodiversity benefits were found to be considerably higher for native forest compared with exotic conifer plantations, although they were not assigned dollar values (Walsh et al. 2017). Nevertheless, exotic plantation forests provide habitat for many species of native fauna, particularly kiwi (*Apteryx* spp.), karearea *(Falco novaeseelandiae)*, kokako *(Callaeas wilsoni)* and native skinks, frogs, bats, and invertebrates; as well as native understory plants (MPI 2015; Nixon et al. 2017).

Pawson et al. (2010) provided a comprehensive synthesis of information on threatened species known to occur in New Zealand's exotic plantation forests. They showed that some indigenous fauna, e.g., insectivorous bird species, are more likely to use exotic plantations than others, but very few fruit and nectar feeders are found in exotic plantations. This reflects the relative availability of food. Most of New Zealand's native frugivorous and honey-eating bird and lizard species are co-adapted to native fruit- and nectar-bearing trees and shrubs (Swaffield et al. 2003). Furthermore, hole-nesting birds are rarely present because the clear-fell harvest regime removes all the old trees, preferred for nesting (Pawson et al. 2010).

The role of regenerating or planted native forests in biodiversity conservation needs to be better recognised, particularly considering the ongoing threats to biodiversity, very high extinction rates, the under-representation of some ecosystem types in the conservation estate, threats to iconic species, and the under-resourcing of the Department of Conservation. Also, pest management in native forest is critically important. Damage to native forests by browsing pest species, such as possum, deer, and goats, can cause regeneration failure of palatable tree species and diminish the value of the forest for habitat (Bellingham et al. 2014). Ground-based pest management is often easier and less controversial in smaller, accessible public and privately-owned forest stands than in extensive public conservation estate, which extends into remote areas where aerial 1080 operations are often deployed.

Regenerating forest stands can have an important role in the conservation of biodiversity (Davis et al. 2016; Walsh et al. 2017; Young and Norton 2017). Young and Norton (2017) noted that private native forests in Northland complement protected public conservation land and substantially improve connectivity in habitat. Although many of the regenerating farm-based tōtara forests in Northland were found to have relatively low species diversity compared to old-growth forests, some stands hosted surprisingly rich native biodiversity. Species richness in regenerating native forest tends to increase with time, especially if grazing is excluded, pests are managed, and the stands are allowed to become more structurally complex.

Department of Conservation guidelines recognise the importance of induced and secondary ecosystems in present-day New Zealand. A large proportion of the original ecosystems have been modified by human activities (Ministry for the Environment 2007; Davis et al. 2016). In highly modified land environments, remnants of secondary indigenous biodiversity and regenerating vegetation are often all that remain. However, they can still be highly natural and valuable for supporting indigenous biodiversity and can be important for their contribution to conservation as they may represent the only indigenous biodiversity remaining in local areas (Davis et al. 2016; Walker et al. 2018). This has direct relevance to land-owners and organisations such as non-government organisations (NGOs) and local regional councils promoting the regeneration or establishment of native forest on land outside of the conservation estate.

As well as the important role that native forests have in the provision of habitat for forest-dwelling species, forests (particularly permanent forests) also have a significant role in protecting riparian zones and maintaining water quality by providing shade and regulating temperature; and filtering nutrients, sediment, and bacteria (Walker et al. 2018). New Zealand has one of the highest levels worldwide of threatened native freshwater species (Joy and Death 2013; OECD 2017a). Replacement of native forest with exotic conifer plantations has much less impact on streams than conversion to pasture, but logging and replanting create periodic disturbances that can significantly alter stream habitats (Fahey et al. 2004; Quinn 2005).

Riparian buffers help limit the negative impact of forestry operations and intensive agriculture (Hamilton 2005; Abell et al. 2011; MPI 2015; Gluckman 2017; Julian et al. 2017). Resources providing information on riparian planting using appropriate native plant species are available on local council websites and through Tāne’s Tree Trust (2012).

An assessment of changes in fish communities in New Zealand rivers showed that the largest decline in freshwater biodiversity has been in rivers in pastoral or urban catchments, compared with exotic and native forest sites (Joy 2009; Joy and Death 2013). The Index of Biotic Integrity (IBI) was applied to a large database of freshwater fish distribution, collected throughout New Zealand over the last 40 years, to summarise temporal and land-use trends in freshwater health. The average fish IBI score was significantly higher for the least-modified native forest and scrub sites than for the other land-cover classes (Joy 2009; Joy and Death 2013).

Biodiversity conservation values are likely to be highest where native forest:

- forms nationally, regionally, and locally significant habitat types especially where these are scarce, e.g., lowland podocarp hardwood forest and wetland-forest complexes; and coastal forest ecosystems, particularly dune forest (Ministry for the Environment 2007);
- provides habitat for threatened or endangered native fauna and flora, or species that are nationally, regionally and locally significant, such as kiwi, kokako, kaka *(Nestor meridionalis)*, native parakeets (kākāriki) (*Cyanoramphus* spp.), native bats (*Mystacina tuberculate* and *Chalinolobus tuberculatus*), various species of native skinks and geckos, and native mistletoe (*Peraxilla* species and *Alepis flavida*) (Ministry for the Environment 2007);
- is dominated by regionally or nationally scarce tree species such as Bartlett's rata (*Metrosideros bartlettii*), or threatened species such as kauri, pōhutukawa, or swamp maire (*Syzygium maire*) (Ministry for the Environment 2007; Biosecurity New Zealand 2018);
- creates ecological corridors connecting natural areas, allowing movement and dispersal of native fauna and flora;
- protects other important associated natural ecosystems, e.g., riparian plantings protecting waterways; and
- is well managed and in good condition (e.g., ongoing animal pest control, lack of invasive weeds) or can be readily restored to a good condition.

The big question is – how can habitat provision and biodiversity values be quantified in economic or other terms? In many cases, standard methods of measuring biodiversity are useful for gaining a measure of habitat provision in smaller-scale settings. For example:

- **RECCE plots:** long-term changes in stand structure using the standard Reconnaissance Plot method based on Hurst and Allen (2007).
- **Seedlings plots:** subplots to assess regeneration of woody seedlings and saplings by species (e.g., Payton et al. 2004).
- **Ground cover:** subplots to compare the change in ground cover vegetation (e.g., Payton et al. 2004).
- **5-minute bird counts:** a method generally used for determining the presence of forest birds, which is relatively easy and requires few resources (Department of Conservation 2018a).
- **Mark-resight and distance sampling:** considered to give better estimates of bird numbers than 5-minute bird counts (Department of Conservation 2018a).

The national biodiversity monitoring and reporting systems implemented across public conservation land in New Zealand emphasize species dominance and occupancy (Lee et al. 2005; MacLeod et al. 2012). Ecological integrity, which is essential for biodiversity conservation, includes three distinct elements: long-term dominance of indigenous species, potential occupancy by all appropriate biota, and full environmental representation of ecosystems. This is typical of other international biodiversity monitoring and reporting systems (Lee et al. 2005).

Local council plans identify ecologically significant areas. Also, the Department of Conservation’s National Biodiversity Monitoring and Reporting Programme provides information on the population status of selected forest-associated species, as well as a useful framework for assessing ecological values (largely synonymous with biodiversity values in this context) (see Davis et al. 2016). The framework includes the following:

- Ecological Districts
- Land Environments of New Zealand (LENZ)
- National priorities for threatened indigenous biodiversity
- Ecosystem and vegetation classification
- Freshwater Ecosystems of New Zealand Geodatabase.

These guidelines reflect accepted good practice and have been prepared to promote a consistent approach to assessing the ecological or biodiversity values of sites. If skilled people are not readily available, such assessments are best done with input from appropriate staff members from the local Department of Conservation or allied agencies.

In addition to this, national lists of threatened species status (from the New Zealand Threat Classification System) identify species that are threatened or at risk, and, by extension, the habitats of these species (Walker et al. 2018). It is also important to protect the habitats of species threatened at the regional level so that species ranges are not further reduced (Walker et al. 2018).

Dymond et al. (2008) developed a landscape approach for estimating the conservation value of sites, and site-based projects, from a New Zealand perspective. The valuation methodology estimates site value, protection value, and restoration project value. Where the costs of proposed conservation projects are known, then a cost-benefit analysis can be performed to prioritise projects to maximise the gain in conservation value per dollar spent. This provides a simple and rapid method for prioritising conservation projects without having detailed site-based biodiversity information.

Carswell et al. (2013) assessed biodiversity benefit in St James Conservation Area. St James is an area of retired marginal farmland in North Canterbury, New Zealand, which had retained large areas of natural habitat, as described earlier. It was purchased with the objective of transitioning the land to conservation and other ecosystem services. Carswell et al. (2013) applied a quantitative framework for assessing biodiversity benefit through management intervention using the Vital Sites and Actions (VSA) model (Overton et al. 2010, cited in Carswell et al. 2013). The VSA Model was used to quantify the ecological integrity of St James. Relatively few areas of high, unique plant diversity were identified, and these were primarily wetlands. The estimated species' naturalness was high, and the vulnerability of native species was relatively low. The authors concluded that much of the indigenous biodiversity at St James was in relatively good order, but generally well represented elsewhere in New Zealand, rather than being unique and rare.

Ausseil et al. (2013) used various tools to assess various ecosystem services at the landscape level, as described earlier. A benefit function was used to assess the contribution of natural habitat to conservation goals - the proportion of natural land cover remaining in a land environment was weighted by a condition index. Indigenous forest, subalpine shrublands, alpine habitats, and tussock grasslands above the treeline, were all assumed to have a condition of 1.0. Tussock grasslands below the treeline and indigenous shrublands are not climax ecosystems, so were assigned conditions of 0.8 and 0.5 respectively, which the authors deduced represented their contribution to biodiversity relative to the climax state. Exotic forests were assigned a condition of 0.3, to reflect their contribution to indigenous biodiversity (based on the work of Pawson et al. 2010). All other land covers were assumed to have a condition of 0. A map of natural habitat provision in New Zealand was produced. High values were associated with rarer habitats in good condition, and low values were associated with well-represented habitats in poor condition.

A loss of native biodiversity can negatively impact our sense of identity and belonging (PCE 2002; Ministry for Environment & Stats NZ 2019). Social and cultural indicators have increasingly been viewed as an integral component of biodiversity assessment programmes, although they are difficult to define (Lee et al. 2005). Lyver et al. (2017a, b) identified community-based indicators and metrics applicable in the New Zealand context to monitor forest health and community well-being from a te ao Māori perspective, as described below in the section on cultural and spiritual values.

At the time of writing, a BioHeritage Eco-index is being developed for use in New Zealand. This will measure biodiversity values and enable land managers to know if they are making positive changes for biodiversity values. It utilises mātauranga Māori and a scientific framework (Dr Kiri Joy Wallace, pers. comm.).

There are many barriers to increasing native forest on our private land. In a pivotal report published in 2002 - *Weaving Resilience into our Working Lands: recommendations for the future roles of native plants* - the Parliamentary Commissioner for the Environment (PCE) stated that New Zealand's legislative and policy frameworks give limited scope for native vegetation to provide both conservation and wealth creation benefits on private land. This is a major constraint on the expansion of native vegetation on private land, and subsequently, the potential for native plants to contribute to the sustainability of land uses, wealth creation, and indigenous biodiversity. The report states that we need to better understand the attributes of native plants (ecologically and economically) and "reflect on the risks that biodiversity in New Zealand faces by our not addressing the barriers in mindsets, the limitations of our research and the legislative hurdles" (preface, PCE 2002).

The PCE also acknowledged that the "protection, establishment and ecologically sustainable use of native plants by a landowner often provides benefits to others, such as improved water and soil quality and enhanced indigenous biodiversity" (p. 34, PCE 2002).

The 2002 PCE recommendations discussed the ability of markets to give a monetary value to ecosystem services provided by native plants, including placing a value on the presence of indigenous biodiversity on private property, e.g., developing a system of tradable biodiversity credits. The recommendations included the government playing a role in setting up frameworks and rules for the management of ecosystem services markets - to ensure that desired objectives are achieved, there are no perverse outcomes, and the markets accurately reflect the value of the ecosystem services (PCE 2002). The need for tax reforms was also discussed - to support the efforts of land-owners in protecting remnant vegetation and increasing the extent of natural ecosystems, this included making "the expenditure incurred by land-owners in conserving indigenous biodiversity tax deductible" (p. 35, PCE 2002).

Recommendations by the Tax Working Group in 2019 included broadening the tax base and making greater use of environmental taxation, and developing the tax system over time to enhance natural capital (Tax Working Group 2019).

The Climate Change Commission (2021) in its advice to Government on the direction for emissions reduction, stated that there are currently limited incentives for land-owners to change less productive farmland to native forest – this was highlighted in submissions, particularly from farmers.

At the time of writing, there are discussions on incentive systems to encourage native forestation on private land, which are largely based on biodiversity values. Policy researcher Dr David Hall (Hall 2021) states the following:

> "Such a payment would monetise the value of biodiversity and enable communities to invest time and resources in successful restoration and conservation. This could be funded through emissions pricing, or an environmental footprint tax as proposed by the Tax Working Group".

Hall and Lindsay (2021) produced a concept paper that identifies financial instruments to deliver biodiversity outcomes in New Zealand and mechanisms for bringing these instruments to market. These include the Hauraki Gulf blue bond, debt-for-nature swaps, Paradise bonds, a regional biodiversity fund and biodiversity notes.

Note that NTVs related to ecotourism and species conservation are reviewed below, in the section on socio-economic, cultural and spiritual values.

4.2.3 Urban forests and environmental services

Many native forest species are in New Zealand's urban parks and reserves. Protected 'town belts' form contiguous tracts of native forest in several major New Zealand cities (Meurk et al. 2013). Some city councils (e.g., Dunedin, Christchurch and Wellington) own multi-purpose forests (largely exotic species) within their urban boundaries, which provide not only wood products, but NTVs such as effluent treatment, recreation and amenity benefits (Meurk et al. 2013).

Urban forests provide a wide range of environmental services in New Zealand cities, including regulatory services that positively impact water quality, storm-water management, flood and erosion control, waste disposal, protection from wind, noise reduction and improvement of air quality (Vesely 2007; Meurk et al. 2013). The USDA Forest Service estimated that trees in New York City provide US$5.60 in benefits for every US$1.00 spent on tree planting and ongoing maintenance (Peper et al. 2007). This includes:

- enhanced visual amenity;
- shade;
- reduced urban heat island effect;
- improved water quality;
- carbon sequestration;
- reduced flood risk;
- increased property values;
- reduced energy costs;
- enhanced biodiversity;
- improved air quality; and
- improved health and well-being, therefore, reduced healthcare costs.

Trees protect people from harmful ultraviolet radiation and reduce the risk of heat stroke. The cooling effect of trees, due to evapotranspiration and provision of shade, reduces the urban heat island effect, which is increasingly important in an era of climate change (Salmond et al. 2016).

Also important in an era of climate change, urban forests and wetland complexes help moderate the impact of severe weather events (Forest Research 2010; Meurk et al. 2013). Lack of natural vegetation in many urban areas reduces interception of precipitation, while the use of impermeable materials in urban construction decreases ground infiltration of precipitation (Forest Research 2010). Reduced ground infiltration increases the speed of run-off, therefore; the risk of flooding is increased in urban areas. Green space in urban areas helps restore natural environmental services including those related to the hydrological cycle, such as flood alleviation and improvement and ongoing protection of water quality (Forest Research 2010).

Internationally, urban areas have been associated with poor air quality (Meurk et al. 2013). However, trees and vegetation are effective in the absorption of gaseous air pollutants and the interception of air-borne particulate matter (PM) (Litschke and Kuttler 2008), resulting in an improvement in air quality. This has a positive impact on people's health, i.e., lower incidences of respiratory and cardiovascular diseases, and a reduction in hospital emissions and health costs (Tiwary et al., 2009; Forest Research 2010).

There is limited information available on how effective urban trees are in improving air quality in New Zealand and how this translates into monetary values; however, there is information in international literature; e.g., Tiwary et al., (2009), Forest Research (2010), Nilsson et al. (2011), and UK National Ecosystem Assessment (2011).

The most widespread air quality problem in New Zealand is PM pollution, which is known to cause a wide array of health problems, including respiratory illness, cardiovascular diseases and premature death (Ministry for the Environment and Stats NZ 2018). In cooler months in some towns and cities in New Zealand, emissions from home heating can raise levels of airborne PM to above national standards and international guidelines, especially when air pollution is trapped near ground level by temperature inversions (Ministry for the Environment and Stats NZ 2018). Only a few studies have directly measured the health impacts of PM and gaseous pollutants on New Zealanders, but there is a depth of knowledge from international studies, e.g., World Health Organization (2013), and Health Effects Institute (2018).

Urban vegetation mitigates the effects of air pollution, as shown in many international studies (Litschke and Kuttler 2008; UK National Ecosystem Assessment 2011) and New Zealand (Fisher et al. 2007; Cavanagh et al. 2009). Cavanagh et al. (2009) measured a 30% attenuation of PM_{10} (airborne particles that are 10 micrometres or less in diameter, i.e., includes coarse and fine PM) from the edge to the interior of native forest in Christchurch, New Zealand. This was in a distance of less than 200 m in Riccarton Bush, which is a remnant podocarp-hardwood, floodplain forest, dominated by kahikatea.

Cavanagh and Clemons (2006) and Cavanagh (2008) (cited in Meurk et al 2013 and Roberts et al. 2015) estimated the many tonnes of various air pollutants that urban trees remove in Christchurch and Auckland, worth tens of millions of dollars in terms of health benefits. In Auckland, Cavanagh and Clemons (2006) estimated that the city's trees annually removed 1230 tonnes of nitrogen dioxide, 1990 tonnes of ozone, and 1320 tonnes of particulate matter. Cavanagh (2008, cited in Meurk et al. 2013 and Roberts et al. 2015) estimated that Christchurch urban trees removed 300 tonnes of pollutants, including 150 tonnes of PM_{10} (equivalent to 4.5% of the estimated PM emissions in 2002) and estimated that the value of urban trees in Christchurch was NZ$19.6 million. This value was largely due to the significant health benefits associated with PM_{10} removal.

There are differences in how various species of trees help improve air quality (Meurk et al. 2013; Roberts et al. 2015). In winter, evergreen trees (including almost all our native species) are more effective at removing air pollutants, although some (mainly exotic species) also emit natural volatile organic compounds, which can contribute to air quality issues (Meurk et al. 2013). Most deciduous trees cease these functions after leaf drop, which often occurs at the time of year when pollutant levels are highest in New Zealand (Cavanagh 2008, cited in Roberts et al. 2015).

A New Zealand study has demonstrated that exposure to natural vegetation can protect against asthma in children, but this was not thought to be due to a reduction in air pollution. Donovan et al. (2018) assessed the association between the natural environment and asthma in a longitudinal study of 49,956 New Zealand children born in 1998 and periodically assessed until 2016. They found that children who lived in greener areas were less likely to be asthmatic. Also, exposure to a greater number of natural vegetation-cover types provided an additional increment of protection. Not all land-cover types were protective; exposure to gorse (*Ulex europaeus*) and exotic conifers were found to be risk factors for asthma.

The reasons for the observed protective effects of exposure to natural vegetation and a diversity of vegetation are unclear. Donovan et al. (2018) found no evidence that it was due to a reduction in air pollution. Instead, they hypothesized that the natural environment may protect against asthma through greater and more diverse microbial exposure (i.e., the hygiene hypothesis), or via currently unknown biological mechanisms.

Urban forests are also important for carbon sequestration, biodiversity values, and amelioration of noise levels (Meurk et al. 2013). Cities are often biodiversity ‘hotspots’ because they frequently sit astride convergences of several biomes, and there is an educated and well-resourced population interested in conservation (Meurk et al. 2013). Often significant remnants of natural vegetation remain in gullies, floodplains and aquifer protection zones. These urban forest remnants help provide ecological corridors from the mountains to the sea.

A recent OECD report notes that major urban biodiversity initiatives such as pest-free bird sanctuaries in Wellington, Auckland and Dunedin, help protect endangered species while providing city dwellers with easy access to nature (OECD 2017a). These sanctuaries are largely composed of native forest, providing critical habitat for native flora and fauna. They also allow the spread of endangered species beyond the sanctuary to remnants nearby where ongoing predator control will assist in increasing their range (Tanentzap and Lloyd 2017).

The importance of socioeconomic and cultural services provided by urban forests are described later in this report. This includes recreation, people’s health and mental well-being, and a sense of place and cultural identity.

4.2.4 Stabilisation of soils, erosion reduction, and catchment protection

It is well established that forests improve water quality in a catchment due to hydrological services (Brauman et al. 2007). Stabilisation of slopes and the subsequent catchment protection provided by forestry is a key ecosystem service in New Zealand because many regions are vulnerable to erosion due to their geology and high frequency of extreme weather events (Basher 2013; MPI 2015).

Enormous amounts of topsoil have been lost due to erosion where there has been clearance of native forest and conversion to agriculture in unstable hill country (Ausseil et al. 2013; Basher 2013; Herzeg et al. 2013; MPI 2015; Gluckman 2017). This has led to loss of topsoil, negatively impacting agricultural productivity, and causing sedimentation of streams, rivers and harbours, which has affected water quality and caused loss of biodiversity in freshwater and estuarine ecosystems (MPI 2015; PCE 2016; Gluckman 2017). Also, denuded hillsides shed more water during intense rainfall events, leading to greater flood events downstream, damaging communities, infrastructure and freshwater, estuarine and marine ecosystems (Brauman et al. 2007; Duncan and Woods 2013; Awatere et al. 2018).

However, the value of avoided erosion is difficult to measure, partly because there are off-site benefits from the soil stabilisation provided by forests, including avoided sedimentation of waterways and flood mitigation. These off-site benefits accrue more to downstream land-owners and the general public than to the original landowner (Yao and Velarde 2014).

Soil conservation programmes began in the 1940s in New Zealand due to concerns over erosion and sedimentation of waterways, particularly where steeplands had been deforested. This resulted in the first catchment protection programmes (MPI 2015; Nathan 2015). The most effective measures for maintaining soil cover (and protecting catchments) is to retain existing forest and shrub cover, or encourage reforestation of erosion-prone areas and riparian zones (MPI 2015; PCE 2016; Gluckman 2017; Yao et al. 2017). There is a wealth of data showing that the area of soil eroded by storms is consistently less (in the range of 50% to 90% less) where native forest is retained, or marginal land is allowed to revert to native vegetation, or forest is planted – as compared with pastureland (Blaschke et al. 2008; Ausseil et al. 2013).

The total annual cost of soil erosion in New Zealand was estimated at NZ$127 million in 2001 (Krausse et al. 2001, cited in MPI 2015), which is the equivalent of $NZ190 million in 2021-dollar values (based on the Reserve Bank of New Zealand's inflation calculator). Hill country erosion was estimated by Jones et al. (2008, cited in MPI 2015) to cost New Zealand between NZ$100 and NZ$150 million per year ($NZ125 to 188 million in 2021-dollar values) through lost production, damage to infrastructure and sedimentation. Dymond et al. (2011) estimated the cost of erosion to be approximately NZ$200 million, which is the equivalent of $NZ229 million in 2021 (using the same inflation calculator). According to Yao et al. (2017) NZ$250 million a year (equivalent to $267 million in 2021-dollar values) could be saved through avoided erosion if another 2.9 million hectares of forests were to be planted.

Dominati and MacKay (2013) reported on ecosystem services lost from grazed pasture following a heavy rainstorm that caused landslides and soil erosion from hill slopes along a 250 km coastal zone in Hawke's Bay in 2011. The cost-benefit analysis showed that planting trees was not profitable unless the trees were harvested for timber, and low discount rates (less than 5%) were used. However, when considering the value of the extra provision of ecosystem services (largely avoided erosion) the Net Present Value of the investment was strongly positive, regardless of the discount rate.

Not all forestry is equal in terms of soil conservation and catchment protection, but there is a lack of comprehensive empirical data on the impact of different types of forests and forestry management practices. According to Basher (2013) closed-canopy, tall woody vegetation typically reduces landslides in large storms by 70 – 90%. However, some production forestry operations negatively impact stream health, particularly road construction and harvesting. In production forestry, displacement of soils can occur during or after clear-fell harvesting, which can result in loss of P to waterways (Hamilton 2005; Payn and Clinton 2005; Yao and Velarde 2014; MPI 2015) particularly in erosion-prone steeplands (Yao et al. 2013; Gluckman 2017).

Riparian buffers can help limit the negative impact of harvesting operations (Hamilton 2005; Abell et al. 2011; MPI 2015; Death 2017; Gluckman 2017).

Also, permanent unharvested forests, or forests managed under continuous cover regimes (Barton 2008) that are only selectively logged under strict sustainable forest management regulations, are likely to provide significantly better maintenance of soil cover and catchment protection, compared with plantation forests managed under clear-fell regimes.

A study of land slipping was undertaken on the highly erodible, steep hill country on the East Coast of the North Island of New Zealand, in the aftermath of Cyclone Bola (Bergin et al. 1995). The study compared pasture to areas reverting to native shrubland of different ages. Landslide damage showed a rapid and highly significant reduction against increasing age of reverting mānuka/kānuka shrubland. Compared to pasture, there was a 65% reduction in shallow slipping of hillsides in reverting shrubland by age 10 years; and a 90% reduction by age 20 years. Other studies indicate that radiata-pine forest provides similar protection from landslide damage as reverting native shrubland, within 10 years of establishment on steep hill country. However, clear-fell regimes of radiata-pine forestry leave a vulnerable period of approximately 6 years between the decaying of root systems of the logged crop and the new crop becoming established, during which time there is a risk of erosion in high-intensity rain events (Bergin et al. 1995; Bloomberg et al. 2019).

Almost one-quarter of New Zealand's plantation forest estate is on erosion-prone land (high to very high erosion susceptibility classification) (Bloomberg et al. 2019; Te Uru Rakau 2019b). High-profile intense weather events in 2018, on the East Coast of the North Island and in the Tasman District at the top of the South Island, have highlighted major issues with logging debris and sediment from clear-fell operations seriously damaging downstream infrastructure. Therefore, social license to operate (community acceptance) has become more of an issue regarding clear-fell regimes and exotic plantation forestry (Bayne et al. 2019). There have been calls for vulnerable hill country to be established in permanent forest, with native forest the obvious choice (e.g., Salmond 2019).

Griffiths et al. (2020) developed a spatial model for landslides that occurred during a period of heavy rain from ex-tropical Cyclone Gita. They used the model to demonstrate that landslide occurrence in the Tasman District, New Zealand, could be substantially reduced by limiting the clear-fell harvest of plantation forests and increasing the extent of permanent forest cover on landslide-prone slopes.

Sediment loss from plantation operations in Marlborough Sounds has damaged marine environments and pāua fisheries, which has had a considerable economic impact on the industry (Ministry for the Environment & Stats NZ 2019). Pāua (*Haliotis* spp.) prefer clean, clear water. The most productive pāua fisheries are found on exposed coasts alongside land-cover in native forest. Awareness has increased about the impacts of logging of nearby forest plantations and recommendations have been made for improved forestry practices, including having setbacks of 200 m from the water-line, and retiring the steepest and most erosion-prone land (Ulrich 2017).

Patterson and Cole (2013) analysed the total economic value of New Zealand's land-based ecosystems and the services they provide. In examining forest ecosystems (native forest and exotic plantations) they valued erosion control at NZ$2092 million in 2012, second only to the production of raw materials. (This is NZ$2353 million in 2021-dollar values). In particular, they found that indigenous forests "play a critical role in maintaining soils and preventing sediment loss on land that is often steep and unstable" (p. 503, Patterson and Cole, 2013). They cite Cyclone Bola as a good example of an erosion event occurring on land once protected by native forest. For just that one event, the economic cost of losing this ecosystem service of erosion control (due to deforestation) was estimated at nearly $200 million (Ministry for the Environment 1997; cited in Patterson and Cole 2013) which is NZ$223 million in 2021-dollar values. The ex-tropical cyclone passed near New Zealand in March 1988. It caused severe damage and was one of the costliest cyclones in the history of New Zealand.

Regenerating native forest provides significant services in erosion control. Patterson and Cole (2013) identified that erosion control was the most important ecosystem service provided by forest–scrubland and native scrubland ecosystems, estimated at NZ$421 million and NZ$364 million in 2012, respectively (NZ$474 million and NZ$409 million in 2021-dollar values, respectively). Erosion control was also important in the agriculture-forest and agriculture-scrub ecosystems.

A case study by Yao et al. (2013) looked at the economic value of timber and erosion mitigation in marginal pastoral land in the two most erodible catchments in New Zealand, in the east coast region of the North Island. An integrated economic model for predicting forestry returns was combined with estimates from the New Zealand Empirical Erosion Model, NZeem® (Dymond et al. 2010, cited in Yao et al. 2013) to estimate reduced erosion from afforesting the area; at an equivalent of 98 tonnes of sediment per hectare per year. However, this estimate was of avoided erosion from forest at full canopy cover and, therefore, did not account for disturbance to the soil during harvesting and establishment, where early forest growth would not provide much protection compared with full canopy cover.

Results from a discounted cash-flow analysis with an 8% discount rate showed that a typical radiata-pine regime on a 28-year rotation, using a value of NZ$1 per tonne of sediment (from Dymond et al. 2011), would have average timber profits of approximately NZ$1,245 per hectare and an avoided erosion value of approximately NZ$1,017 per hectare in the erosion-prone catchment. A similar analysis of a 'plant and leave' regime (i.e., no timber harvest) showed that there would be less erosion, with a present value of approximately NZ$1,114 per hectare, and total carbon stock would accumulate to over 3000 tonnes of carbon dioxide per hectare after 90 years (Yao et al. 2013).

Yao and Velarde (2014) also used NZeem® to estimate avoided erosion values in exotic production forest and native forest in the Ōhiwa catchment. They calculated the aggregated economic value of avoided erosion and sedimentation, and flood mitigation, by using economic data based on avoided expenditure costs, derived from discussions with regional and city council staff. An estimate of NZ$6.50 per tonne of avoided erosion was applied to the NZeem® results to determine the benefit of having an existing planted forest (modified from Barry et al. 2014). The results indicated that, on average, the avoided erosion and catchment protection value were (per hectare per year) NZ$121 for exotic forest and NZ$166 for native forest in the Ōhiwa Catchment (Yao and Velarde 2014). The value of avoided erosion provided by the native forest was about 37% higher than for the exotic forest. This was because the exotic production forest included the negative impacts of establishment, harvesting, etc.; however, differences in topography and soil types for the two different types of forest may have also been factors (Yao and Velarde 2014).

In the situations described above (Yao et al. 2013; Yao and Velarde 2014) where there are erodible hill country soils, a better land use would arguably be permanent native forest that is grown primarily (or solely) for environmental services, rather than exotic timber plantations grown on a clear-fell regime. Carbon forestry would provide an income and incentivise such plantings, if carbon prices remain stable at a good level, as discussed above.

Mason and Morgenroth (2017) modelled reforestation with various types of forestry (six different combinations of species and silvicultural regimes) on highly erodible land in New Zealand. They explored the potential to achieve international climate change commitments by increasing the forest estate. Erosion-prone land was chosen because re-establishing forest greatly reduces the likelihood of further erosion, and this type of land often has marginal farm productivity. They recommended a ‘plant and leave’ regime of radiata-pine (because of its very fast initial growth), with an understory of native forest species, including late-successional species that they assumed would subsequently take over (Mason and Morgenroth 2017). However, intervention may be necessary to accelerate secondary native forest succession (Forbes et al. 2019) as discussed above. And ‘plant and leave’ radiata pine is seen by many in rural communities as a controversial and undesirable land use, as exemplified by the ‘50 shades of green’ lobby group.

The Ministry for Primary Industries commissioned Landcare Research to perform ecosystem services analyses of different afforestation scenarios in erosion-prone, pastoral hill country (Walsh et al. 2017). As described earlier, the scenarios included planting pine plantations and encouraging native forest regeneration. The report concluded that afforestation programmes could represent the most economically and environmentally viable land use for some of New Zealand’s erosion-prone pastoral hill country.

Government programmes recognise that avoiding erosion has significant long-term benefits beyond merely protecting the productive capacity of New Zealand’s pastoral and forest lands (MPI 2015; 2017b). There have been targeted grants that indicate the value of this environmental service provided by forests, i.e., the stabilisation of soils and prevention of erosion and sedimentation, as well as protection of downstream infrastructure and ecosystems. Most of these grants were replaced by the New Zealand government’s One Billion Trees Programme, which set a goal to plant one billion trees in the decade 2018 to 2028 (MPI 2017b; Te Uru Rākau 2018, 2019a).

However, at the time of writing, the Sustainable Land Management Hill Country Erosion (HCE) Programme is still running. This is a partnership between central government and regional councils to support hill country farmers in mitigating soil erosion through sustainable land management practices, including establishing forestry plantations and land retirement, i.e., encouraging natural reversion to native forest. These soil conservation initiatives are co-ordinated by regional councils, which can apply for funding from an annual pool of NZ$2.2 million (MPI 2015).

According to a report from the Parliamentary Commissioner for the Environment (PCE 2016), there are additional benefits of enabling native forest to regenerate on marginal, erodible hill country (aside from preventing erosion and sedimentation). These additional benefits include habitat for native flora and fauna, ameliorating downstream flooding, and income from carbon credits, offsetting up to 17% of the agricultural sector's GHG emissions each year.

4.2.5 Coastal buffers

There is limited information about the important role of native forest in coastal buffers. However, they are an important part of the coastal ecosystems that provide sustainable and effective permanent barriers that protect productive land, infrastructures, and other natural ecosystems. They provide critical salt and wind shelter, prevent erosion and help mitigate the impact of climate change.

Unfortunately, natural coastal vegetation has been cleared from much of New Zealand's coastline, with almost total removal of dune forest (Bergin and Dahm 2014). Restoration of indigenous dune vegetation is recognised as a national priority for biodiversity conservation (Ministry for the Environment 2007; Bergin and Dahm 2014). The need for coastal protection zones was first recognised in the late 1800s (Cockayne 1911). Subsequently, monocultures of exotic species were mostly planted, particularly the relatively short-lived radiata-pine, which is now dying off in many coastal protection zones. The need for more sustainable and resilient protection zones was recognised with coastal native forest a logical solution (Bergin et al. 2014). This is the focus of an applied research project undertaken by Tāne's Tree Trust in collaboration with the Coastal Restoration Trust of New Zealand, regional councils, iwi, Coastcare groups, and forestry companies.

Mangroves also provide coastal protection services (Ruckelshaus et al. 2016; Waikato Regional Council 2016). New Zealand has one mangrove species (*Avicennia marina* subspecies *australasica*, or Manawa), which is found in the northern part of New Zealand, from Northland to Bay of Plenty. However, mangroves are sometimes viewed as a nuisance due to their expansion in estuaries, causing loss of amenity values. This expansion happens because of sedimentation, which is often due to poor land management practises (Waikato Regional Council 2016).

4.2.6 Water yield

Water yield is an ecosystem service that can be negative for forest ecosystems, i.e., water yield from forested catchments can be lower compared with other land uses (Ausseil et al. 2013). This can be an issue in arid or semi-arid climates, where there are downstream water shortages (Brauman et al. 2007). There is currently limited information on forests and water yield in New Zealand (Ausseil et al. 2013; Duncan and Woods 2013). However, key mechanisms in water use, storage, and release in forests have become a research focus because of the intensification of land use, a growing population and increased water demand by rural and urban users, and the potential implications of climate change on water availability (Duncan and Woods 2013; Meason et al. 2019; Ministry for the Environment & Stats NZ 2020).

Carswell et al. (2013) assessed ecosystem services in an area in North Canterbury, which was transitioned from New Zealand's largest privately-owned farm to St James Conservation Area, as described above. Changes in ecosystem services likely to occur in the future at St James were discussed. Water yield was expected to decrease. The authors concluded that the superior water yield of pasture cover, compared with shrubland or forest, represents a major trade-off between biodiversity and water provision, if regeneration of native forest was encouraged.

With the increased demand for water in some parts of New Zealand, plantation forests are increasingly regarded as a competitor for water resources (Meason et al. 2019). A review of catchment studies (comparing water yield in conversion from pasture to radiata-pine, and conversion from existing native forest to radiata-pine) indicated that afforestation with radiata pine could reduce water yield by varying amounts. However, without an understanding of the hydrological processes, Meason et al. (2019) contend that the results are catchment-specific and empirical relationships cannot be directly transferred to other catchments. More research is needed on the impact of land-use changes on hydrological processes, particularly water yield in regard to afforestation with plantation species or reforestation with native species.

Meason et al. (2019) also undertook a phone survey on how regional councils perceive forestry in their water management plans. Council staff generally saw planted forests as having a positive role in mitigating floods and stabilising slopes, and a negative impact on water yield in water-sensitive catchments. Conversely, at an earlier workshop on the same topic, forest managers regarded planted forests as an important storer of water during winter and a supplier of water in drier months (Meason et al. 2019).

4.2.7 Nutrient regulation and water quality

Freshwater resources are a vital natural asset for New Zealand - for human and animal health, natural biodiversity, tourism, and land-based industries, as well as recreational and cultural values important for economic growth and quality of life (OECD 2017a). As well as the need for clean water, many local people rely on natural fisheries for food, and the mauri (life force or vitality) of waterways is culturally important for Māori.

The main water pollutants are nutrients, sediments and pathogens (Payn and Clinton 2005; Gluckman 2017; Nixon et al. 2017; OECD 2017a). Nutrient losses from land - mainly nitrogen (N) and phosphorus (P) - are largely determined by how the land is used (Julian et al. 2017). There is substantial documentation of the changes in environmental conditions of streams associated with forest clearance (see Davies-Colley 2013). Losses of both N and P are low from land covered in plantation forest or native bush but are much higher from pastoral and arable land (Payn and Clinton 2005; PCE 2015; Nixon et al. 2017). An overload of nutrients entering waterways stimulates algal blooms and aquatic weed growth. Algal blooms significantly reduce the amenity value of lakes and rivers, pose a risk to human and animal health, and have resulted in lakes being closed to swimming and fishing in parts of New Zealand (Gluckman 2017; Ministry for the Environment 2017; Nixon et al. 2017; OECD 2017a).

Payn and Clinton (2005) were among the first to highlight the important role that forests have in the maintenance of water quality in New Zealand. In their work on modelling the nutrient fluxes and balances of New Zealand's plantation forests, they highlighted the low impact of forestry, compared with the high impact of dairy farming with its much higher nutrient inputs and impacts on water quality. They concluded that forestry's low nutrient footprint should be factored into the economic value for forestry, and made the following comments:

> "currently there seems little acknowledgment of the benefits of forestry in the wider community" [however, in regard to nutrient trading] … "There is potential for forestry to be a major financial beneficiary if trading schemes were implemented based on actual nutrient footprints of the different sectors. This would allow the recognition of the non-timber values …" (p. 21, Payn and Clinton 2005).

To a certain extent this is currently happening, with nutrient capping and trading in the catchments of two iconic lakes, as described below. Also, there is now wide acknowledgment that the intensification of agricultural land use has had a significant negative impact on water quality, whereas, in comparison, forestry is regarded as a low-impact land use (Drewry et al. 2006; Abell et al. 2011; Palliser et al. 2011; Park and MacCormick 2011; Rutherford et al. 2011; Davies-Colley 2013; MPI 2015; Hall 2016; Death 2017; Nixon et al. 2017; OECD 2017a; Yao et al. 2017).

In addition to comparatively low nutrient leaching, forests can improve water quality by recycling excess nutrients from intensive agriculture that would otherwise be discharged into the water (Payn and Clinton 2005; Palliser et al. 2011; Park and MacCormick 2011; Rutherford et al. 2011; MPI 2015; Monge et al. 2015; PCE 2015; Hall 2016; Death 2017; NZFOA 2017; Nixon et al. 2017; Yao et al. 2017; Walsh et al. 2017). Riparian plantings in pastoral land can help reduce nitrate leaching and loss of phosphates (Abell et al. 2011; MPI 2015; Death 2017; Gluckman 2017; Julian et al. 2017; OECD 2017a) but do not provide a complete solution (Hamilton 2005).

According to a report in 2017 on freshwater quality by the Prime Minister's Chief Science Advisor, water quality and measures of aquatic ecosystem health generally worsen across land-cover classes in the following order: natural vegetation, exotic forest, pastoral land, and urban settings (Gluckman 2017). This trend across land-cover classes is also mirrored in the health of fish communities, as described previously (Joy 2009; Joy and Death 2013). Water quality of rivers in plantation forests is generally appreciably better than that of rivers in pastureland, and approaches the water quality of rivers in native vegetation, except for when there is the periodic disturbance associated with harvesting (Davies-Colley 2013).

It is, therefore, a concern that much of the deforestation in New Zealand, from 2004 to 2014, was due to land-use conversion from exotic plantation forestry to pastoral agriculture, particularly dairy farming, as discussed previously (Manley 2015; PCE 2015; Nixon et al. 2017; OECD 2017a). In regions where dairy farming has expanded, nitrate concentrations in waterways have increased and water quality has declined (PCE 2015; Death 2017; Gluckman 2017; Nixon et al. 2017; OECD 2017a). In the Waikato region, large areas of new dairy land were developed after the felling of plantation forest on the porous soils of the Volcanic Plateau. This led to increases in nutrient losses in the upper Waikato catchment, negatively affecting water quality (PCE 2015).

Foote et al. (2015) undertook a nationwide assessment of the environmental costs of dairy intensification in New Zealand. They estimated that the costs of removing nitrates from drinking water were between NZ$1.7 billion and NZ$10.7 billion annually. Monge et al. (2015) quantified market values of production and non-market values of environmental externalities (effectively ecosystem services) from similar areas of land used for dairying and forestry. Their modelling gave an estimated loss of NZ$18 million on environmental externalities from dairying compared to an estimated benefit of NZ$30 million from forestry, although dairying could produce a production surplus per year that was about three times that from forestry on the same land. Forestry had lower (but less variable) returns than dairy farming, but its environmental impacts were net positive, whereas dairy farming had environmental impacts that were net negative.

There is currently no direct market value for nutrient recycling and low nutrient leaching services associated with forestry in New Zealand. However, this has implicit value as regional councils have applied regulations to control nutrient application and land use in the Lake Rotorua and Lake Taupo catchments, to reduce nutrient run-off and leaching into waterways (Nixon et al. 2017) with incentives for forestry land use, as explained below.

Not all forestry is equal in this regard, but there is limited empirical data on nutrient losses from different types of forests and forestry management practices, and how this impacts water quality (Drewry et al. 2006; Abell et al. 2011; Julian et al. 2017). Larned et al. (2004) assessed water quality at the national level by land cover types. Differences between native and exotic plantation forest land cover classes were not statistically significant for any water quality parameters. However, disturbance or displacement of soils frequently occurs during or after clear-fell harvesting (as described previously) resulting in loss of fine sediment and phosphates to waterways (Hamilton 2005; Payn and Clinton 2005; Davies-Colley 2013; MPI 2015; Death 2017; Julian et al. 2017). Replacement of native forest by pine plantations has much less impact on streams than conversion to pasture, but phosphate loss due to forestry operations can negatively impact water quality (Abell *et al.* 2011; Death 2017; Gluckman 2017; Julian et al. 2017). Nitrate leaching can also occur after harvesting on some soils when nitrogen uptake is disrupted, and decomposition of organic matter is accelerated (Hamilton 2005; Payn and Clinton 2005).

In contrast, a native forest managed solely for NTVs (i.e., not harvested) is likely to have minimal nutrient losses. Likewise, native forest managed under a continuous cover regime, where only single trees and small coupes are felled (Barton 2008) will retain a high-forest structure, minimising soil disturbance and nutrient loss (N and P) to waterways (MPI 2015; OECD 2017a). Native forests are not artificially fertilised, whereas large-scale plantation forests are sometimes fertilised to ensure long-term productivity (MPI 2015). However, nutrient inputs into plantation forests are generally very low compared with pastoral land uses in New Zealand (Payn and Clinton 2005; Death 2017), and most plantations generally only require naturally occurring inputs as they are effective scavengers for key limiting nutrients, usually N and P, due to the symbiotic association of tree roots with ectomycorrhizal fungi (Payn and Clinton 2005).

Note that in 2009, restoration ecologist Roger MacGibbon proposed various options for native plantings to be utilised as tools for management of nitrogen (and other environmental factors) in the Lake Taupo catchment. This included native tree and shrub plantings replacing nitrogen-producing gorse and broom on marginal and unproductive land, and targeted planting of native species to intercept, extract and utilise nitrogen from the soil and waterways (MacGibbon 2009).

Ausseil et al. (2013) estimated nitrogen leaching throughout New Zealand using OVERSEER®. They combined OVERSEER® data with other agricultural data in a spatial framework to produce a map of nitrogen leaching in New Zealand. OVERSEER® is a software system developed in New Zealand to model the flow of nutrients on a farm and can estimate the amount of nutrients lost from across the land (OECD 2017a). It has been used as a tool in modelling nutrient flows in catchments from various land uses, including forestry as well as multiple agricultural land uses. OVERSEER® has also been used as a tool for nutrient load modelling and management of diffuse pollution in the Rotorua lakes (Palliser et al. 2011; Park and MacCormick 2011; Rutherford et al. 2011).

Yao and Velarde (2014) estimated key ecosystem values in Ōhiwa catchment, Bay of Plenty, in a desktop study. The results were preliminary and indicative and based largely on the extrapolation of data from other studies rather than data collected on site. Non-market values were collated from data published in journal papers and reports, and then rescaled to conditions in the Ōhiwa catchment. Despite the limitations of the study, the authors contend that the results provide a foundation to support land management decisions at the catchment level. They examined the seven major land types in Ōhiwa catchment including four productive land uses (dry stock and dairy farming, exotic forest and horticulture) and three natural vegetation types (indigenous forest, scrub, and wetlands and mangroves).

Environmental costs for leaching of nitrogen were estimated using nitrogen leaching data measured elsewhere for the different land uses, and assuming a nutrient cap and trade system was in place; i.e., the dairy, horticulture and dry stock land uses would need to offset their shortfall by buying nitrogen credits. A nitrogen price of NZ$400 per kg per hectare per year was assumed (MacGibbon 2011; Barns 2014, cited in Yao and Velarde 2014). The net total ecosystem services of plantation forestry were estimated at NZ$5,609 per year, per hectare, about half of which (NZ$2800) was attributed to forestry's reduced leaching of nitrates compared to other land uses (Yao and Velarde 2014). Another significant component was the supporting service of nutrient cycling at NZ$994 (18% of the total value).

Dairy farming had the lowest net negative aggregated ecosystem services value in the catchment (about - NZ$29 million), largely due to the negative environmental service of nutrient regulation. Native forests provided the highest positive aggregated ecosystem value overall in the catchment of about NZ$24 million, closely followed by exotic forests at NZ$19.5 million (Yao and Velarde 2014). All three natural landscape types and exotic forests had positive total ecosystem service values per year, whereas the other productive land uses (dairy, dry stock and horticulture) had negative values. Among the natural landscape types, wetlands provided the highest value per hectare, followed by native forest and scrub.

The socio-cultural approach to valuation, as described above (Scholte et al. 2015; Felipe-Lucia et al. 2015) may be applicable here, i.e., the values that society attributes to nutrient retention, nutrient recycling and clean water provided by forests, as opposed to monetary values. Alternatively, standard methods of measuring water quality can provide an estimate of this NTV in smaller-scale settings when measurements are taken before and after forestation. NIWA provides a good overview of water quality measures and freshwater ecosystem values (NIWA 2021).

Quinlan et al. (2018) describe water quality parameters that are regularly being measured in waterways within and downstream from regenerating tōtara forest in Northland. This includes the Macro-invertebrate Community Index (MCI), a biological indicator of stream health based on the presence or lack of macroinvertebrates (e.g., insects, worms and snails); and fish surveys, i.e., the presence of native and exotic fish species.

The regulation of land use can also provide an indicative value of this NTV. Regional Councils are putting catchment management plans in place to prevent loss of N and protect water quality, and have begun to set N limits in environmentally sensitive catchments (OECD 2017a). This includes the nitrogen cap-and-trade system in the Lake Taupo catchment (OECD 2017a) and the development of nitrogen capping in the Lake Rotorua catchment area (Ministry for the Environment 2017) (see below). The Lake Taupo Nitrogen Market was the first diffuse pollution trading scheme in the world (OECD 2017a).

According to a New Zealand Institute of Economic Research (NZIER) report (Nixon et al. 2017) water clean-up operations in Lake Taupo, the greater Waikato catchment, and the Rotorua lakes (all within the central North Island) give an indication of the value of cleaner water bodies (i.e., society's willingness to pay for water improvements) and forestry's contribution to improved water quality. An indicative economic value for these environmental services can be made by extrapolating from site-specific examples to overall national figures, although with a wide margin for error (Nixon et al. 2017). This approach can be criticised as there are marked differences in land use, environmental sensitivities, rainfall patterns, soil characteristics (including nutrient holding capacity) and the hydrological, geological and ecological characteristics of different regions, but it provides a starting point for determining monetary values for environmental services.

According to the NZIER report (Nixon et al. 2017), New Zealand's central and local government agencies committed NZ$526 million, in the decade 2006 – 2016, to taxpayer and ratepayer-funded programmes to clean up freshwater bodies, including:

- NZ$220 million on the Waikato and Waipa Rivers,
- NZ$144 million for the Rotorua lakes,
- NZ$30 million on Lake Taupo, and
- NZ$30 million on the Manawatū River.

The full costs of programmes to improve water quality, including private costs to land-owners and opportunity costs of lost production from regulatory measures, are unclear but would be higher than these government costs alone (Nixon et al. 2017). However, the question is how much of this cost can be regarded as a proxy for environmental services potentially provided by forestry?

There is little doubt that forestation contributes substantially to improved water quality because of the recycling of nutrients and lower nutrient losses from forests compared with other land uses (Payn and Clinton 2005; PCE 2015; Nixon et al. 2017). Also, there is the premise that existing forests in a catchment make the clean-up task less severe than it would otherwise be; however, the extent to which these avoided clean-up costs can be attributed to forestry is not clear from current information as it is difficult to estimate how different the water quality situation would be if there was more (or less) forestry (Nixon et al. 2017). However, despite recognition of the reduced nutrient leaching in forests, and the capacity of forests to recycle nutrients from more intensive land uses, there is very limited empirical data available to quantify these services.

The water quality issues and cost of clean-up in the Lake Rotorua catchment demonstrates the impact of deforestation and intensification of land use on water quality. Although sewage outflow initially had an impact, intensification of land use in recent decades has been identified as a major factor in the decline of water quality (PCE 2006; Palliser et al. 2011; Park and MacCormick 2011; Rutherford et al. 2011). Excess nutrients from agriculture either flow over land into waterways or leach into underground aquifers and eventually into the lake. Water quality in Lakes Rotorua and Rotoiti (which are hydrologically linked) has declined significantly since the 1960s. The overload of nutrients has stimulated algal blooms and aquatic weed growth. Algal blooms have significantly reduced the amenity value of the lakes, they pose a risk to human health and have regularly resulted in lakes being closed to swimming and fishing (Ministry for the Environment 2017).

The Rotorua-based Te Arawa Lakes Programme was established in 2007 with the main purpose to improve the water quality of the 12 large lakes in the Rotorua district (PCE 2006). The lakes are recognised as being of special importance to the Te Arawa people, the health of the water is essential for well-being, and the lakes are of national importance as tourist destinations (PCE 2006). Much of the focus has been on improving water quality in the iconic Lake Rotorua, which normally receives over half a million international visitors each year, i.e., it is important for the local tourism industry (PCE 2006; Ministry for the Environment 2017).

OVERSEER® has been used as a tool in modelling nutrient flows and also for managing diffuse pollution outputs in the Rotorua lakes (Palliser et al. 2011; Park and MacCormick 2011; Rutherford et al. 2011). Pastoral land use contributes the greatest N load in the Lake Rotorua catchment, particularly dairy farming. In contrast, low N loads are associated with forested land, which includes native forest and scrub as well as commercial plantations. The 'forest' category involves 46% of the land use, but only an estimated 10% of the N load for the groundwater catchment. This is because of the very low average nitrogen load, i.e., 3.6 kg of N per hectare per year, based on the groundwater catchment figures from the ROTAN (Rotorua and Taupo Nitrogen) model. This compares with 54.1, 15.7 and 23.6 kg of N per hectare per year for dairy farming, dry stock farming, and urban areas, respectively (Palliser et al. 2011; Park and MacCormick 2011; Rutherford et al. 2011).

Much of the input of phosphorus (P) to Lake Rotorua is from natural sources (Tempero et al. 2015). Alum dosing provides a temporary solution for removal of some of this P but is not a good long-term solution due to potential toxicity and ongoing cost of alum (Bruere 2017, Tempero et al. 2015). Most of the focus has, therefore, been on the reduction of the N load.

A combination of rules and incentives is being used in the Lake Rotorua catchment to reach the sustainable N limit (Rotorua Lakes Protection and Restoration Programme 2012; Ministry for the Environment 2017; Te Arawa Lakes Programme 2020, 2021). Land-use change is seen as the most vital part of the sustainable long-term recovery for Lake Rotorua, which is supported by the science programme underpinning Te Arawa Lakes Programme (Bruere 2017). An Incentives Scheme is part of a wider framework aimed at cleaning up Lake Rotorua. A NZ$40 million fund was set up to 'buy' nitrogen from land-owners who have decided to permanently lower their nitrogen discharge, aimed at buying 100 tonnes of nitrogen by 2022 (Te Arawa Lakes Programme 2020). A permanent land-use change will likely be necessary for some farmers to lower their nitrogen discharge below their Nitrogen Discharge Allowance, which is their allowable rate of N loss for their property.

Mueller (2017) used an ecosystem services approach in an integrated assessment of different options for reducing nutrient loads and meeting water quality targets in Lake Rotorua. Direct and indirect valuation approaches were used to assess the annual economic value of the lake ecosystem, including existence value, hedonic pricing, and replacement cost. A potential damage cost of the impacts of continued eutrophication was estimated, based on the current value of the lake, plus estimated reduction factors in ecosystem service provision and associated values.

An options analysis showed that the most cost-effective methods to achieve the nutrient load reduction to the lake, to meet the agreed water quality target, would be a combination of mitigation practices and land-use change in the catchment. Best water quality outcomes were achieved by conversion of intensive land use to exotic or native forest; this option also showed the best economic outcomes, when non-market values were considered.

Mueller's research integrated the analysis of ecological processes with an economic assessment of lake and catchment ecosystem services, and subsequently placed this within a policy and management context. The research shows the value of integrated assessments - taking ecological, economic, social and cultural values into consideration. The results also show the economic significance of preserving and restoring ecosystems, particularly (in this case) forest ecosystems and how this would positively affect the health of a lake ecosystem.

Restrictions on land use and nutrient run-off will become more widely applied in New Zealand with the Action for Healthy Waterways legislation, aimed at improving and protecting water quality (Ministry for the Environment 2019). Regional councils are already required to have a process in place to reduce contaminant losses to waterways, including nitrate leaching.

4.2.8 Native forests and pollination services

Pollination is defined as the delivery of pollen from the male parts of a flower to the receptive female parts of a flower (Newstrom-Lloyd 2013). Pollination services are important for New Zealand's horticultural sector, particularly kiwifruit, apples, avocados, stone-fruit and blueberries; as well as pastoral agriculture, e.g., clover (Newstrom-Lloyd 2013; Dymond et al. 2014; MPI 2019). Pollinators are declining in New Zealand and world-wide due to multiple factors, including habitat loss (Millennium Ecosystem Assessment 2005; Newstrom-Lloyd 2013).

As discussed above, apiculture strongly relies on New Zealand's native forest as native flowering species provide pollen and nectar for honey bees (Butz Huryn 1995; MPI 2015). Beekeepers frequently move their hives into forested areas or forest margins in early spring, as early-season nectar flow and pollen are critical for building up bee colonies. Beekeepers have also traditionally utilised honeydew from beech forests *(Fuscospora* species and *Lophozonia menziesii*) for feeding bees outside nectar flow periods (Crozier 1981).

Native forest also provides habitat for native pollinators, i.e., native bee species, honeyeater bird species, and native bats (Newstrom-Lloyd 2013). However, the contribution of native forest species to the well-being of honey bee colonies and other pollinators, and therefore pollination services, is difficult to quantify as there is very limited research on this. Habitats that support a diverse and abundant pollinator community will result in better provision of pollination services. Fenced riparian areas in rural areas that are planted in native trees and shrubs provide habitat and floral resources, helping assure pollination services (Dymond et al. 2014).

Table 1 (pp. 421 – 422) in Newstrom-Lloyd (2013) provides a list of 71 native plant species selected by beekeepers as good bee forage in New Zealand. Note that some exotic (flowering) forestry species are also identified as providing good bee forage, including eucalyptus species.

Yao and Velarde (2014) estimated the ecosystem value of pollination services in Ōhiwa catchment for various land uses. Radiata-pine plantations and native forest were both estimated to have pollination services of NZ$206 per year per hectare. The pollination functional richness index of a New Zealand native garden in Canterbury (Rader et al. 2014) was used as a proxy. However, radiata-pine does not produce nectar and has very poor quality pollen for bees. Although some native species are found in the understory of radiata-pine plantations, native forests (per se) are likely to have a far greater density and diversity of species important to honey bees and other pollinators, as compared with radiata-pine plantations (which are likely to have nil or very low pollination services).

4.2.9 Green firebreaks and fire risk reduction

Intense, large wildfires have been predicted to become more common in parts of New Zealand (Pearce et al. 2010; Scion 2011; NIWA 2016) as already experienced in Port Hills (in 2017), Pigeon Valley (in 2019), Lake Pukaki (in 2020), and Lake Ohau (in 2020). Whereas considerable resources are invested to combat and suppress wildfires, much less is invested in ecosystem-based approaches for fire risk reduction (Depietri and Orenstein 2019) except in China (Cui et al. 2019).

A concerted response is needed to mitigate the increased risk of wildfires, particularly where there are extensive areas of highly flammable vegetation. Not all vegetation burns the same - there are varying fire risks associated with different types of forest.

Ecosystem services for fire regulation are rarely accounted for and generally excluded from ecosystem service classifications (Depietri and Orenstein 2019). However, they are included in the most recent version of the Common International Classification of Ecosystem Services (CICES v. 5.1) and defined as "the capacity of ecosystems to reduce the frequency, spread or magnitude of fires". This encompasses many types of wetlands and also green firebreaks, which contain plant species of low flammability that can help block or slow down the advancement of fires (Haines-Young and Potschin 2018; Depietri and Orenstein 2019).

Depietri and Orenstein (2019) reviewed relevant literature and further defined fire-regulating services as "benefits resulting from specific, co-produced ecosystem features and ecosystem management, that prevent the social-ecological system from experiencing impacts from catastrophic fires". They also defined fire-regulating disservices as those that “increase the potential for catastrophic fires affecting people, buildings, infrastructures and ecosystems”. Fire-regulating disservices can occur when fire risk is increased due to highly flammable species grown in monocultural plantations, such as some conifer and many eucalypt forestry monocultures, and mānuka and kānuka plantations.

Fire regulation is an important ecosystem service considering the loss of lives, environmental damage and economic losses often associated with large wildfires. Natural wildfires have always occurred, but increased fire risk associated with anthropogenic climate change means that they are becoming more prevalent, intense, and extensive, and fire seasons are becoming more prolonged in many parts of the world (Flannigan et al. 2013; Depietri and Orenstein 2019). Parts of New Zealand are becoming warmer, drier and windier because of anthropogenic climate change; subsequently, an increase in fire danger has been predicted for many regions (Scion 2011; NIWA 2016).

A heterogeneous landscape with diverse land use that includes patches of less flammable vegetation amid more flammable vegetation, increases fire resilience (Depietri and Orenstein 2019). Land managers can reduce fire spread across landscapes by planting green firebreaks, particularly where fire risk is greatest, such as on the edge of areas of highly flammable vegetation; or where fire losses are likely to be highest (in human terms) such as in rural settlements and rural-urban interfaces (Wyse et al. 2016; Cui et al. 2019; Depietri and Orenstein 2019).

Green firebreaks, comprising multiple low-flammability species from groundcover to canopy, are increasingly being implemented, particularly in China, which has a long history of this means of fire suppression (Cui et al. 2019). Over 364,000 km of green firebreaks were planted in China before 2016, and a further 167,000 km was planned for construction before 2025. Carefully planned and planted green firebreaks (Figure 5) are effective, long-term, low-cost tools for fire suppression, which complement more traditional approaches, such as man-made firebreaks (Cui et al. 2019).

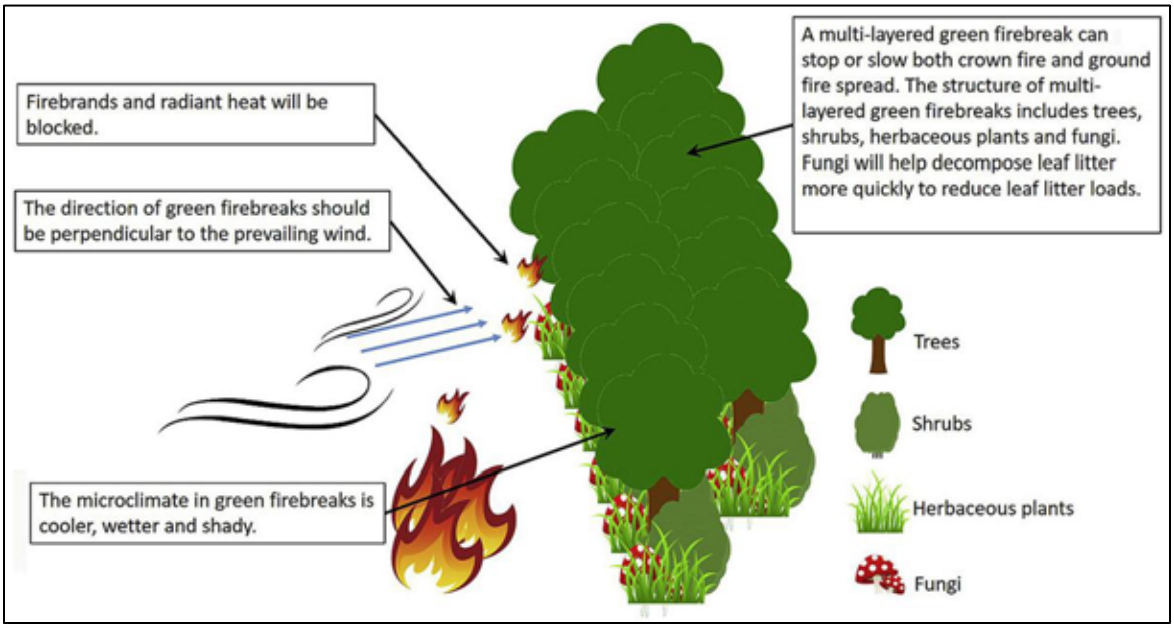


Figure 5: Properly constructed green firebreaks, with a multi-layered structure and closed canopy, are effective, long-term, low-cost tools for fire suppression (diagram from Cui et al. 2019)

Research in China shows that properly constructed green firebreaks with a diversity of low-flammability species forming a multi-tiered forest structure with a closed canopy, planted perpendicular to the predominant wind direction, are more effective than conventional fire breaks. Green firebreaks are particularly effective when used in conjunction with conventional natural and man-made firebreaks, e.g., ridges, rivers, gullies, previously burned areas, or bare soil. Generally, a width of at least 10 – 12 m is recommended for green firebreaks, with up to a 60 m width on steep slopes, as fire travels more quickly uphill (Cui et al. 2019).

The effectiveness of green firebreaks largely depends on the selection of suitable plant species, i.e., they have low flammability (Wyse et al. 2016; Cui et al. 2019). This means that they are fire-resistant, but not necessarily fire-proof. All vegetation will burn if conditions are very dry and if fires are hot enough and fanned by winds, but low-flammability species do not readily ignite and will slow and possibly stop the progress of fires (Wyse et al. 2016; Fire & Emergency New Zealand 2020a,b).

Wyse et al. (2016) measured the flammability of 50 indigenous and 10 exotic tree and shrub species found across a broad range of habitats in New Zealand. With a few exceptions, shoot flammability was found to be strongly correlated with expert opinions of New Zealand fire managers (Fire & Emergency New Zealand 2020a,b). Wyse et al. (2016) determined that the most flammable species was the invasive introduced gorse (*Ulex europaeus*), the only species they ranked as having very high flammability. The next most flammable was manna gum *(Eucalyptus viminalis),* also an exotic species. (*Eucalyptus* species mostly have high to very-high flammability).

Four native species - kumarahou*,* rimu *(Dacrydium cupressinum),* tawhai (silver beech *Lophozonia menziesii)*, and mānuka were next in rank of flammability. However, rimu and silver beech naturally occur in relatively wet habitats that have a low risk of wildfires (Wyse et al. 2016). Kumarahou is found along roadside edges and in early to mid-successional coastal and lowland habitats and is not commonly found in large dominant stands.

Of the species identified as very-highly or highly flammable by Wyse et al. (2016) and others, the most significant species in terms of dominating landscapes, and therefore posing a high fire risk, are gorse and mānuka. Eucalypt and Douglas-fir plantations also pose a relatively high fire risk. Radiata-pine, which is grown in extensive plantation monocultures throughout much of New Zealand, was assessed as having moderate flammability (Wyse et al. 2016). Scope exists to establish green firebreaks as part of management practices for mānuka plantations and exotic plantation forestry.

Highly flammable plants generally have the following characteristics - fine, dead material contained within the plant, such as dry twigs and leaves; volatile waxes, terpenes or oils; gummy, resinous sap with a strong odour; aromatic leaves; and loose or papery bark. In contrast, species with low flammability have the following characteristics - moist, supple leaves, little dead-wood or dry material accumulating within the plant, watery sap that does not have a strong odour, and low levels of resin (Wyse et al. 2016; Fire & Emergency New Zealand 2020a).

In creating green firebreaks, it is important to select species with low flammability that are suitable for the area, with native species ecosourced (Tane's Tree Trust 2020). Some native species have high to moderate flammability, but many native species have low flammability, e.g., kawakawa, lancewood *(Pseudopanax crassifolius)*, large-leaved *Coprosma* (e.g., karamu and taupata), marbleleaf *(Carpodetus serratus)*, five-finger *(Pseudopanax arboreus)*, kapuka (broadleaf, *Griselinia littoralis*), puka *(Griselinia lucida),* kohekohe *(Dysoxylum spectabile)*, fuchsia, karaka, hangehange *(Geniostoma ligustrifolium)*, kowhai *(Sophora microphylla)*, mapou (*Myrsine australis)*, harakeke (flax) and poroporo *(Solanum aviculare)* (Wyse et al. 2016; Fire & Emergency New Zealand 2020b). Many of these species are available from native plant nurseries while others will naturally regenerate if there is a local seed source.

Fast-growing native plants with low flammability can be useful in quickly establishing cover, such as large-leaved *Coprosma* species, broadleaf, marbleleaf, five finger, harakeke, and hangehange. Canopy or sub-canopy species can be included in the initial mix or planted later, e.g., kapuka, mapou, kohekohe, fuchsia and karaka. Matching species to microclimates is also important, such as moist gulley (e.g., kawakawa or harakeke) or drier ridge (e.g., lancewood).

Another strategy is to encourage natural regeneration that includes low-flammability species, e.g., kawakawa and hangehange in understorey tiers, and hangehange and poroporo along forest edges.

Green firebreaks with a diverse range of native species also provide other NTVs, such as biodiversity enhancement, pollination services, and cultural values (Wyse et al. 2016; Cui et al. 2019; Tane's Tree Trust 2020). And they can be a tool to aid natural succession (Tane's Tree Trust 2020). Birds are likely to bring in a range of additional species, some of which may not be in the low flammability category, but the resulting complex forest is likely to be far more resistant to fire than monocultural plantations of moderately or highly flammable species.

Healthy native bush is quite resistant to fire in normal circumstances because the understory is thick with shrubs, ferns, seedlings, saplings, lianes, epiphytes, mosses and liverworts. A microclimate of cool, moist air is created by shade and evapotranspiration from the multiple layers of vegetation (Tane's Tree Trust 2020). The moist environment provides a good habitat for fungi, which help decompose leaf litter more quickly, reducing potential fuel for wildfires (Cui et al. 2019).

Fire-regulating ecosystem services can be valued in economic terms by measuring the avoided damage cost, i.e., the cost society would incur if fire damages were not avoided (Depietri and Orenstein 2019). However, loss of human life and biodiversity is ethically and logistically difficult to quantify in economic terms. Regardless, risk reduction, via improved fire regulating ecosystem services, requires active ecosystem management (Depietri and Orenstein 2019).

4.2.10 Flood protection and green infrastructure

Forests and wetland complexes are particularly important in an era of climate change, as they help moderate the impact of severe weather events (Blaschke et al. 2008; Forest Research 2010; Meurk et al. 2013; PCE 2016; Ruckelshaus et al. 2016). Hillsides denuded of forest cover shed more water during intense rainfall events, leading to greater flood events downstream, damaging downstream communities and ecosystems (Brauman et al. 2007; Duncan and Woods 2013; Awatere et al. 2018).

Forest in New Zealand may intercept between 23% and 42% of rainfall, depending on the type of forest (Duncan and Woods 2013). Riparian vegetation can play an important role by reducing water directly flowing into waterways, as well as promoting infiltration. When land is deforested, run-off from the land increases markedly, subsequently increasing floods and low flows. When mature pine plantations replace pasture, flood peaks may decrease by up to 80% (Duncan and Woods 2013).

Urban forests and wetlands help moderate the impact of severe weather events (Forest Research 2010; Meurk et al. 2013). Restoration of vegetation in urban areas provides environmental services related to the hydrological cycle, such as flood alleviation and protection of water quality; this is known as green infrastructure (Forest Research 2010). Hard surfaces and lack of natural vegetation reduce interception and ground infiltration of precipitation in urban areas. This increases the speed of run-off and the risk of flooding. Green infrastructure counteracts this, taking pressure off stormwater systems (Forest Research 2010).

Green infrastructure is created by either strategically retaining natural vegetation in urban planning, or by planting trees and restoring wetlands, as opposed to creating manmade infrastructures. It is effective, economical, and has many other benefits that enhance quality of life in urban areas (Forest Research 2010). These natural systems often perform more effectively and efficiently than manmade 'hard' infrastructure solutions, and the overall cost can be much lower (Auckland Council 2019).

100% PURE NEW ZEALAND EXPERIENCE

Socioeconomic, cultural and spiritual services

4.3 Socioeconomic, cultural and spiritual services

"New Zealand's natural environment is part of its cultural identity and a pillar of its economic growth, but it can't be taken for granted" (p. 2, Simon Upton, OECD Environment Director, OECD 2017b).

Socio-cultural and spiritual ecosystem services are defined as "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (p. 40, Millennium Ecosystem Assessment 2005). These types of values are difficult to quantify because they have no direct material benefits, i.e., the "challenges in valuing the invaluable" (p. 57, Small et al. 2017). For instance, many New Zealanders would regard a kauri forest or a tuatara *(Sphenodon punctatus)* as 'priceless' (Patterson and Cole 2013).

Rather than a monetary value, per se, the socio-cultural approach to valuation (Scholte et al. 2015; Felipe-Lucia et al. 2015), as described above, may be appropriate for quantifying cultural and spiritual services. In the New Zealand context, Lyver et al. (2017a) identified community-based indicators and metrics from a te ao Māori perspective, for monitoring forest health and community well-being, and mapping ecosystem services in native forest (Lyver et al. 2017b).

Trees are important for human well-being. At the time of writing this review, there were very few studies quantifying human health benefits associated with New Zealand's forests. Nevertheless, international research suggests that the aggregated benefits of forests for human well-being are significant (Hall 2016). Nilsson et al. (2011) edited a book on 'Forests, Trees and Human Health and Well-being', which provides an analysis of international research largely based in Europe and North America. It includes epidemiological evidence of the health benefits of trees and green space, including mental health and spiritual well-being.

New Zealand's forests provide general amenities and ambient environments for recreation and tourism, and they have significant spiritual and cultural value (MPI 2015). In the book 'Ecosystem Services in New Zealand', edited by Dymond (2013), recreational and tourism values were identified for both native forests and exotic plantation forests (Clough 2013; King et al. 2013; Swaffield and McWilliam 2013; Yao et al. 2013). New Zealand has an international reputation as a 'green' country, both as a tourist destination and a producer of natural, safe food (Kaefer 2014; OECD 2017a). Forests provide environmental services (as described above), which are vital to maintaining this international reputation (MPI 2015; Nixon et al. 2017, OECD 2017a).

An increasing focus on sustainability has emphasised the importance of local interconnections between community, ecosystems, and the economy (Swaffield et al. 2003). There are links between environmental services, cultural and spiritual services, and non-timber forest products. This includes, for instance, the role of forests in protection and maintenance of water quality. Poor water quality results in reductions in enjoyment of recreational activities such as boating, swimming, and fishing; and the loss of cultural values such as access to natural resources, including traditional food gathering; and economic costs for sectors dependent on clean waterways and distinctive New Zealand landscapes, such as tourism, and associated loss of political and commercial reputations and social licence to practice due to fallout associated with water pollution.

Employment opportunities also need to be factored in. Forestry work, forest-based livelihoods, and industry based on native forest species are important to local economies. And how the benefits derived from the existence of forests and their management accrue to people living in and around them is also important. Forests need to be socially and culturally beneficial to contribute to sustainable development.

There is evidence for land-owners' recognition of the importance of cultural and spiritual services provided by forests in a recent rural survey. In Manaaki Whenua's 2019 Survey of Rural Decision Makers, non-foresters were asked for their reasons for planting trees in the near future (Stahlmann-Brown 2019). Interestingly, the most popular reasons were non-monetary – with aesthetic-landscape values, personal well-being/spiritual/cultural values, and kaitiaki/guardianship among the most popular reasons for planting trees.

This reiterates earlier conclusions drawn from a report published by the Parliamentary Commissioner for the Environment (PCE) in 2002 - *Weaving Resilience into our Working Lands: future roles for native plants on private land*. Submitters to a discussion paper variously expressed personal relationships with native plants, i.e., "It is the social and cultural values that land-owners associate with native plants that are most often cited as the reason for retaining or increasing their presence" (PCE 2002).

NTVs under this category are described under the following subcategories:

- Cultural and spiritual values associated with native forests;
- native forests and tourism, including ecotourism;
- kaitiakitanga and conservation of native species;
- outdoor recreation;
- wild foods, hunting and fishing;
- New Zealand landscapes, native forests and aesthetic values;
- Native trees and human well-being in urban areas;
- forest-based livelihoods and training opportunities; and
- international branding, political and commercial reputations, and social licence to practice.

4.3.1 Cultural and spiritual values associated with native forests

Human cultures, religions, spiritual and cultural values, language, knowledge systems, social interactions, and amenity services have been influenced and shaped by our ecosystems (Millennium Ecosystem Assessment 2005). Natural ecosystems have inspired visual arts, songs, drama, dance, design, and fashion for millennia. Loss of natural ecosystems due to intensification of land use and urbanisation has significantly weakened the linkages between ecosystems and cultural diversity and identity, negatively impacting the cultural and spiritual fabric of society (PCE 2002; Millennium Ecosystem Assessment 2005).

Native forests are of significant cultural importance to New Zealanders and are a critical component of our national identity (PCE 2002; Dymond et al. 2014, MPI 2015; Ministry for the Environment & Stats NZ 2019). Outdoor activities and hunting and gathering wild food are a traditional part of New Zealand culture, as described above. The environmental services provided by native forests also have an important influence on cultural services, particularly regarding water quality and provision of habitat for native biodiversity. "Poor water quality reduces cultural health" and "The biodiversity of Aotearoa New Zealand is essential to our culture, identity, and well-being" (p. 13, and p. 71, respectively, Ministry for Environment and Stats NZ 2019). And there are many culturally important non-timber forest products (NTFPs) as described above.

However, these cultural and spiritual services are not easily quantified in economic terms.

As mentioned earlier, the socio-cultural approach to valuation (Scholte et al. 2015; Felipe-Lucia et al. 2015) may be more appropriate for quantifying cultural and spiritual services rather than trying to determine a monetary value. In the New Zealand context, Lyver et al. (2017a) identified community-based indicators and metrics from a te ao Māori perspective for monitoring the health of native forest and community well-being, based on interview narratives through a series of workshops. Ecosystem services for the native forest were also mapped, across four biocultural themes identified by Tuawhenua Māori, in central Te Urewera, New Zealand (Lyver et al. 2017b).

A survey of forestry stakeholders demonstrated that there were inherent cultural differences in how stakeholders value forest ecosystem services that soils support (Coker et al. 2019). The authors concluded that cultural views must be understood and integrated to reflect the needs of all stakeholders.

Māori traditionally have a holistic view and deep spiritual connection with the environment (Harmsworth and Awatere 2013; OECD 2017a; Walker et al. 2019). As with other indigenous cultures, there are clear links between healthy ecosystems (with greater life-supporting capacity) and people's cultural and spiritual well-being (Harmsworth and Awatere 2013; Ministry for the Environment & Stats NZ 2019). The holistic Māori world view sits comfortably with the holistic concept of ecosystem services: "Māori aspirations and well-being are interdependent on ecosystems and ecosystem services" (p. 274, Harmsworth and Awatere 2013). In te ao Māori (the Māori world), people care for ecosystems (manaaki whenua) and ecosystems care for people (manaaki tangata) (Dymond et al. 2014). The concept of taiao - the earth, sky, air, water and all life within these realms – implies that all elements are interdependent.

In many parts of New Zealand, Māori have had to adjust to the loss of large areas of native forest, culturally significant flora and fauna, traditional food sources, and their traditional way of life, which negatively impacts on cultural values and well-being.

A revival of interest is occurring in traditional Māori knowledge of native forest and its fauna and flora (MPI 2015; OECD 2017a). Notable natural resources are viewed as taonga (treasured things). A Waitangi Tribunal report (Wai 262) documents the fundamental importance of treasured native flora and fauna species to modern Māori in terms of their identity and kaitiakitanga (environmental guardianship or stewardship) (Waitangi Tribunal 2011). This includes plant species used in rongoā (traditional healing) and traditional crafts, as described above in the section on non-timber forest products. Accessibility to these resources is recognised as being important for fulfilling Māori concepts of health and well-being (McGowan 2000, cited in Meurk et al. 2013). Rongoā Māori has recently seen a revival and scientific studies have supported much of the traditional knowledge about the medicinal use of plants for improving health and well-being (Jones 2007; Dodd and Ritchie 2007; Roberts et al. 2015).

Ngā Whenua Rāhui is a programme that began operating in 1991, helping to protect the natural integrity of Māori land and preserve mātauranga Māori so that the values, stories and history associated with natural taonga (treasures) are not lost to the world (Department of Conservation 2018b). Ngā Whenua Rāhui funding (administrated by the Department of Conservation) is available to support the protection of indigenous ecosystems on land owned by Māori. The principles of the fund are geared towards the owners retaining tino rangatiratanga (ownership and control). In its kaupapa and role, Ngā Whenua Rāhui is reaffirming the bond between tangata whenua and the land - Ki te āwhina i te tangata whenua ki te tiaki i ngā ngahere motuhake-ā-Tāne me ērā atu wāhi motuhake i runga i ōna ake whenua (Department of Conservation 2018b).

Ngā Whenua Rāhui reflects the importance of the cultural and spiritual connection of Māori to the land (Department of Conservation 2018b). Criteria for Ngā Whenua Rāhui funding include:

- the area has strong cultural, spiritual and symbolic significance to whanau/hapu/iwi;
- it is an important source for food, cultural materials and rongoā; and
- the area is traditionally known for taonga species.

Durie (1999) describes the strong link between human health and the surrounding environment under **the concept of waiora**, i.e., human well-being and the natural environment are strongly interconnected. Durie emphasises the importance of striking a balance between development and environmental protection for the benefit of human well-being:

> "… health promotion must take into account the nature and quality of the interaction between people and the surrounding environment. It is not simply a call for a return to nature, but an attempt to strike balance between development and environmental protection and recognition of the fact that the human condition is intimately connected to the wider domains of Rangi and Papa" [the sky father and earth mother, respectively] (p. 3, Durie 1999).

Durie states that this involves environmental protection, so that "water is free from pollutants, earth is abundant in vegetation" and "opportunities are created for people to experience the natural environment" (p. 3, Durie 1999).

In recent years, Mātauranga Māori (the traditional Māori knowledge base and philosophy) has become increasingly integrated into natural resource management in New Zealand, which was previously based on Western knowledge and paradigms (Harmsworth and Awatere 2013; MPI 2015; Roberts et al. 2015; OECD 2017a; Awatere et al. 2018).

The following principles are particularly relevant to NTVs:

- **The principle of kaitiakitanga** (stewardship) defines the important role of tangata whenua (people of the land) as temporary guardians of the environment with the responsibility to maintain it for future generations (Roberts et al. 2015; OECD 2017a; Ministry for the Environment & Stats NZ 2019). Kaitiakitanga acts as a cultural bridge between Māori and their kin (based on whakapapa) in the environment (Walker et al. 2019). It is how Māori manage the natural environment based on Māori world views.
- **The principle of whanaungatanga** (community connectivity) refers to how well-being and social prosperity are improved through connection to, and interactions with, the natural environment. This includes the abundance and access to rongoā and mahinga kai (traditional food gathering places) and the ability to express manaakitanga (fulfil obligations as a host) (Scheele et al. 2016; Ministry for the Environment & Stats NZ 2019). Freshwater and marine fisheries benefit from riparian zones in native forest, as described above in the section on environmental regulating services.
- **The principle of tūrangawaewae** (sense of place and identity) refers to how well whānau, hapū and iwi well-being is reflected in their home environment (Scheele et al. 2016; Ministry for the Environment & Stats NZ 2019).
- **The principle of whakapapa** (genealogical lines) implies a deep connection to the land and environment, with all living things sharing genealogical descent. Engagement with living things is likened to visiting kin (Walker et al. 2019).

These principles have become increasingly part of the wider New Zealand ethos.

Māori have taken timber for carving, plant materials for weaving, and feathers of indigenous birds for traditional purposes from native forests (and their associated catchments) for hundreds of years (Waitangi Tribunal 2011; MPI 2015). No data are available regarding the extent of these traditional uses of forest products - in a national context they are limited, but regarded as culturally important (MPI 2015). Traditional foods that have been hunted and gathered have recently become a focus for contemporary New Zealand cuisine, as described below.

Iwi (Māori tribes) have recently become more actively involved in restoration of their native forests and wetlands, helping them to connect more deeply with their rohe (tribal lands) and regain their identity and mana (honour, respect and authority) (MPI 2015; Roberts et al. 2015; Allen 2016). For example, Whirinaki Forest is regarded as a taonga by Ngāti Whare, a central North Island iwi (tribe) who are the kaitiaki (guardians) of this internationally renowned forest. Although Whirinaki contains some outstanding examples of dense podocarp forest, grading into beech forest at higher altitudes, much of the lowland forest was logged, cleared and converted into exotic plantations. A timber mill was established in Minginui in 1977, initially to process native timber from Whirinaki, and then radiata-pine logs from exotic plantations (Beveridge et al. 2004).

As part of a Treaty of Waitangi settlement, signed in 2009, the Whirinaki Regeneration Project was initiated to restore 640 hectares of exotic forestland adjacent to Whirinaki Forest Park, back to native forest (Allen 2016; Department of Conservation 2017). Ngāti Whare wants to re-establish the lowland podocarp forests that were largely dominated by tōtara (Allen 2016; Department of Conservation 2017). Forest plantation land was returned to Ngāti Whare with an agreement to progressively re-establish native podocarp-dominated forest as the exotic plantations are harvested (Allen 2016). As part of the settlement, the New Zealand government apologised for past injustices and acknowledged the park was integral to the cultural identity and well-being of Ngati Whare. The settlement provided for a joint Ngati Whare and Crown regeneration project that will ultimately enhance the value of Whirinaki Conservation Park, and adjacent areas, for all New Zealanders, and provide socio-economic benefits to the local Te Whāiti-Minginui community (Allen 2016; Department of Conservation 2017).

The project vision is to "enhance the mauri [life force] of the Whirinaki Forest and the mana of Ngāti Whare" (p. 6, Allen 2016). This vision takes a holistic view of the native forest landscape and acknowledges the aspirations of Ngāti Whare, as tangata whenua for Whirinaki (Allen 2016). The native plant nursery project is described below in the section on employment based on NTVs.

Indeed, for all New Zealanders, our identity suffers when native species become locally extinct, natural ecosystems are degraded, and recreational opportunities and connections with nature are lost (PCE 2002; Ministry for the Environment & Stats NZ 2019). New Zealanders tend to value and culturally identify with indigenous flora and fauna, as opposed to exotic species (Meurk et al. 2013; Roberts et al. 2015; Lyver et al. 2017b; Ministry for the Environment & Stats NZ 2019). Environmental groups fought hard in the 1960s and 1970s to protect old-growth native forests, as described at the beginning of this review. There is also evidence that environmental volunteering and involvement in community activities in natural areas benefits health and well-being (e.g., Townsend 2006; Forest Research 2010; Roberts et al. 2015).

There is evidence from international studies on the positive effects of natural areas on human health and well-being, based on controlled experiments that compare the differences in people's responses after exposure to natural and non-natural settings. This research is described more fully below, in the section on native trees and human well-being in urban areas.

4.3.2 Native forests and tourism (including ecotourism)

The natural environment is integral to tourism in New Zealand: "… it is no exaggeration to say that the natural environment is the asset on which the New Zealand tourism industry is built" (p. 12, Speden 2008). The forest estate is a significant component of the tourism industry (MPI 2015). Forests also play an important part in the 'clean, green', '100% pure' branding for New Zealand – particularly with regards to providing the ambient environment for tourism activities, environmental services for water quality, scenic values and amenity functions.

The tourism industry has been one of the top economic drivers of the New Zealand economy, prior to the COVID-19 pandemic. For the year ended March 2018, total tourism expenditure was over NZ$39 billion, generating a direct contribution to GDP of NZ$15.9 billion, or 6.1% of GDP (Stats NZ 2018). For the year ended March 2019, total tourism expenditure was $40.9 billion, an increase of 4.0% ($1.6 billion) from the previous year, and generated a direct contribution to GDP of $16.2 billion, or 5.8% of GDP (Stats NZ 2021). Tourism was New Zealand's biggest export industry before the COVID-19 pandemic. The tourism industry has also been a major means of employment in New Zealand, directly employing 8.0% of the workforce before the pandemic (Stats NZ 2018; Tourism New Zealand 2019; Stats NZ 2021) and is likely to be significant for employment again, once international tourism recovers.

It is very difficult to determine the economic contribution of NTVs of native forests to the tourism industry. While it is acknowledged that the benefits provided by native species (Roberts et al. 2015; Ministry for the Environment & Stats NZ 2019) and exotic forest plantations (Yao et al. 2013, 2014, 2017) underpin many recreational and tourism ventures, particularly ecotourism, there has been limited measurements of these benefits, particularly regarding native species (Roberts et al. 2015; Ministry for the Environment & Stats NZ 2019).

Before the COVID-19 pandemic, nature-based tourism (ecotourism) activities were among the principal attractions for overseas and domestic visitors, creating significant employment in local communities (MPI 2015). Many ecotourism ventures have a strong conservation ethos and provide natural heritage education. Nature-based activities and pleasure in supporting conservation efforts are culturally and spiritually important to many New Zealanders. In a 2015 survey of the New Zealand public on walking access, 20% of survey respondents had visited wildlife areas or nature reserves on their most recent outdoors activity (Colmar Brunton 2015).

A large proportion of ecotourism ventures in New Zealand are based in native forests, including the following examples:

- **Canopy Tours**, near Rotorua - a zipline tour through native forest that also funds an extensive conservation project, based largely on pest control to protect the native plants and animals that live in the forest.
- Fenced eco-sanctuaries such as **Sanctuary Mountain Maungatautari** in the Waikato region; **ZEALANDIA**, an urban eco-sanctuary in Wellington; and **Orokonui Ecosanctuary**, which is close to Dunedin.
- **Foris Eco-tours**, an outdoor guiding company that takes nature tours in natural areas, including Whirinaki Forest and Sanctuary Mountain Maungatautari.

All of these ventures have a strong conservation ethos and enable people to enjoy interactions with nature while providing education and opportunities for participation in biodiversity conservation. They demonstrate that viable business models can be based on biodiversity conservation values and ecotourism. The visitor numbers demonstrate willingness-to-pay for biodiversity conservation and experiencing nature, plus the large number of people volunteering or paying for memberships to the three ecosanctuaries, demonstrates the depth of community support. Visitor and volunteer numbers and admissions costs provided below are from before the COVID-19 pandemic.

Note that there are many ecological sanctuaries in New Zealand where there is ongoing pest control, but only a few are fenced to exclude predators – examples of the latter are described below.

ZEALANDIA was the world's first fully-fenced urban ecosanctuary (ZEALANDIA 2018). The vision has been to restore forest and freshwater ecosystems in a Wellington valley to resemble the pre-human state as closely as possible. New Zealand flora and fauna evolved in the absence of mammalian predation and, therefore, have been vulnerable to introduced mammals. Many native species have become extinct since the arrival of humans and associated pests, and biodiversity losses are continuing today through predation and habitat fragmentation (Brown et al. 2015; MPI 2015; OECD 2017a; Ministry for the Environment & Stats NZ 2019). The challenge now is to halt this decline and predator-free wildlife sanctuaries offer one solution.

ZEALANDIA is managed by Karori Sanctuary Trust, a not-for-profit community-led organisation (ZEALANDIA 2018). The establishment of the Trust in 1995 was a radical idea and a breakthrough in the conservation and recovery of native wildlife on mainland New Zealand. An 8.6-km pest-proof fence was erected to protect 225-ha of native forest. Introduced pests were eradicated and the sanctuary was declared free of all mammalian predators except mice in June 2000. Eighteen species of native wildlife have been re-introduced back into the area, six of which had been absent from mainland New Zealand for over 100 years (ZEALANDIA 2018).

In the 2018/19 year; ZEALANDIA had 138,141 visitors, including 11,727 engaged through educational programmes; 608 volunteers helped deliver conservation and community goals (Karori Sanctuary Trust 2019). In 2019, general admission for an adult was $21.00, with tours varying from $55.00 to $85.00 for non-members and $27.50 to $42.50 for members.

Sanctuary Mountain Maungatautari is based on the ZEALANDIA model but covers a much larger area (Kaval 2004). It is located between Rotorua and Hamilton, and is the largest and most ambitious community restoration project in New Zealand (Sanctuary Mountain Maungatautari 2018). It is a 3,400-ha mainland ecological island sited in old-growth forest on an ancient volcano, and includes rolling Waikato lowland forest through to montane forest. The Maungatautari Mountain was first made into a reserve in 1912 after a wildlife survey found the forest to be a highly significant habitat. Nearly 100 years later, a survey of 2000 Waikato residents found a favourable majority were supportive of protecting Maungatautari with a pest-proof fence and restoring the area for visitors. A year later, the Maungatautari Ecological Island Trust (MEIT) was formed (Sanctuary Mountain Maungatautari 2018).

Many of the local community, including land-owners, local iwi and local residents, have a strong emotional connection with the mountain and were keen to work together to protect it (Sanctuary Mountain Maungatautari 2018). The mountain is protected by a 47-km, pest-proof fence (the world's longest) that keeps the forest free from mammalian predators, allowing it to regenerate and provide a flourishing, safe habitat for endangered or threatened native species such as kaka, hihi or stitchbird *(Notiomystis cincta)*, takahe *(Porphyrio hochstetteri)*, kokako, native parakeets, giant weta *(Deinacrida* species), popokatea or whitehead *(Mohoua albicilla)*, kiwi and tuatara. Plans are underway to introduce more endangered species such as kakapo *(Strigops habroptilus).* Educational programmes are offered, which are popular with schools (Sanctuary Mountain Maungatautari 2018, 2019). In 2019, the cost of tours varied from $33 to $270 per adult, depending on the type of tour.

Orokonui Ecosanctuary is an ecosanctuary just north of Dunedin, New Zealand, managed by the Otago Natural History Trust. It is based on the ZEALANDIA model. A predator-exclusion fence encloses 307-ha of coastal Otago forest, pests have been removed, habitat enhanced with weed control and planting, and many rare and endangered species re-introduced (Orokonui 2018a). There is also evidence that forest health and bird numbers are improving outside the fence (Tanentzap and Lloyd 2017). For the year ending 31 March 2018, there were over 12,000 hours of volunteer time supporting work programmes and over 6000 school students participated in Orokonui's education programmes. There was a net surplus after expenses in the 2017/18 and 2018/19 tax years (Orokonui Ecosanctuary 2018b; Orokonui Ecosanctuary 2019). In 2019, the cost of tours varied from $20 to $50 per adult, depending on the type of tour.

Rotorua Canopy Tours Ltd is another successful ecotourism business. It has been operating since 2012 in Dansey Road Scenic Reserve, close to the major tourism centre of Rotorua. The main business operation is a guided zipline tour within the canopy of the old-growth native forest - it tells the story of the ecological restoration project and educates visitors about New Zealand's flora and fauna (Martin 2017; Canopy Tours 2018). Conservation and environmental awareness are a strong focus of the business. Most of the forest is rimu-hardwood forest of high ecological value. Some of the rimu and miro (*Prumnopitys ferruginea*) are estimated to be over 1000 years old (Canopy Conservation Trust 2018).

Issues with pests were apparent when the business was initiated (Martin 2017; Canopy Tours 2018). The company made a commitment to clearing the forest of predators, but it turned out to be a much bigger operation than initially anticipated. The Canopy Conservation Trust was subsequently formed with the support of the Department of Conservation, with the main focus on pest eradication. Part of each visitor's participation fee is allocated to the Canopy Conservation Trust, which uses the funds to implement conservation activities within the Reserve (Canopy Tours 2018). Native birds and other species (including native skinks and bats) have been steadily returning in good numbers (Martin 2017).

In 2016, Canopy Tours won the highest accolade in New Zealand's tourism industry - the Air New Zealand Supreme Tourism Award, as well as two other awards (Rotorua Chamber of Commerce 2016). Each year, visitor numbers have been increasing rapidly and outstanding environmental outcomes have been acknowledged at the Dansey Road Scenic Reserve. In November 2016, Canopy Tours was ranked the top outdoor activity in New Zealand on TripAdvisor (Rotorua Chamber of Commerce 2016). In 2019, the cost of the Canopy Tours zipline was $149 or $219 per adult, depending on the tour, with 100 to 300 people per day on tours during the peak summer months (November to February) and about 20 to 100 people during the winter months (Canopy Tours, pers. comm.) before the COVID-19 pandemic.

4.3.3 Kaitiakitanga and conservation of native species

"The biodiversity of Aotearoa New Zealand is essential to our culture, identity, and well-being" (p.13, Ministry for the Environment & Stats NZ 2019).

In this context, conservation is defined as a process for maintaining and protecting certain values including indigenous biodiversity (PCE 2002). Kaitiakitanga, as described above, is defined as guardianship or stewardship of natural resources.

Native forests are critical for the survival of most of New Zealand's native fauna, particularly fruit and nectar feeders, as explained above (in the section on habitat provision and biodiversity values). Most of New Zealand's native frugivorous and honey-eating bird and lizard species are co-adapted to native fruit- and nectar-bearing trees and shrubs (Swaffield et al. 2003).

Losing biodiversity affects people's sense of belonging and connection to their environment (Ministry for the Environment & Stats NZ 2019). New Zealanders call themselves 'Kiwis' after a flightless endemic bird, and proudly display the native silver fern (*Alsophila dealbata*) as a national symbol, indicating the importance of native (and particularly endemic) species for our national identity. Recreation opportunities and connections with nature are also affected by loss of biodiversity, particularly the extinction of endemic species (Meurk et al. 2013; Ministry for the Environment & Stats NZ 2019).

Kaitiakitanga (guardianship of natural resources) is an important cultural value linked with the conservation of native species (Walker et al. 2019).

Meurk et al. (2013) and Roberts et al. (2015) discuss, within the New Zealand context, the importance of involvement in ecological restoration and conservation efforts, for personal and community well-being. Roberts et al. (2015) note that thousands of New Zealanders volunteer every year for biodiversity restoration projects; and the collective action needed to protect natural ecosystems is a unifying force in communities. Blaschke (2013) suggested that volunteer ecological restoration programmes may be important for increasing health and well-being in New Zealand society.

“Ecological restoration indeed is often as much about restoring communities and spirit as it is about ecology” (p. 268, Meurk et al. 2013).

The number of visitors and prices paid for ecotourism packages provide an indication of the value of conservation, as discussed above. Also, research in New Zealand has provided estimates of the value of species conservation (Yao and Kaval 2009; Yao and Kaval 2010; Yao et al. 2013; Roberts et al. 2015; Ministry for the Environment & Stats NZ 2019).

Yao and Kaval (2009) conducted a two-stage phone-mail survey and a focus group to determine how willing New Zealanders were to participate in biodiversity enhancement, which involved the planting of native and exotic tree species. Of the 729 observations, 57% of the respondents were willing to volunteer to plant trees in their neighbourhood, indicating that the spirit of volunteerism in conservation efforts is relatively high in New Zealand.

The two most preferred alternatives for planting stock, selected by respondents in a choice modelling exercise, were to have purely native trees or a mixture of native and non-native tree species. The least preferred option was purely exotic (non-native) tree species. Yao and Kaval (2009) also found that respondents in northern regions of New Zealand (which are more highly urbanised) were more supportive of biodiversity enhancement on their properties, compared with those from southern regions. Also, many respondents appeared to need advice and subsidised trees to encourage them to support biodiversity enhancement through tree planting (Yao and Kaval 2009).

Biodiversity enhancement in New Zealand's exotic plantation forests has been measured using socioeconomic and spatial determinants of willingness-to-pay. A discrete choice method was used in 2010 to test if the public would be willing to financially support a proposed native falcon conservation programme in pine plantations in Kaingaroa Forest (Yao and Kaval 2010; Yao et al. 2013). About 219 randomly selected individuals provided valid responses to a survey questionnaire. Results suggested that a typical respondent would be willing to pay about NZ$14 per year for 5 years to help sustain the falcon population in radiata-pine plantations (Yao and Kaval 2010).

Similarly, a survey of more than 1500 people showed that the average New Zealand household would willingly pay approximately NZ$264 (minimum of NZ$126 to a maximum of NZ$693) per year for 5 years to conserve key identified native species in planted exotic forests (Yao et al. 2014).

4.3.4 Forests and outdoor recreation

New Zealand is internationally renowned for its outdoor recreational activities. According to Kaval and Yao (2007), over 75% of local residents and approximately 50% of tourists annually participate in outdoor recreation activities in New Zealand. This includes hiking, walking, tramping, mountain biking, horse trekking, kayaking and other outdoor pursuits. Also, hunting, fishing and wild foods are important cultural services (Dymond et al. 2014), as described below.

Planted and natural forests, particularly the latter, are either directly or indirectly important for most forms of outdoor recreation - they provide much of the ambient environment and the ecosystem services that help protect the natural environment, including waterways. There is a body of international research that has quantified improvements in people's well-being associated with time spent in natural environments. There are also many small to medium-sized enterprises that support outdoor activities and create revenue for the local economy.

According to Clough (2013), natural ecosystems provide the settings for a high proportion of recreation in New Zealand, but the informal nature of that recreation and the limited number of studies in New Zealand means the total economic value is hard to determine. It is even more difficult to quantify the contribution to outdoor recreation of native forests on private land.

In 2015, a survey of walking access showed that for 88% of New Zealanders, spending time in the outdoors was an important part of their life (Colmar Brunton 2015). A large proportion (93%) of respondents had done at least one form of outdoor activity in the past year and 12% of survey respondents participated in tree planting and other conservation activities in 2015, with similar results in the 2011 and 2013 surveys. Short walks on tracks (63 – 64%), hiking or day walks (24 – 26%), mountain biking (15 – 17%) and tramping trips (9%) were also popular activities in the 2011, 2013, and 2015 surveys. Also, 20% of survey respondents visited wildlife areas or nature reserves on their most recent trip. Many of these activities would likely be based at least in part in forested areas.

Forests featured highly when these respondents were asked: "On your last visit to the outdoors for leisure and recreation, what types of areas did you visit?" Public forest or native bush was visited by 53% of the respondents, second only to beaches at 65% (Colmar Brunton 2015). However, there is no indication about the types of forest visited, or whether respondents valued native forest over exotic forest for recreational activities.

In 2007, Kaval and Yao reviewed multiple studies on the benefits of outdoor recreation in New Zealand. They found that most of the studies concentrated on the market value of outdoor recreation (including money spent on fuel, equipment, food, lodging, and guides), but concluded that this is only part of the benefit derived from outdoor recreation. The total economic value includes both market and non-market values, with the latter equating to the net benefit derived over and above anything the participant has paid. Kaval and Yao utilised a meta-analysis approach to determine the non-market benefit of outdoor recreation. There were limited New Zealand studies to draw on at the time, but results showed that non-market benefits from outdoor recreation were over NZ$5 billion NZ dollars annually, exceeding market benefits of approximately NZ$4 billion (Kaval and Yao 2007).

Yao et al. (2013, Table 5, page 71) provided a summary of studies calculating the economic value of cultural ecosystem services in New Zealand forests. The authors also reviewed two studies of recreation in Whakarewarewa Forest that estimated recreational values to be worth NZ$9 million and NZ$28 million per annum. Whakarewarewa Forest is in Rotorua, is largely composed of exotic species, and has high recreational usage. These estimated recreational values exceeded the value of the potential annual timber production from this forest (Yao et al. 2013).

4.3.5 Hunting, fishing, forest foraging and wild foods

Many New Zealanders and overseas visitors participate in hunting and fishing trips. According to a survey, 32% of New Zealanders went fishing and 8% went hunting at least once in 2015 (Colmar Brunton 2015). Planted and natural forests are critical to hunting and fishing as they provide the habitat for game, as well as the ambient environment, and also the ecosystem services that support clean waterways (MPI 2015, Nixon et al. 2017; OECD 2017a).

Hunting, fishing and gathering wild food is a traditional way of life and an important cultural service in New Zealand (Dymond et al. 2014, MPI 2015). Traditional foods, methods and places of food gathering (mahinga kai) remain important to Māori (King et al. 2013; Roberts et al. 2015). The harvesting and consumption of wild foods are increasingly featured in the media. The Hokitika Wildfoods Festival has been an annual event since 1990, which has become increasingly popular. Television broadcasters present wild food programmes, restaurants participate in wild food competitions, and small businesses are selling wild food products (King et al. 2013).

Traditional hunted and gathered foods have recently become a focus for contemporary New Zealand cuisine helping to create a distinct New Zealand food identity (Royal and Kaka-Scott 2013; Tourism New Zealand 2017). The growing profile of indigenous cuisine has created new markets for wild foods, but the value of this market is unknown. The Wildfoods Festival held for the last 30 years in Hokitika on the West Coast has become hugely popular for cuisine and fashion featuring a wide range of animals hunted and fished often from native forest areas.

Māori cuisine and New Zealand's wild foods were celebrated by internationally renowned chef Gordon Ramsay during a visit to New Zealand in 2019 (Robinson 2019).

Recreational hunting has historically been a significant activity in New Zealand, and it continues to be popular (MPI 2015). In 2012, there were estimated to be approximately 40,000 game hunters, who spent about 1.3 million days per year hunting (Kerr 2012, cited in MPI 2015).

Hunting, fishing, trapping and firewood collection are important for household subsistence and maintenance of cultural and familial traditions in many rural areas. Also, many city dwellers enjoy recreational hunting in New Zealand's forests. As mentioned above, investment in 4WDs and other equipment, travel costs and time off work – all provide a measure of the value people place on this type of NTV.

A rural-urban difference in the importance of NTVs was observed in Sweden by Mattsson and Li (1993). NTVs were determined in northern Sweden forests based on on-site consumptive use (berry- and mushroom-picking), on-site non-consumptive use (hiking, camping, etc.), and off-site visual experience. Data were obtained via a mail survey using the contingent valuation method (willingness to pay). Results indicated that aggregated NTVs accounted for a considerable portion of the total forest value. On-site-use values accounted for two-thirds of the aggregated NTVs, while the value of the off-site visual experience accounted for one-third. On-site consumptive use was more valuable to rural people. In contrast, on-site, non-consumptive use was more valuable to urban people.

Yao et al. (2017) estimated the value of recreational hunting among the wider benefits (ecosystem services) provided by the Wenita Forest Estate, the largest planted forest in Otago. Pig hunting is a popular activity in the forest and a price-based valuation technique was used to quantify this, based on an estimation of the value of the game meat. Assuming about 15,000 hectares of the estate are classified as a pig hunting area, the value of pig hunting (based on meat value) was about NZ$15/ha/year (Yao et al. 2017).

4.3.6 New Zealand landscapes, native forests and aesthetic values

Worldwide, people across all cultures and regions generally express an aesthetic preference for natural environments over urban or built ones, but the conversion and degradation of natural environments have diminished these aesthetic values (Millennium Ecosystem Assessment 2005).

Native forests are an important part of New Zealand's spectacular natural landscape, and they are intrinsically part of New Zealand's cultural identity (PCE 2002; Meurk et al. 2013). In Manaaki

Whenua's 2019 Survey of Rural Decision Makers, non-foresters were asked for their reasons for planting trees in the near future (Stahlmann-Brown 2019). The most popular reason was aesthetic-landscape values, which are particularly difficult to objectively quantify. An MPI report recommended using a stated preference survey to determine aesthetic landscape values (Walsh et al. 2017) but there are difficulties in that aesthetic preferences can vary significantly across the population and over time (Swaffield and McWilliam 2013).

There is limited research on aesthetic values in landscapes, from New Zealand and overseas; however, studies consistently indicate that people prefer landscapes that include mountains, natural waterways and forest (Swaffield and McWilliam 2013). Evidence of preference for native forests, rather than exotic plantations in landscapes, is provided by district and regional plans, which identify outstanding natural features and landscapes. Exotic forests are usually excluded from outstanding or significant landscape designations, whereas in contrast, native forests are commonly mapped in many significant landscape designations (Paul Quinlan, pers. comm.). Also, clear-fell harvesting of plantation forests has large aesthetic impacts (Bloomberg et al. 2019).

A study based in the UK examined the value of urban green space for health (Forest Research 2010). The authors reviewed international research on the benefits of green space and found that there was evidence that even the visual presence of green spaces and natural views of trees and natural waterways, such as lakes, is enough to have a positive effect on stress levels, can reduce blood pressure and encourage faster healing in patients following surgery (Forest Research 2010). This may be because trees and water provide resources and shelter, important for the survival of humans; and this subconsciously impacts the human mind and reduces stress (Grinde and Patel 2009).

Tengberg et al. (2012) published a research paper on the cultural ecosystem services provided by landscapes, including assessment of heritage values and identity. It is not written in the New Zealand context, and it does not focus on NTVs in native forests, but it provides insight into valuing some of the more difficult to quantify (but important) non-market ecosystem services. The authors provide a conceptual analysis of cultural ecosystem services and how they are linked to the concepts of landscape, heritage and identity. They discuss how these cultural ecosystem services can be assessed and integrated into spatial and physical planning.

4.3.7 Native trees and human well-being in urban areas

Urban forests provide important environmental services in cities, as described previously, which is important to the physical well-being of residents. This includes improved air quality, provision of shade and reduced urban heat island effect.

Urban forests also provide cultural services such as recreation and education about nature, and spiritual and cultural values that contribute to mental health and well-being (Hartig et al. 2014; Walker et al. 2019), including providing a sense of place and identity (tūrangawaewae). These cultural services are difficult to value economically, but are "valued very highly by most urban residents and contribute significantly to the quality of life and social capital in cities, with consequences for mental well-being, innovation, and economic activity" (p. 254, Meurk et al. 2013).

When the cultural and environmental services of trees in urban areas are aggregated, these benefits can "make a considerable contribution to adaptation and mitigation against climate change, helping climate-proof our towns and cities and their communities, whilst improving people's mental and physical health" (p. 195, Forest Research 2010).

New Zealand is one of the most urbanised countries in the OECD, with 86% of the population living in cities and towns (OECD 2017a). Urbanisation generally diminishes people's connection with nature, negatively impacting physical and mental well-being (Hartig et al. 2014) and cultural connections (Walker et al. 2019).

The rapid urbanisation of Māori over the last 100 years has resulted in a disconnect between mana whenua (Māori with historic and territorial rights) and their tribal areas, their natural environment, and their culture (Durie 1999; Walker et al. 2019). Walker et al. (2019) discuss the impacts of urbanisation on Māori and why the inclusion of tikanga Māori (values and principles) such as kaitiakitanga can improve cultural connection for Māori, and overall well-being through restoring their connection to the environment – while simultaneously improving outcomes in urban ecological restoration. Walker et al. (2021) note that traditional practices like weaving, food foraging, and rongoa harvesting in urban forests support cultural vitality, well-being, and relationships with nature. And lack of access to urban forest is an issue for those in low socioeconomic areas with a low tree canopy cover.

Meurk et al. (2013) noted that while many ecosystem services may be provided equally or occasionally better by introduced tree species in urban settings, it is native forest species that underpin New Zealand's unique sense of place (e.g., silver fern), cultural values (e.g., harakeke), and add to tourism, international obligations and reputation (e.g., conservation of indigenous flora and fauna).

An OECD report on the state of New Zealand's environment, notes that major urban biodiversity initiatives, such as pest-free bird sanctuaries (e.g., ZEALANDIA in Wellington), help protect endangered species while providing city dwellers with easy access to nature. These sanctuaries are largely composed of native forest, providing vital habitat for native species (OECD 2017a). Also, protected 'town belts' in several major cities in New Zealand consist of significant contiguous tracts of urban native forest and significantly contribute to general amenity, recreation and well-being of local residents, providing shade and shelter, and amelioration of noise pollution (Meurk et al. 2013).

Urban trees are highly valued by local residents. A study was undertaken by Vesely (2007) to determine the perceived value of urban trees in New Zealand using the contingent valuation method. Households in 2003 were, on average, willing to annually pay NZ$184 over 3 years to avoid a (hypothetical) 20% reduction in urban trees in their local area. The benefits perceived to be most important were aesthetics, followed closely by having nature in the city, habitat for wildlife, and fresh air - these benefits were rated important or very important by over 80% of respondents. Shade, carbon storage and protection from wind and noise were rated important or very important by 60% to 70% of respondents.

The perceived value of native trees was demonstrated by well-publicised protests in 2020 – 2021, at the Canal Road site in Avondale, Auckland. Despite vigorous protests and multiple arrests (Neilson 2021) the entire grove of 46 mature native trees was felled after the section was sold to developers.

According to Walker et al. (2021) "Urban planning should prioritise the restoration of urban forest by integrating trees into development plans".

Swedish and American researchers (Hartig et al. 2003) provided evidence of the positive effects of natural settings on well-being, including improved attention functioning, emotional gains and lowered blood pressure. Participants in the research were either required to drive to a natural area or were asked to perform a 40-minute cognitive task designed to induce mental fatigue. Participants were then exposed to various environments and activities. Walking in a nature reserve had a more positive impact, including greater stress reduction, than walking in a purely urban setting. Also, even sitting in a room with tree views resulted in a rapid decline in diastolic blood pressure, compared with sitting in a viewless room.

A study based in the UK examined the value of urban green infrastructure for health-enhancing activities such as walking, running or cycling (Forest Research 2010). The authors reviewed international epidemiological studies and found evidence for a positive relationship between green space and population health. This included research showing evidence for the restorative effects of green space on the well-being and development of children, and the mental health and well-being of adults (Forest Research 2010). This was presumed to be due to an increase in exercise and reduction in health issues associated with a sedentary lifestyle, as well as improved mental health and well-being. There is evidence that people living in urban areas tend to experience more stress and have poorer mental health. However, green spaces in urban areas counteract this by providing a restorative environment that helps alleviate stress and mental fatigue. This has important economic implications because a healthy population is more productive (Forest Research 2010).

Ecotherapy, which involves exercise activities in nature, is a recognised treatment programme that utilises the restorative effects of green space to benefit mental health and well-being (Forest Research 2010).

In a study in the USA, Bratman et al. (2015) showed that spending time in nature improves mental health. Participants who went on a 90-minute walk through an urban green space, with scattered oak trees and shrubs, were compared with participants who walked through a nearby urban environment, beside a busy highway. Participants who went on the 90-minute nature walk showed reductions in self-reported rumination, a known risk factor for mental illness, and also decreases in neural activity in an area of the brain linked to risk for mental illness. Those who went on an urban walk did not show these effects. The authors argue that these results suggest that access to natural areas may be vital for mental health in our rapidly urbanising world (Bratman et al. 2015).

Considering the considerable economic burden of mental health illnesses on the economy (RANZCP 2018) and research demonstrating the positive impact that natural areas have on mental well-being and social cohesion, there is good justification for investing in green space in urban areas. A ‘rule of thumb’ for urban forestry and greening has been developed (van den Bosch 2021) and adopted by the IUCN (International Union for Conservation of Nature), i.e., the 3-30-300 rule. The three rules are: (i) three trees visible from every home; (ii) 30% tree canopy cover in every neighbourhood; and (iii) a maximum distance of 300 m to the nearest park or green space for every city dweller.

Various toolkits are available for assessing the cultural values of green space (Forest Research 2010; O’Brien et al. 2017). O’Brien et al. (2017) provide an overview of the cultural ecosystem benefits of urban green space across different European countries. Knowledge gaps were identified, e.g., difficulties in determining monetary values for some cultural services, and a lack of information on the various characteristics of green spaces and how important they are in determining cultural ecosystem benefits.

4.3.8 Forest-based livelihoods and training opportunities

It is difficult to ascertain figures for employment and training opportunities regarding sustainably managed native forests because the available employment data is not categorised in sufficient detail. However, Roberts et al. (2015) and MPI (2015) discuss the importance of natural ecosystems and forests, respectively, for employment opportunities in New Zealand.

There is also limited information on how different types of forests and forestry management practices affect forest-based livelihoods and local economies in New Zealand. However, examples of types of businesses, employment and educational opportunities associated with native forests in New Zealand are described below:

- **Ecotourism**, e.g., Canopy Tours, Sanctuary Mountain Maungatautari, ZEALANDIA, Orokonui Ecosanctuary, and Foris Eco-tours, which are described above. There are also supporting industries associated with ecotourism ventures, such as local accommodation providers generating revenue for the local economy.
- **Industries based on outdoor activities**, e.g., hunting, fishing, tramping, mountain biking and horse trekking. Business enterprises involved in hunting of game, management of pests, and trapping possum for fur and pelts have ranged in number from 140 to 170 (MPI 2015). Commercial operators provide guided tours in wilderness areas, with other enterprises providing provisions and accommodation, generating revenue for the local economy.
- **Native forestation and conservation projects** funded by government agencies, local councils, community organisations, and iwi groups. This includes the New Zealand government's One Billion Trees Programme, as described previously.
- **Native plant nurseries** are distributed throughout New Zealand. Those that are well-managed can be a significant employer of local people. Commercial and community-based nurseries also provide opportunities for training and skills development. For example, the Minginui Nursery provides employment and training opportunities and contributes to the socio-economic and cultural values of a local community, as described below.
- **The honey industry** - There were 1,271 beekeepers with 50 or more hives in the 2019/20 season (MPI 2020). Many honey enterprises are completely dependent on native forest species, e.g., mānuka honey production, while other honey industries rely on native forest for part of the season, particularly for early season nectar flow (MPI 2015).
- **Forest-based health products** such as nutritional supplements, antibacterial oils and health remedies, e.g., bioactive compounds for pharmaceuticals (e.g., mānuka and kānuka oils). Māori have been significantly involved in businesses and associated research initiatives on these types of products, frequently drawing on customary knowledge (MPI 2015; Roberts et al. 2015; Phytomed Medicinal Herbs NZ 2017).
- **Wild food and fibre enterprises** have been described above under non-timber provisioning services. While these industries are small-scale, they are important for providing employment and supporting local economic activity, and they are often culturally important (MPI 2015). This includes hunting of wild game and trapping for fur, and traditional foraged food for fine dining – as described previously.
- **Sphagnum moss is important for the Westland economy** with exports of $5.1 to $5.2 million in 2015 and 2016 (Plant & Food Research 2016) – locals are employed in the collection and preparation of sphagnum moss for harvest.

The One Billion Trees Programme (1BT) is an initiative funded by the New Zealand Government's Provincial Growth Fund, aimed at enhancing regional economic development opportunities, creating sustainable employment and helping meet climate change targets (Te Uru Rākau 2019a). One of the objectives has been to fund two-thirds in indigenous species (as opposed to exotic species) (Coughlan 2018; Te Uru Rākau 2020). There was criticism that most of the earlier plantings funded were radiata-pine, but this was inevitable because of the massive, highly developed infrastructure for the production and deployment of radiata-pine planting stock. Native nurseries were at a low ebb when the 1BT programme was introduced and have been slow to upscale. Also, it takes 2 to 3 years to produce native planting stock, and there are many species to consider, adding to the complexity.

At the time of writing, native forest plantings have steadily been increasing under the 1BT programme. Native forest establishment is likely to continue to increase, given the priorities published by Te Uru Rākau (2020) and the Climate Change Commission's advice to Government, which includes a significant scaling up of native forestation to help New Zealand meet international climate change commitments (Climate Change Commission 2021).

One of the projects funded in part by the 1BT programme, is the Minginui Nursery, in the Whirinaki region of the central North Island. This nursery specialises in the production of native plants, including planting stock for the 1BT projects.

The Whirinaki area has an interesting history. As a result of intense national and international protests, logging of native trees was stopped in Whirinaki, and the Whirinaki Forest Park was established (Beveridge et al. 2004; Department of Conservation 2017). The sawmill continued with the processing of exotic plantation timbers but was closed in 1988, which was a major blow to the community as it had been the main employer (Beveridge et al. 2004; Allen 2016). Ecotourism was suggested as an income generation opportunity, based on the remaining native forests, and small ecotourism ventures have since been established (Beveridge et al. 2004; Allen 2016).

As part of a Treaty of Waitangi settlement, signed in 2009, the Whirinaki Regeneration Project was initiated to restore 640 ha adjacent to Whirinaki Forest Park back into native forest (Allen 2016; Department of Conservation 2017). Ngāti Whare Holdings Limited established a native plant nursery in Minginui in 2016 to supply plants for the Whirinaki regeneration project and other similar projects. This has created employment and a unity of purpose in an area where there has been high welfare dependency and socioeconomic deprivation since the closure of the timber mill in 1988 (Ngāti Whare Group 2018; Te Uru Rākau 2021). There are 30 permanent and seasonal staff from the local community employed at Minginui Nursery (Te Uru Rākau 2021) and other people are employed in the restoration and management of native forest as part of the Whirinaki Regeneration Project.

4.3.9 Forests, brand image, political and commercial reputations

There are NTVs directly and indirectly associated with the following:

- New Zealand's brand image;
- New Zealand's international branding: 'Clean, Green' and 100% Pure';
- New Zealand's political reputation, particularly as a trade partner and major international producer of agricultural products;
- the environmental consciousness of organisations and 'green branding' as a marketing strategy;
- public acceptance and social license to practice; and
- development of good working relationships with regulatory authorities.

Native species are vital to our identity and our international reputation. As discussed above, New Zealanders call themselves 'Kiwis' after a flightless endemic bird, and proudly display the native silver fern (ponga) as a national symbol (Figure 6), indicating the importance of our unique native species for our national identity (Meurk et al. 2013; Ministry for the Environment & Stats NZ 2019).

Figure 6: The native silver fern is a national symbol included on the New Zealand one dollar coin, and in the branding of many New Zealand sports teams, including the Silver Ferns and All Blacks.

This national identity, based on our natural heritage, is also vitally important to our international branding, and therefore, our economy – as stated by Speden (2008):

> “The New Zealand brand gives our products an advantage, in several high-value markets, against those from countries with less wholesome environmental reputations. But this advantage is fragile and vulnerable to attack. ... International consumers no longer take claims such as ‘clean and green’ at face value. They are increasingly interested in tracing such claims back to the source, to test for good environmental practices and social responsibility. … The nation needs to invest in the maintenance of its national brand as surely as does any major corporation. The brand must be validated as an accurate statement of how we manage our environment and produce our exports” (p. 12, Speden 2008).

Tourism and export of agricultural and forestry products are vital to the New Zealand economy. Therefore, New Zealand’s track record on environmental issues is a significant issue due to the vulnerability of tourism and exports to adverse publicity; i.e., New Zealand’s reputation is important in regard to competitiveness in the global market (Ministry for the Environment 2001; Speden 2008; Su 2013; Kaefer 2014, 2016; Roberts et al. 2015; MPI 2017b; Nixon et al. 2017; OECD 2017a).

Before the COVID-19 pandemic, millions of tourists visited New Zealand every year, attracted by the pristine wilderness and spectacular landscapes (Roberts et al. 2015; OECD 2017a). Tourism was one of the most important industries in New Zealand, based on GDP and export earnings (OECD 2017a; Stats NZ 2018; Tourism New Zealand 2019) and it is critical to New Zealand’s economy that the international tourism industry recovers post-pandemic.

There is a risk of adverse publicity from environmental issues associated with deforestation, such as loss of biodiversity, failure to meet net emissions targets, eroded hillsides impacting water quality and scenic values, decrease in water quality and associated algal blooms, plus subsequent impacts on swimming, fishing and quality of drinking water. The importance of forests to water quality and scenic values is described above. Healthy waterways and scenic values are in turn critically important for tourism. A substantial proportion of tourism activities in New Zealand occur in or adjacent to fresh water (Gluckman 2017) and in natural landscapes (Roberts et al. 2015). Native forests are particularly important, directly and indirectly, for many outdoor activities enjoyed by domestic and international tourists, and by local communities.

Forests (particularly native forests) and their associated ecosystem services are very important for New Zealand's much touted and increasingly criticised 'Clean, Green' image and '100% Pure' destination branding (Figure 7) (Speden 2008; Roberts et al. 2015; Hall 2016) but this is very difficult to monetarise. This is partly because it is difficult to unravel the complexity of environmental services of forests, particularly native forests. It is also difficult to determine the economic impact and the associated risks of damage to the ‘Clean, Green and 100% Pure’ New Zealand branding (Speden 2008; Roberts et al. 2015; Kaefer 2016).

100% PURE NEW ZEALAND EXPERIENCE

Figure 7: ‘100% Pure’ tourism destination branding for New Zealand.

In 2001, the Ministry for the Environment suggested a potential loss of NZ$530 million to NZ$938 million in revenue if tourists’ perceptions of the environment worsened (Ministry for the Environment 2001; Kaefer 2014), which is NZ$799 million to NZ$1,414 million in 2021-dollar values. However, the potential loss in today's currency would be much greater due in part to significant growth in the tourism industry since 2001.

A loss of reputation would also negatively impact agricultural exports, but there is a lack of understanding of the potential risks associated with this 'green positioning' or the potential financial fallout (Insch 2011; Kaefer 2014, 2016). In 2001, research findings from the Ministry for the Environment suggested that if New Zealand's environment was perceived as being degraded, on average the consumers surveyed would purchase 54% fewer consumer products from the dairy sector. The actual revenue loss would depend on how much product could be redirected to markets where our environmental image was less important, so the potential annual loss would vary between NZ$241 million and NZ$569 million (Ministry for the Environment 2001), which is NZ$363 million to NZ$858 million in 2021-dollar values.

On a smaller scale, green branding and the environmental consciousness of individual companies are becoming increasingly important. Investment in ecological restoration or conservation projects can improve the social acceptance and reputation of organisations. For example, working relationships with regulatory authorities are enhanced when organisations work to protect or restore natural ecosystems – this is important for industries utilising land and other natural resources. Also, green certification, such as Forest Stewardship Council certification, helps increase market acceptance with consumers and it also creates the impetus to improve NTVs by, e.g., protecting native forest remnants or restoring native vegetation in riparian zones within areas of exotic forest plantations (Forest Stewardship Council New Zealand 2017).

Investment in forest planting and conservation projects can become a part of an organisation's brand. Examples of this include Canopy Tours, with environmental stewardship as an important part of their branding; Air New Zealand and their carbon offset programme with the Native Forest Restoration Trust; Body Shop partnering with the 'Million Metres' project; and Trees that Count (TTC), which is an initiative developed and supported by multiple organisations, as described below.

Canopy Tours, as explained above, is New Zealand's only zipline tour through native forest (Martin 2017). Environmental education and conservation are an important focus and part of its commercial branding. The business is involved in an extensive conservation project to protect the native species that live in the forest. When the business started operation in 2012, the forest was eerily quiet and there was plenty of evidence of pests (Martin 2017; Canopy Tours 2018). The company made a commitment to clear the forest of predators and hand-built many kilometres of trapping lines. Through a large investment of Canopy Tours' own money, plus sponsorship deals, customer donations, and a partnership with the Department of Conservation, the hard work of pest eradication has paid off. Native birds and other species (including native skinks and bats) have been steadily returning (Martin 2017). Part of each visitor's fee is allocated to the Canopy Conservation Trust, which uses the funds to implement conservation activities (Canopy Tours 2018).

Air New Zealand has partnered with New Zealand's Native Forest Restoration Trust (NFRT), a non-profit, largely volunteer organisation that acquires, protects and regenerates blocks of native forest and wetland. By purchasing carbon offsets when booking flights, Air New Zealand customers directly fund the NFRT's efforts to regenerate and manage native forest reserves. This approach helps make the voluntary offsetting option 'front of mind' (Air New Zealand 2017). Air New Zealand head of Sustainability Lisa Daniell explained the rationale for the scheme:

> "… people increasingly want to take a responsible approach to their carbon footprint. We want to make that offering more prominent, and easier to engage with … all the funds go back into work to purchase more land and restore and manage the forest through biodiversity work, often engaging with communities to protect the land" (p. 85, Air New Zealand 2017).

The airline wanted a New Zealand source of carbon units involving native forests, which was why they partnered with the NFRT (Air New Zealand 2017). NFRT has a strong record in retiring marginal farms to safeguard regenerating native forest. The funds generated by the carbon offsetting scheme help pay for professional contractors for pest control and fencing, and also for the supplementary planting of eco-sourced native species, which is expensive to fund (Air New Zealand 2017).

This is an example of a commercial entity responding through green branding to negative perceptions associated with fossil fuel and greenhouse gas emissions. Air New Zealand and participating passengers are investing in a forestation programme that has public appeal because of the positive environmental and cultural services associated with native forests. Air New Zealand's profits are highly dependent on the tourism industry and the company benefits from the 'clean, green, 100% pure New Zealand' branding, which it helps promote through its various sustainability programmes. In Air New Zealand's Sustainability Report 2018, Jonathon Porritt, Chair-person for the Sustainability Advisory Panel, stated that:

> "Societal expectations that companies should become more of a force for good in the world increase all the time, both on big background challenges like climate change or diversity, and on more spontaneous spikes in public concern … All of which means there's no place any longer for one-off reactive responses, or corporate green washing …" (p. 8, Air New Zealand 2018).

Body Shop is another business investing in environmental restoration. The business is focused on natural cosmetics and skincare products, and it has a strong social, ethical and environmental ethos as part of its branding. It upholds the belief that businesses have responsibilities towards the communities in which they operate.

> "When we moved into our Retail Support Centre ten years ago, the stream behind the building was quite degraded, but with support from the Wellington Regional Council and hard work from our staff we've brought the stream back to life. The quality of the water in our New Zealand rivers and streams needs to be improved and we'd love for our staff and customers throughout the country to have the opportunity to help achieve this. For this reason, we're proud and delighted to partner with Million Metres in the quest to replant and reinvigorate one million metres of our waterways" (Body Shop 2017).

'Million Metres' is an online crowdfunding platform for stream planting projects that enables people to fund the planting of edges of their local river, stream, lake, wetland, or estuary. Crowdfunding with Million Metres makes each stream planting project part of a bigger story. This initiative is supported by the Department of Conservation and aims to replant one million metres of New Zealand's waterways and help tackle water pollution.

Trees that Count (TTC) is an initiative developed and managed by the Project Crimson Trust with support from The Tindall Foundation, Pure Advantage and the Department of Conservation, with the aim to substantially increase the number of native trees planted throughout New Zealand (Trees that Count 2019). TTC has created a market place whereby businesses, organisations and individuals can donate funds to provide native planting stock, which is then matched to groups involved in planting programmes, which are designed to counteract climate change, restore biodiversity and enhance the environment. TTC records, maps and monitors the native trees planted.

5.0 Discussion and Conclusions

In modern times, a focus on short-term monetary returns has often prevailed over traditional indigenous viewpoints of the wider value of natural resources, resulting in environmental degradation. This has caused an imbalance between those benefiting from short-term economic gains and those who suffer the long-term environmental, cultural, and socioeconomic impacts from the destruction of natural resources. However, governments can incorporate natural capital into measures of economic performance, and introduce policies that incentivise sustainable use of natural resources, and protection of natural ecosystems and the communities that depend on them. And corporations and investors can limit their investments to support the sustainable use of resources.

New Zealand's current growth model is approaching its environmental limits, largely due to the intensification of land use (OECD 2017a). Fortunately, there is now increased awareness of the finite nature of natural resources and the importance of natural capital (i.e., all aspects of the natural environment needed to support life). Natural capital can be quantified via an ecosystem services framework. Forest ecosystem services include timber products and non-timber values (NTVs).

New Zealand's economy relies heavily on forests - natural and planted, native and exotic - for clean air and water, stable soils, biodiversity conservation, carbon sequestration, ambient environments for outdoor recreation and tourism, and their integral part of distinctive and unique landscapes, cultural identity, spiritual well-being, and New Zealand's international branding as a clean, green country. While both exotic and native forests provide many of these values, native forests contribute comparatively more to our cultural heritage, national identity, indigenous biodiversity, and our unique natural landscapes.

Until recently, the wider benefits of forests have often been overlooked in decision making, resulting in a distortion of policies around land use, to the detriment of forestry. There has also been a lack of knowledge of the full spectrum of forestry management practices in New Zealand, beyond the current dichotomy of exotic forest plantations managed under clear-fell regimes and old-growth native forests protected in the conservation estate. And the importance of native forest on private land has largely been overlooked.

In 2002, New Zealand's Parliamentary Commissioner for the Environment published a pivotal report - *Weaving Resilience into our Working Lands: recommendations for the future roles of native plants*. The report recommended the development of markets for ecosystem services to support future roles for native plants on private land (PCE 2002). It stated that narrow mindsets and legislative frameworks led to limited scope for native plants to provide benefits of both wealth creation and conservation, creating barriers to the protection and expansion of native vegetation on private land.

The wider value of native forests in New Zealand is increasingly being recognised, as demonstrated by initiatives undertaken by the Government (e.g., the One Billion Trees programme) and by corporate and community organisations (e.g., Trees That Count). The New Zealand Government's programme to plant one billion trees from 2018 to 2027, aims to have two-thirds of new plantings in native species (Te Uru Rākau 2021). This has been a significant challenge given the substantial cost and limited infrastructure for establishment of native forest. Protecting soil, water quality and other natural resources are key goals, as well as carbon sequestration and job creation.

In 2021, the Climate Change Commission's advice to the New Zealand Government included a recommendation for land use change to permanent native forests, particularly on erodible, steep farmland (Climate Change Commission 2021). This will help offset the long-lived greenhouse gas emissions in sectors with limited opportunities to reduce emissions from 2050, including offsetting residual nitrous oxide emissions from agriculture.

The Commission recognised that current sector infrastructure and policy settings heavily favour the planting of radiata pine over other species. The stabilisation of the carbon market and improvement in carbon prices has encouraged afforestation, but this has largely favoured exotic rather than native forest establishment. The Commission recommended incentives for expanding the native forest estate, acknowledging that costs to land owners need to be reduced; also, the co-benefits of water quality and biodiversity need to be considered, as well as cultural, social, and economic outcomes (Climate Change Commission 2021). The Commission also acknowledged calls for the ETS Permanent Forest Category to be limited predominantly to native forests.

Publicised impacts of environmental degradation have influenced public opinion, which in turn has put pressure on policy makers. Increasingly, there is recognition that some of the estimated one million hectares of erosion-prone, steep pastoral hill country in New Zealand would benefit from afforestation in permanent native forest. In 2018, high-profile intense weather events on the East Coast of the North Island and in the Tasman District, highlighted issues with logging debris and sediment from clear-fell forestry operations damaging downstream infrastructures and ecosystems. There were multiple calls for vulnerable hill country to be established in permanent native forest, rather than clear-fell regimes (e.g., Salmond 2019).

In addition to this, there is an under-representation of lowland natural ecosystems in the conservation estate and a recognised need to increase indigenous biodiversity conservation on our productive rural lands – to complement biodiversity conservation on public land (Brown et al. 2015). There is also growing awareness of decreased water quality in intensively developed urban and agricultural land in New Zealand, and recognition of the benefits of green infrastructure and the importance of riparian zones (e.g., OECD 2017a).

There are recognised risks associated with environmental degradation and New Zealand's international reputation (Insch 2011; Kaefer 2014). The much touted (and increasingly criticised) 'clean, green' and '100% pure' destination brandings are vital for the reputation of New Zealand's most important industries - tourism and agriculture. It is difficult to quantify the economic values, risks, and potential financial fallout linked with this 'green branding', and the part that forests (particularly native forests) play in this brand image, but it would be substantial. Companies are increasingly using green branding and investment in environmental initiatives to gain market leverage as well as offsetting the environmental impacts of their operations. There also appears to be a preference in the wider community for supporting establishment of native rather than exotic forest.

Quantifying NTVs allows for the accounting of the wider benefits of forests in economic analyses. However, NTVs have largely not been factored into the economic value of forests because of the difficulty in tracking and quantifying the myriad of associated products and services. Identifying and estimating NTVs would aid decision making and encourage investment in the most appropriate type of forestation, particularly regarding environmental benefits and community preferences. And it would leverage native forests as a sustainable land use in land management decisions and policy making.

Universally accepted methods for measuring NTVs are needed. There are widely differing methods for quantifying non-market services. Interpretation invariably involves subjective judgments with inevitable caveats and extrapolation from site-specific examples to other sites, or to a national level, which is likely to involve a wide margin of error. There is the conundrum of 'valuing the invaluable', i.e., ecosystem services with no direct material benefits but which are critical to human well-being.

NTVs are, therefore, currently not easily monetarised in New Zealand, other than carbon forestry and honey. Ideally, NTVs should be determined on a case-by-case basis, with fair and inclusive stakeholder engagement. Procuring site-specific quantitative NTVs data is important, but qualitative measures of NTVs that are difficult to assess should be regarded as equally important. The use of complementary approaches that include monetary and non-monetary valuation is recommended. Non-monetary values include biophysical data (e.g., water quality measures) and qualitative measures. The socio-cultural approach is recommended, i.e., ecosystem services are identified and subsequently ranked by stakeholders (Martin-Lopez et al. 2012; Scholte et al. 2015).

Much of the information on NTVs in New Zealand has been researched and quantified within narrow disciplines and communicated in isolation, in a way that hinders the comprehension and recognition of the accumulative, wider value of native forests. And there are significant knowledge gaps.

Knowledge gaps identified in this review:

1. There is limited information on economic values for most non-timber forest products in New Zealand because these industries are often small scale, except for the honey and mānuka oil industries.
2. The apiculture industry strongly relies on native forest, particularly for early season nectar flow and pollen, but there is a lack of empirical data on this. The contribution of native forest species to the well-being of honey bees and other pollinators (and pollination services) is largely unquantified.
3. Look-up tables have been criticised for under-representing the carbon sequestration of native forest. There is a need to provide a defensible dataset of the amount of carbon likely to be sequestered via the goals set by the Climate Change Commission for native forestation.
4. There is limited information on how effective urban trees are in improving air quality in New Zealand, how this impacts human well-being and translates into monetary values, and what types of trees are most effective for improving air quality.
5. There is a lack of comprehensive empirical data on the influence of different types of forests and forestry management practices on soil stability and prevention of erosion and sedimentation.
6. Research is needed on forestation and hydrological processes, particularly water yield where there has been afforestation with exotic plantation species versus restoration of native forest.
7. There is limited empirical data on the capacity of forests to recycle nutrients from nearby intensive land use, and the influence of different types of forests and management practices.
8. There are recognised difficulties in determining monetary values for cultural services.
9. The services provided by native forests that contribute to the many recreational and ecotourism enterprises, and human enjoyment and cultural values, have largely not been quantified.
10. There has been limited use of the socio-cultural approach in the valuation of ecosystem services in New Zealand, but this is an important method for capturing stakeholder perspectives on NTVs.
11. There is limited information on the importance of various characteristics of urban green spaces for environmental services and socio-cultural values, and how this benefits human well-being.
12. There is limited information on how different types of forests and forestry management practices affect forest-based livelihoods and local economies in New Zealand.
13. Overall, there is a lack of information on the aggregated NTVs of native forests in New Zealand, based on data collected within New Zealand, as opposed to overseas proxies.
14. Simple-to-use tools need to be developed to allow land-owners, iwi groups, NGOs, local councils, and other stakeholders to assess NTVs in existing and proposed native forest.

Despite the identified knowledge gaps, it is apparent that sustainably managed native forests deserve a much higher profile as an economically viable land use in New Zealand. This could legitimately be achieved with the inclusion of NTVs in economic analyses. It is likely that, in most cases, the aggregated NTVs of native forests would be greater than that for exotic plantations – particularly concerning scenic, cultural and spiritual values, conservation of indigenous biodiversity, and protection of erodible land, water quality, and downstream infrastructures and ecosystems.

Permanent native forests managed for NTVs alone, or sustainably managed under continuous cover regimes, are likely to have the highest aggregated NTVs, which could potentially exceed timber values, depending on the type of forest and its state of health. Native forest in riparian areas is likely to have particularly high aggregated NTVs because of the: (i) buffering of the negative impacts of plantation forestry operations, intensive agriculture, and urban development through prevention of sediment loss, recycling of nutrients, and protection of water quality; (ii) decreased run-off and flood peaks, protecting downstream infrastructures and ecosystems; (iii) increased biodiversity and cultural values due to habitat provision, creation of wildlife corridors, protection of aquatic habitats and traditional food sources; (iv) creation of connections between ecosystems to enable seasonal migrations; (v) support for apiculture, and pollination services for adjacent horticultural and agricultural industries; and (vi) landscape aesthetic values.

A healthy, structurally complex native forest will have high NTVs and will be more resilient in the face of climate change. Pest and weed control are essential. NTVs will be compromised, and the forest will be less resilient if it is fragmented and degraded, unfenced from livestock; and the forest is damaged and natural regeneration processes are hindered by browsing pests, predators and invasive weeds. NTVs can also be compromised by biosecurity incursions, as is already evident with kauri dieback disease and myrtle rust incursions.

NTVs are best viewed in a broad socio-economic and environmental context, rather than focussing on a single NTV to the neglect (or even at the expense) of other NTVs. There could potentially be trade-offs where an increase in one NTV could lead to a decrease in other NTVs. For example, forestation on farm sites prone to water shortages could potentially lead to a trade-off between water yield and other environmental values. And a narrow focus on carbon sequestration could potentially create negative outcomes if other ecosystem services such as biodiversity are not considered.

There is also the question of 'who pays – who benefits?' NTVs often accrue to a much wider community than the land-owner, including:

- **locally**, e.g., amenity services such as shade and shelter, increased soil stability, biodiversity enhancement, flood protection, and aesthetic landscape values;
- **catchment-wide**, e.g., conservation of biodiversity, reduction in sedimentation, improved water quality and water flow regulation, and increased resilience to intense weather events including protection of downstream infrastructures and ecosystems;
- **regionally**, e.g., benefits associated with all the above mentioned NTVs, including catchment protection and increased profitability in land-based, aquatic and marine primary industries; mitigation of the effects of climate change, and increased visitor numbers and profitability in tourism and hospitality industries.
- **nationally**, e.g., accumulative benefits mentioned above, New Zealand's climate change commitments, conservation of New Zealand's unique biodiversity, and international branding as a clean, green country; and
- **internationally**, e.g., carbon sequestration and mitigation of climate change.

At the time of writing, there are discussions on incentive systems to encourage native forestation on private land. **It is recommended that government and corporate grants are linked to the broader range of ecosystem services provided by forests,** rather than a single ecosystem service such as carbon sequestration**.** However, biodiversity is a pivotal NTV, which is likely to leverage most other NTVs, i.e., actions to increase biodiversity values are likely to concurrently improve most (or possibly all) other NTVs, in most situations.

In conclusion, weaving native forest back into our rural and urban landscapes will provide a myriad of ecosystem services that will improve environmental and cultural values, and mitigate the effects of climate change, urbanisation, and intensification of land use. Native forestation should be incentivised as the benefits accrue far beyond the sites where land owners sustainably manage and extend native forest cover.

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Photo Credits

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Front cover:

Native forest zipline [Rotorua Canopy Tours, https://www.canopytours.co.nz/]; two hikers [Nicky Haisman]; North Island kaka [Tom Lynch, Foris eco-tours www.foris.co.nz]; kawakawa and fern images [Michael Bergin]; mānuka honey [Jacqui Aimers]; honey bees feeding on nectar from pohutukawa flowers [Michael Bergin]; background image – clear water in beech forest catchment, North Canterbury [Michael Bergin].

Title page:

Restored native forest at Awahou Stream, Rotorua [Jacqui Aimers].
When restoration began in January 1994, the riparian area was overgrown with blackberry and full of rubbish - it had been used as a dump for many years. The restoration of 9 hectares was led by Jaap and Sue van Dorsser, as documented in a Tāne's Tree Trust video '24 years of Trial and Error' - https://www.tanestrees.org.nz/resources/links/.

Frontispiece:

The reasons to love native trees by Ezra Whittaker-Powley, commissioned by Trees That Count. The artwork was inspired by this research on non-timber values.

Photo montage - Non-timber forest products & other provisioning services (pp. 19-20):

Page 19: Wilderland Organics kawakawa tea [internet image – Wilderland Organics https://organics.wilderland.org.nz/shop]; pikopiko on a plate [internet image - Mike Heydon]; Honey of te Urewera [Jacqui Aimers]; Mossop's mānuka honey [Jacqui Aimers]; kawakawa [Michael Bergin].

Page 20: Mānuka essential oil [internet image – PureNature Ltd https://www.purenature.co.nz/]; endangered swamp maire [Ruth Fleeson]; dried kawakawa and horopito, Charles Royal Maori food [Jacqui Aimers]; kawakawa skin balm [internet image – Honest Skincare https://www.honestskincare.co.nz/]; miro berries [Michael Bergin].

Photo montage - Environmental Regulating Services (pp. 31-32):

Page 31: clear water in beech forest catchment, North Canterbury [Michael Bergin]; tui feeding in kowhai tree [Sharon Lye photography]; native blue mushroom - Werewere-kokako *(Entoloma hochstetteri)* [Rotorua Canopy Tours https://www.canopytours.co.nz/]; native eel [Jacqui Aimers];

pohutukawa providing shade, Wellington [Susan Bergin]; North Island kaka [Tom Lynch, Foris eco-tours www.foris.co.nz].

Page 32: kahikatea – our tallest native tree is good at sequestering carbon [Michael Bergin]; planting native trees on eroding steepland, Te Miro, Waikato [Michael Bergin]; kereru *(Hemiphaga novaeseelandiae)* eating a karaka berry [Trees That Count https://www.treesthatcount.co.nz/]; honey bees feeding on nectar from pohutukawa flowers [Michael Bergin]; clear running water in an ecologically restored riparian area, Ngongotaha, Rotorua [Jacqui Aimers].

Photo montage - Socioeconomic, Cultural and Spiritual services (pp. 65-66):

Page 65: Michael Bergin collecting tree growth data in tōtara forest [Paul Quinlan]; Minginui Nursery [Michael Bergin]; native forest gecko (*Mokopirirakau* species) at Te Urewera [Jacqueline Bond]; NZ$50 note [internet image]; forest walkway [Rotorua Canopy Tours https://www.canopytours.co.nz/]; pohutukawa bowl – produced by Jo Luping Design [Jacqui Aimers]; thinning operation, Northland Tōtara Project [Paul Quinlan]; silver fern [Jacqui Aimers]; father and daughter planting [Michael Bergin]; bird in hand [Rotorua Canopy Tours https://www.canopytours.co.nz/]; tree fern and pohutukawa, Lake Tarawera [Jacqui Aimers].

Page 66: "Nature's Blessing" – depicting flowers and leaves of puriri *(Vitex lucens)*, the puriri moth *(Aenetus virescens)*, and puriri tincture [artwork by Santie Cronje https://www.santie.nz/]; pohutukawa at Aotea Harbour [Michael Bergin]; City to Sea Walkway, Wellington [Jo White]; canopy zipline [Rotorua Canopy Tours https://www.canopytours.co.nz/]; unfurling ponga fern [Michael Bergin]; Tāne's Tree Trust intern Anna Manning collecting tree growth data in tōtara forest [Paul Quinlan].

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TĀNE'S TREE TRUST'S VISION

"To see the majority of New Zealand landowners successfully planting and sustainably managing indigenous trees for multiple uses".

TRUST OBJECTIVES

- Promotion of indigenous forestry as an attractive land-use option by consolidating and advancing the state of knowledge of indigenous tree species through research and practical demonstration.
- Resolving any legal or other obstacles to the planting and management of indigenous trees.
- Maximising economic incentives for establishing indigenous forests including reducing the cost of establishment and early management.
- Encouraging and facilitating knowledge-sharing amongst stakeholders and interest groups.

For further information about the Trust please contact:

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