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Alt-F Reset: Examining the drivers of forestry in New Zealand

April 2025

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

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April 2025

ISBN
978-0-473-74223-2 (print)
978-0-473-74335-2 (electronic)

Photography
Cover image: Hinewai Reserve, photo supplied by Edward Hathway; Photo supplied by Beef + Lamb New Zealand; Native trees integrated on farmland in the Wairarapa, photo supplied by MPI.

Chapter header images: Rimu (*Dacrydium cupressinum*); Macrocarpa (*Cupressus macrocarpa*); Monterey pine (*Pinus radiata*); Blackbutt (Eucalyptus pilularis), PCE; Mataī (*Prumnopitys taxifolia*), Aimey Tahu, iNaturalist; Tōtara (*Podocarpus totara*), White peppermint (*Eucalyptus pulchella*), PCE; Kauri (*Agathis australis*), Chiara Switzer, Flickr; Redwood (*Sequoioideae*), Tony Hisgett, Flickr; Japanese cedar (*Cryptomeria japonica*), Poplar (*Populus*), Douglas fir (*Pseudotsuga menziesii*)

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Acknowledgements

The Parliamentary Commissioner for the Environment, Simon Upton, is indebted to a number of people who assisted him in conducting this investigation. Special thanks are due to Dr Lizzy Green and Dr James Newman who co-led the project with support from Bill Gray and Dr Geoffroy Lamarche. Leana Barriball, Meg Crozier, Dr Robert Dykes, Shaun Killerby, Charlotte Lee-Smith, Megan Martin, Matt Paterson, Geoff Simmons and Rebecca Thornley all provided valuable support.

The Commissioner would like to acknowledge the following organisations for their time and assistance during this investigation:

- Auckland University of Technology
- Eastland Wood Council
- Forbes Ecology
- Forest Growers Research
- Gisborne District Council
- Interpine Innovation
- Mana Taiao Tairāwhiti
- Manaaki Whenua – Landcare Research
- Ministry for Primary Industries – Manatū Ahu Matua
- Ngā Pou a Tāne
- New Zealand Dryland Forests Innovation
- New Zealand Farm Forestry Association
- New Zealand Forest Owners Association
- New Zealand Institute of Forestry
- Scion – New Zealand Forest Research Institute Ltd
- Tāne's Tree Trust
- Toha Network
- University of Canterbury
- University of Otago
- the many other forestry groups, landowners, land managers and technical experts engaged with.

The Commissioner wishes to thank the following individuals for reviewing earlier drafts of the report:

- Dr David Bergin, with support from other trustees, Tāne's Tree Trust
- Neil Cullen, New Zealand Farm Forestry Association
- Dr David Hall, Toha Network
- Dr Nikki Harcourt, Landcare Research
- Dr Hervé Jactel, French National Research Institute for Agriculture, Food, and Environment (INRAE)
- Dr Tim Payn, Scion.

While he has benefited hugely from their insights, any errors, omissions or opinions are entirely his own.

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Rimu *(Dacrydium cupressinum)*

1 Introduction

This report started out as an enquiry into what we know – and what we don't know – about large-scale re-establishment of native forests in New Zealand. It was spurred by some very large estimates of the contribution native afforestation could make to meeting New Zealand's climate mitigation targets.

In 2021, the Climate Change Commission (CCC) released a report, *Ināia tonu nei: a low emissions future for Aotearoa*, which included a modelled scenario showing 300,000 hectares of new native forests being established between 2021 and 2035 as a contribution towards meeting New Zealand's net zero target for long-lived greenhouse gases by 2050.[1] The same scenario also modelled some 380,000 hectares of new exotic forests. While these afforestation figures were merely modelling assumptions, some quickly interpreted them as recommendations, thereby sparking interest in the role that different types of large-scale afforestation could play in the future.

The area of new native forest used by the CCC was large – around twice the area of Rakiura National Park. It immediately raised the question of whether native afforestation on this scale was feasible. If it was, would it contribute to the commercial forestry sector or would it be a restorative gesture made possible, ironically, by a national reluctance to actually drive down gross emissions? In seeking answers to these questions, it is impossible not to ask questions about the existing drivers of afforestation in New Zealand because the current policy context is so heavily distorted.

Prior to the creation of the New Zealand Emissions Trading Scheme (NZ ETS), the decision to plant forests was driven by two quite distinct imperatives: commercial returns or conservation gains. On the one hand, forestry companies planted forests as the feedstock for products ranging from pulp to construction timber. The decision to acquire land for forestry was driven by its productivity and its distance from processing facilities and ports.

On the other hand, forest planting in some places was driven by the belated realisation that land that should never have been cleared of native forest for pasture needed to be stabilised. Nearly 40 years ago, Cyclone Bola presented the country with a stark example of what can happen to young, steep, geologically unstable land when trees are removed. But it was the less dramatic evidence of soil erosion which led to the promotion of conservation tree planting across wide areas of hill country terrain. Rather than commercial considerations determining which land should be afforested, nature identified the land for us.

1 CCC, 2021c.

In both cases, one species – radiata pine (*Pinus radiata*) – offered the preferred way forward. This was largely as a result of significant government-led investments in the identification and development of a fast-growing species that could deliver the volumes of timber that a fast-shrinking native estate could never supply. Starting in the early twentieth century, radiata pine has become the dominant and unchallenged commercial option for large-scale forestry in New Zealand, with almost all managed for timber production under a clear-fell regime.

The advent of the NZ ETS as a carbon market in 2008, which allowed forest offsetting as an alternative to emissions reductions, radically changed the commercial justification for afforestation and demand for the land needed to accommodate it. The returns from carbon credits have hastened the move from pasture to radiata pine, particularly on sheep and beef land for which profitability has been marginal. This has also increased the price of land for prospective buyers with knock-on consequences for the business model of commercial forestry companies among others.

In the space of 15 years, the NZ ETS has become the principal driver of land use change. Record high carbon prices in 2022 coincided with total afforestation rates exceeding 70,000 hectares.[2] By the end of 2024, over 650,000 hectares of forest was registered in the NZ ETS.[3] The Climate Change Commission's most recent scenarios for their emissions budget projections have future plantings totalling between 0.93 and 2.2 million hectares by 2050.[4] This is a huge area to commit to trees for reasons that are neither strictly commercial nor truly environmental.

The commercial driver relies on the artificial policy construct of an NZ ETS, which can be changed at any time. The environmental driver – sequestering carbon to offset emissions – is based on a deeply flawed assumption of equivalence between carbon dioxide emissions from fossil fuel combustion and their capture in stocks of biological carbon. To put it simply, because of the long-lived nature of carbon dioxide emissions in the atmosphere, any forests planted to offset those emissions need to effectively remain there forever. If we continue to emit carbon dioxide and not reduce gross emissions, we will need to continually plant more and more forests.

The PCE has repeatedly drawn attention to the multiple environmental and economic risks that are being run. The scale of land use change caused by the NZ ETS, driven by its singular focus on carbon and with almost no limit to the number of carbon credits that can be created, is setting up increasingly negative economic, social and environmental consequences.

If current settings remain largely unchanged, those negative consequences will compound. The PCE has previously made the case to phase forest offsets out of the NZ ETS, at least as an offset for fossil fuel emissions.[5] Successive governments have resisted the logic of doing so on the basis that planting trees is a cheap and easy way of kicking the gross emissions reductions can down the road. Some voices in rural New Zealand have raised concerns but even these are muted to the extent that carbon farming may offer the best exit route from land uses that have become economically marginal and environmentally controversial.

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2 Manley, 2024. In November 2022 the price of a New Zealand emission unit (NZU) reached a historical high of $88.50. Total afforestation that year was estimated to be 72,500 hectares.

3 MPI, pers. comm., 3 December 2024. This excludes forests established before 1990, which were automatically included in the NZ ETS.

4 CCC, 2024c.

5 PCE, 2024a. See also PCE, 2023b and PCE, 2024b.

Radiata pine has, and will continue to have, an important role in New Zealand's economy. Sited appropriately and managed well, it provides a sound economic return and local employment in growing, managing and processing the trees for domestic and export markets. Production forestry continues to generate revenue and economic benefit long after any carbon dividend has been spent.

But if we are going to continue to drive large-scale afforestation – and airily advocate at the same time for a switch to alternative species and in particular natives – it is legitimate to ask what sort of trees we want and what benefits they might provide. Should we continue to encourage pine (especially for carbon) or look to broaden our horizons? There are other types of forests that could also contribute towards large-scale afforestation in New Zealand. And in the case of both native and exotic species, different management regimes from those currently deployed are possible. The question arises: could some of these alternative forestry systems support wider environmental benefits for New Zealand and address some of the risks of the current approach?

Any consideration of alternative options for forestry requires a thorough understanding of what is and isn't known about establishing and maintaining these different types of forests over the long term. Evidence of the risks and benefits that might be associated with them must also be carefully analysed and considered. Establishing and then managing a forest through to maturity (and beyond, in the case of permanent forests) is a long-term endeavour with many challenges along the way. Understanding some of the potential pitfalls and traps would help anticipate adverse environmental consequences and could avert costly mistakes that are hard to undo. Without this, we risk embarking on a wave of rapid land use change without necessarily having a clear idea of what long-term outcomes are feasible for these forests, or if we know enough about how to deliver them.

People are passionate about forests for a multitude of reasons, and emotions can run high when talking about them. In the course of this investigation, a wide range of perspectives were encountered about what types of forests should or shouldn't be incentivised or established. Some contended that native forests were the answer, while others argued that exotics were the only economically viable solution. In some cases, this was reduced to a simplistic binary judgment that labelled native forests as 'good' and exotic forests as 'bad'. The evidence to support these judgments was often lacking. This investigation is about trying to improve the evidence base to support a more informed debate.

Definitions can also be contentious. While the term 'forest' can be defined in various ways, all definitions have their own limitations and implications. Some object to calling a pine plantation a forest and would rather call it a 'crop', especially when it is clear-felled on rotation. Others would question whether a mānuka plantation managed for honey qualifies as a forest. This report has erred on the side of a wide view of what constitutes a 'forest'.

Source: Geoff McKay, Flickr

Figure 1.1: Currently in Aotearoa New Zealand, there are two large-scale forestry systems: native forests managed for conservation values, such as the Ruahine Forest Park pictured here, or radiata pine forests for commercial purposes.

This report investigates whether there is a wider spectrum of forest options that could contribute to large-scale afforestation within New Zealand. This not only includes different types of forests in terms of species but also those established for different purposes (such as timber, carbon, or improved mauri, including biodiversity and ecosystem services) and which can be managed in different ways. The report inevitably challenges how we see these different forests: for instance, establishing native forests for timber production, exotic forests for ecosystem services, or multi-purpose forests for commercial, cultural and environmental purposes. There is a vast number of potential alternative exotic tree species that could be considered if we cast the net widely enough.[6] For reasons of simplicity and practicality, this report focuses on those species and groups of species that are best understood and seem the most promising in the New Zealand context.

The investigation also set out to understand the factors that have driven the current direction and focus on radiata pine as the predominant type of planted forest. If alternative forestry systems exist that could be better suited for some purposes than radiata pine, why aren't they currently attracting as much investment and interest? What regulatory levers are supporting or hindering a more diverse forestry system? Are there economic or system level barriers that need to be addressed?

This report looks at what other types of forests could meet carbon, biodiversity and land use objectives in a way that pine forestry may not be best placed to deliver.

6 A recent literature review identified 45 alternative exotic species with commercial potential (Jones et al., 2023).

Specifically, it seeks to answer the following questions:

- What do we know about establishing native forests at scale? What are the different approaches that can be taken? How does this vary spatially? What are the key knowledge gaps?
- What are some of the most promising alternative exotic species that could be established in New Zealand? How much do we know about them? What role could they play?
- What do we know about long-term management of different types of forests?
- What would be the environmental impacts of establishing more alternative forests?
- What are the incentive structures that are affecting afforestation in New Zealand, and what outcomes are they driving? What is preventing greater uptake of alternative forestry?

The structure of this report:

Chapter 1 is this introductory chapter.

Chapter 2 outlines the current composition of forests in New Zealand, including radiata pine, other exotic species and natives. It moves on to discuss the motivations driving afforestation at scale (which are predominantly commercial: for timber, and more recently carbon).

Chapter 3 expands on the environmental and social impacts of establishing vast new areas of radiata pine forests, including the role climate change will play in modifying risks.

Chapter 4 introduces some of the alternative forest types discussed in this report.

Chapter 5 describes what we know about establishing **new native forests** at scale. This includes the various steps that need to be considered, different approaches that are both being employed and have been proposed, the economic realities of native afforestation, and the environmental effects of any such forests.

Chapter 6 describes what we know about employing **transitional forestry techniques** to create new native forests from exotic forests – either by converting existing exotic forests or by establishing entirely new exotic forests first. It also considers the economics of transitional forestry.

Chapter 7 looks at some of the **alternative exotic forest species** that could play a role in large-scale afforestation in New Zealand. What do we know about these other types of exotic forests and what are the environmental effects of establishing them?

Chapter 8 asks what **better management of existing native forests** could achieve.

Chapter 9 covers the **New Zealand Emissions Trading Scheme** (NZ ETS), a key piece of legislation incentivising the current wave of afforestation.

Chapter 10 turns to some of the key barriers that stand in the way of the alternative forest types discussed in preceding chapters. The focus is on government interventions, both financial and regulatory, as well as other factors constraining the uptake of alternative forestry.

Finally, **Chapter 11** pulls together the learnings this investigation has yielded and offers some recommendations.

Box: 1.1 Useful terms for this report

An **alternative forestry system** is any type of forest being established in New Zealand that is not a radiata pine plantation forest managed under a clear-fell or carbon forestry regime. The forest could comprise native and/or exotic species and be established for any purpose.

A **carbon forest** is a forest managed only for carbon sequestration and storage and will not be harvested for wood. Note that some production forests are also managed for carbon too — but these are not included in this category.

A **clear-fell regime** is a management regime where a production forest is harvested by clearing large sections all at once. If the land is then replanted and the process started over again, this is referred to as a **rotation forest**.

A **continuous cover production forest** is a production forest that will retain a high canopy cover across time but will undergo some low-intensity harvest, such as selective tree harvest or small coupe harvest. It may additionally be managed for carbon.

An **exotic forest** is any type of forest that is dominated by exotic tree species.

A **native forest** is any type of forest that is dominated by native tree species.

Ngahere is a term used by Māori for the broad purposes of defining a forest or any other land that predominantly has rākau (trees) on it. When reference is made to a te ao Māori perspective of forests, ngahere will be used. However, it should be noted here that there are many words for forest in te reo Māori due to local dialectical differences. Here the term ngahere is used as it is the most common kupu (word) for forest.

A **permanent forest** is a forest that is intended to be managed over the long-term (potentially indefinitely) while maintaining a high level of canopy cover. Note that 'permanent' has a specific meaning in some legislation that will be set out when necessary.

A **plantation forest** is a forest where the trees have been planted en masse for commercial purposes (such as wood production or carbon). Typically, a plantation forest is composed of one or two species, has one age class and has regular tree spacing.

A **production forest** is a forest that is managed for some level of wood (timber and/or pulp) production. This includes rotational forests that are clear-felled (and then replanted) and continuous cover forests where harvesting is more selective and managed so as to maintain a high level of canopy cover.

Rākau is a common te reo Māori word meaning trees, timber or wood.

Whenua is a term used by Māori to refer to land.

Whenua Māori is land that is collectively owned by Māori who whakapapa to it under Te Ture Whenua Māori Act 1993, settlement or any other arrangement

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Monterey cypress (*Cupressus macrocarpa*)

The forests of Aotearoa: where we are and where we're headed

There are 10.1 million hectares of forests in Aotearoa New Zealand today, covering 38% of the land area, but only 2.1 million hectares were planted.[1] The remaining 8 million hectares comprise native forests located on Crown and private land as well as whenua Māori.[2] Before the arrival of humans, native forests covered roughly 80% of New Zealand's land area.[3]

The native forest estate

Native forests include the remnants of old-growth forest (native forests with large mature trees that have never been cleared by humans) and regenerating or secondary forest (areas that were deforested but are reverting to native forest, whether through natural regeneration or planting). While there is considerable variation in native forest composition across New Zealand, native forests can be broadly classified as either beech forest (*Fuscospora* and *Lophozonia* species) or mixed broadleaf-conifer forest.[4,5] Beech forests make up the largest remaining area of native forest. This is probably because many of them are located in mountainous areas that are unsuitable for agriculture and were therefore never cleared.

The planted forest estate

Of the planted forest estate, 1.79 million hectares are plantation forests managed for commercial production purposes (mostly wood and fibre) and are predominantly on private land or whenua Māori. A single species, radiata pine (*Pinus radiata*), makes up roughly 90% of plantation forests. The other 10% is made up of different exotic tree species, predominantly Douglas fir (5% of the plantation area) but also cypresses, eucalypts, redwoods and others.[6] These alternative exotic species have generally been planted at small scales, such as woodlots on farms, although some

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1 MPI, 2025.

2 Whenua Māori consists of land under Te Ture Whenua Māori Act 1993 and land owned by post-settlement governance entities.

3 Stats NZ, 2015.

4 Besides kauri (*Agathis australis*), New Zealand has more than a dozen native conifer species in the families Podocarpaceae, Phyllocladaceae and Cupressaceae. Some of the most well-known are rimu (*Dacrydium cupressinum*), tōtara (Podocarpus totara), kahikatea (*Dacrycarpus dacrydioides*), mataī (*Prumnopitys taxifolia*), and miro (*Prumnopitys ferrugineus*). There are also hundreds of native broadleaf tree species. Around 80% of New Zealand's flora are endemic (found only in New Zealand) (Brockie, 2007).

5 Wyse et al., 2018.

6 MPI et al., 2024.

larger scale commercial plantations do exist.[7] Historically, alternative exotic species played a larger role in forestry than they do today: in 1970, roughly half of the 270,000 hectares of State plantations were alternative species.[8]

Over 70 years of targeted research and development has led to a highly efficient industry built around radiata pine. Large areas can be planted fairly cheaply using improved seedling stock, clear-fell harvested at around 28 years of age (with an average productivity of 27.4 m^3 per hectare per year) and replanted a couple of years later.[9] This efficiency has been the cornerstone of a forestry industry that contributes an annual gross income of around $6.6 billion (1.6% of New Zealand's GDP) and employs some 35,000–40,000 people.[10] About 60% of New Zealand's harvested wood is exported.[11]

Māori and forestry

Māori form a key component of the forestry sector, making up a large part of the forestry workforce and owning large areas of plantation forestry (190,000 hectares) and native forest (570,000 hectares).[12] They also own more than half a million hectares of land covered in exotic forests owned by private companies.[13] In 2022, Māori forestry assets were worth $4.3 billion.[14]

Māori also have unique relationships with their whenua and ngahere that need to be considered when discussing land use and land use change.[15] Many whānau, hapū and iwi aspire to sustainably utilise their whenua Māori through afforestation – as part of protecting Papatūānuku.[16] Box 2.1 describes key concepts from te ao Māori.

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7 For example, over 1,000 ha of redwoods have been planted at Hundalee Forest, Canterbury, by the New Zealand Redwood Company (LINZ, 2024).

8 Although radiata pine already made up about 90% of the 295,000 ha private forest estate (Department of Statistics, 1970).

9 Average productivity estimates range from 22.2 m^3/ha/year in Canterbury to 32.2 m^3/ha/year in Gisborne, but productivity can be highly variable between low and high productivity sites (Palmer et al., 2010).

10 MPI, 2024a.

11 NZFOA, 2023a.

12 Ngā Pou a Tāne, 2024.

13 Ngā Pou a Tāne, 2024. Māori ownership of land and forests will increase as Treaty of Waitangi settlements conclude (Scion, 2025).

14 New Zealand Government, 2022, p.275.

15 Mika, 2021.

16 Salmond and Caddie, 2024.

Box 2.1: Key concepts in te ao Māori

Whakapapa

How Māori relate to a forest has implications for how they utilise resources within a forest and ultimately how they contribute to afforestation. This relationship is organised using whakapapa (familial, hierarchical relationships) and describes the interaction between the physical and metaphysical and between human and non-human. Atua are the representation of the metaphysical and are defined as guardians of particular domains, deities or creators, ancestors, or tuakana (elder siblings). Tāne mahuta is the atua of the ngahere, which includes rākau (trees), manu (birds), the insects and lizards, the soils, rocks and stones.[17] Atua of other domains are also important in this relationship with forests, e.g. Ihorangi who, in a simplified definition, is the atua of rain. Rainfall is an important component of forests and their composition. Whakapapa is intricate and detailed but provides a good understanding of the relationships needed to sustain a healthy forest.

Mauri

Another important concept is mauri which is defined as life force, life principle or vital essence. Everything has mauri and the strength of the whakapapa relationship determines the mauri or health of a forest. If the forest is thriving from the top of the canopy to deep into the soil and beyond, then the mauri is resilient and reciprocal, but if damaged or disrupted the whole mauri of the place is affected.[18] Additionally, a strong relationship between the whenua and people is needed for the establishment of forests where mauri can thrive.

Many Māori landowners are aiming to sustainably manage land for their future and their mokopuna.[19] Any land use activities that aim to do this will improve or maintain the mauri of an area thus having environmental and human implications for today. If forestry impacts the environment and therefore the mauri in some way, so too will it impact on the mana whenua of the land that the ngahere is on.

Tikanga

How Māori traditionally interact with a forest is determined by tikanga (the correct way of doing something) and tikanga is determined by understanding whakapapa and mauri. When applying tikanga, Māori as kaitiaki are responsible to care for the mauri of the forest in a way that represents their whakapapa to the forest. This requires that when something is taken from the forest potentially diminishing the mauri, something needs to be given back to rebalance the mauri, a concept some hapū define as tauutuutu.[20] The connection that an individual may have with the forest also needs to consider the connection that others have with that same forest. Therefore, the responsibility not only lies with the individual but also collectively.

[17] McGowan, 2021.
[18] McGowan, 2021.
[19] MfE, 2024a.
[20] Reid, 2021.

Breaches of te Tiriti o Waitangi led to large losses of Māori land and disrupted the traditional relationships Māori had with forests. Treaty settlements have led to the return of some land but much of it, as well as land that has remained in Māori ownership, is marginally productive. Notwithstanding that, the relationship with the whenua once again provides Māori with an opportunity to exercise rangatiratanga and kaitiakitanga, and afforestation is one way of doing this.

Today, many Māori landowners are trying to use the asset base represented by their land as a source of resilience for future generations. A significant percentage of whenua Māori is dedicated to commercial forestry that generates income and employment. In addition, Māori are the owners of large blocks held for customary purposes, thereby making major contributions to the protection and conservation of forest biodiversity.

For Māori who want to apply te ao Māori principles to forestry, reforesting land in diverse native rākau strengthens whakapapa links and improves the mauri of the land. For these Māori, exotics, like pine, lack association with their cultural identity and their whakapapa.[21] Native forests are seen as a central component of Māori whakapapa and tend to better support taonga species than exotic forests. Therefore, more value is placed on native forests than exotic forests. However, not all Māori hold the view that native rākau are the only option and there are large areas of whenua Māori planted in pine and alternative exotic species. Exotic species are therefore valued as a way of generating revenue and may be seen as having fewer negative impacts than some other land uses. This reflects the need for a balance between non-monetary values (like access to taonga species) and an economic return from the whenua.

What is clear is there is no one-size-fits-all and there is not one Māori forestry voice.

Drivers of past afforestation

The configuration of our planted forest estate today is the result of succeeding drivers of large-scale afforestation over the past century or so, starting with the need for a sustainable supply of wood for timber, pulp and paper. The unsustainability of New Zealand's native forest logging industry became evident in the late nineteenth and early twentieth centuries, as it was increasingly clear that the growth rates of native forests, coupled with the diminishing forest area, would be insufficient to meet the future demand for timber. This sparked interest in fast-growing exotic tree species to relieve pressure on native forests and protect future wood production.[22] Hundreds of different exotic species were planted experimentally to determine their suitability to New Zealand conditions.[23]

From the early twentieth century, radiata pine stood out due to its rapid growth rates, reliable propagation, and tolerance of a wide range of environmental conditions.[24] These properties made it suitable for high-volume wood production and an attractive investment opportunity. Large-scale plantings of radiata pine forests were undertaken throughout the twentieth century by the government and private companies in response to afforestation programmes and spikes in log prices.[25] Planting of other exotic species for wood production became relatively smaller scale as time went on. Native harvest volumes dropped from the mid-twentieth century as the first radiata pine plantations reached harvest age (Figure 2.1).

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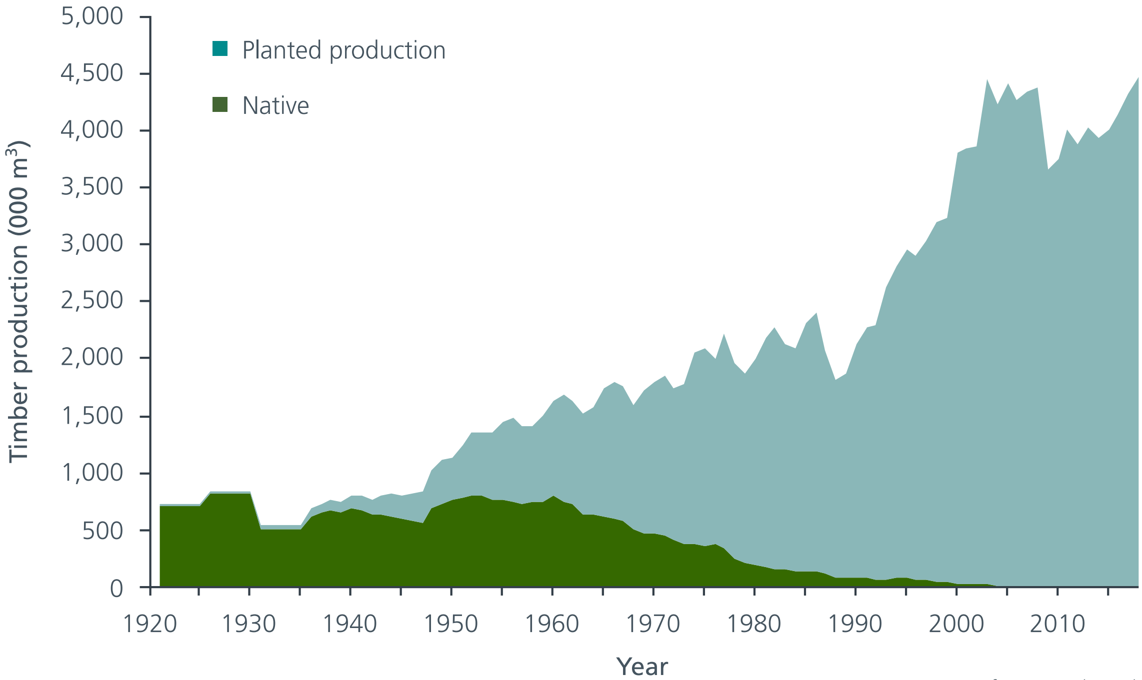
[21] Lyver et al., 2017.

[22] Killerby, 2003.

[23] 170 tree species were planted at Whakarewarewa Forest alone (Nicholas, 2007).

[24] This is despite radiata pine's native range being a thin strip of coastal land in California, covering just 8,000 ha (McDonald and Laacke, 1990).

[25] Particularly from 1925–1935, the 1960s to mid-1980s, and the mid-1990s (Roche, 2008).



Source: Data from MPI (2018)

Figure 2.1: Sawn timber from indigenous and planted production forests in New Zealand, 1921–2018. Data was collected five-yearly between 1921 and 1936.

Large-scale plantings have also been undertaken for soil protection purposes, particularly erosion control.[26] By the mid-twentieth century it was recognised that clearing forest from erosion-prone land increased soil erosion with the risk of downstream damage.[27] Since then, the reintroduction of trees to highly erodible landscapes for erosion control has been incentivised through various government-led initiatives. In some cases, this has led to large areas of highly erodible land being converted from pastoral systems to radiata pine production forest.[28] Less extreme interventions have involved planting trees with strong root systems (such as willows and poplars) at wide spacings on hill country to allow continued grazing underneath (a form of agroforestry) and fencing off gullies to enable native forest regeneration within grazed landscapes.[29]

In recent years the New Zealand Emissions Trading Scheme (NZ ETS) and voluntary markets have provided a new economic incentive to plant trees – offsetting carbon dioxide emissions from fossil fuel combustion. The ability of a forest to sequester and store carbon from the atmosphere as it grows is well recognised. NZ ETS-registered forest owners earn carbon credits for each tonne of

[26] We use the term 'establish' to refer to any purposeful growth of trees or forests – whether through planting or assisting natural regeneration of natives.

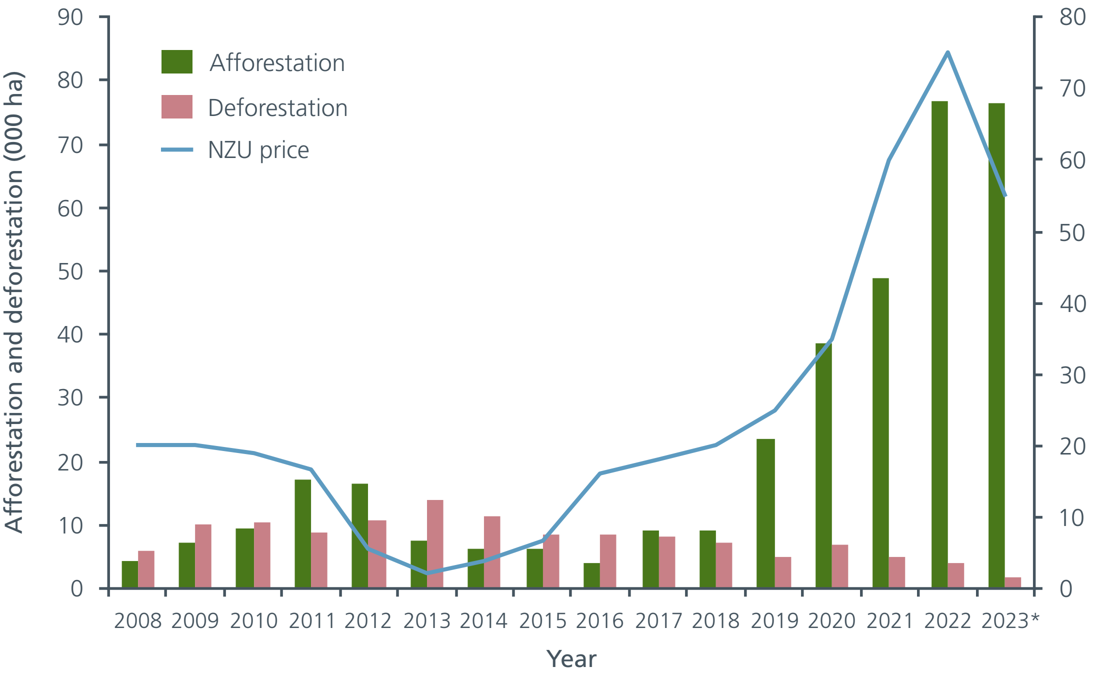
[27] The Soil Conservation and Rivers Control Act was enacted in 1941 to conserve soil resources, prevent damage from erosion, and protect property from flood damage. This included provisions around afforestation and browser control to protect vegetation.

[28] For example, in 1988, Cyclone Bola struck the East Coast causing severe damage to pastoral hill country and downstream infrastructure. Slow progress in planting forests for conservation and protection led to a refocus on commercial planting to achieve rapid afforestation, incentivised by government grants through the East Coast Forestry Project (ECFP) launched in 1992. Radiata pine was the preferred species of choice for planting. When the scheme was renamed the Erosion Control Funding Programme, the ECFP had incentivised 42,000 ha of planting (MPI, 2014).

[29] From 2019 to 2024, 33,291 ha was treated for erosion control through the Hill Country Erosion Fund (MPI, 2020; MPI, 2021; MPI, 2022b; MPI, 2023c; MPI, 2024b).

carbon sequestered by their forests.[30] The credits (or forestry units) can then be sold to emitters to enable them to meet their surrender obligations.[31] This has largely incentivised the planting of fast-growing exotic species, particularly radiata pine, as these sequester more carbon and earn more credits in the short-term to medium-term than slower-growing tree species.[32] The NZ ETS has made new production forests planted since 1989 more economically attractive (by adding an additional source of revenue alongside wood production) and has also triggered the establishment of so-called 'carbon forests' – plantations that are intended to be long-term carbon stores for climate mitigation purposes and not harvested.

Participation in carbon markets also disincentivises deforestation because forest owners are required to surrender credits if production forests are not replanted after harvest or if the stocks in carbon forests reduce. Figure 2.2 shows that higher carbon prices have coincided with significant increases in afforestation and decreases in deforestation.



Source: Adapted from Manley, 2024

Figure 2.2 Actual post-1989 forest planted, deforestation, and average New Zealand emission unit (NZU) price in that year, 2008–2023. Note: 2023 afforestation and deforestation rates are projections based on the Afforestation and Deforestation Intentions Survey 2023.[33]

[30] The NZ ETS includes the above-ground and below-ground carbon stored in trees (including the roots) and their coarse woody debris. The carbon stored within forest soils is not included.

[31] The actual number of credits earned over time depends on the forest type, size and NZ ETS accounting system.

[32] Under the NZ ETS it is estimated that on average exotic forests in New Zealand contain around 650 tonnes of CO_2 equivalent per hectare at age 28 under typical silvicultural management, while native forests contain about 240 tonnes per hectare at the same age. The exotic estimate is averaged across radiata pine, Douglas fir, exotic softwoods and exotic hardwoods. Data from Te Uru Rākau – New Zealand Forest Service (2020).

[33] Manley, 2024; MPI pers. comm., Afforestation and deforestation request, 23 December 2024.

Some native afforestation has occurred for commercial purposes, such as honey and timber production, and non-commercial purposes, such as enhancing biodiversity, improving water regulation and restoring the mauri of the whenua. This has been relatively small scale compared to the exotic forest estate, although programmes, such as the government-funded One Billion Trees programme, have given a boost to native afforestation efforts.[34] A survey of over 120 planted stands of native trees and shrubs found the main tree species that have been planted are tōtara, rimu, kauri, kahikatea, red beech (*Fuscospora fusca*), black beech (*F. solandri*), karaka (*Corynocarpus laevigatus*) and pūriri (*Vitex lucens*).[35]

Periods of increased deforestation of the planted estate have also occurred. For example, following a peak in production forest area of 1.82 million hectares in 2004, a dairy boom coincided with a fall in log prices and uncertainty about the evolution of climate policy.[36] This caused an increase in conversion from forestry to alternative land uses, largely dairy.[37] However, this had a minor effect on the overall planted forest area, which has since almost completely recovered to 2004 levels (Figure 2.3).

The overall picture of forestry in New Zealand has been one of rapid land use change in different regions in response to short-term market and regulatory signals. Figure 2.3 shows afforestation since the 1920s in relation to various drivers.

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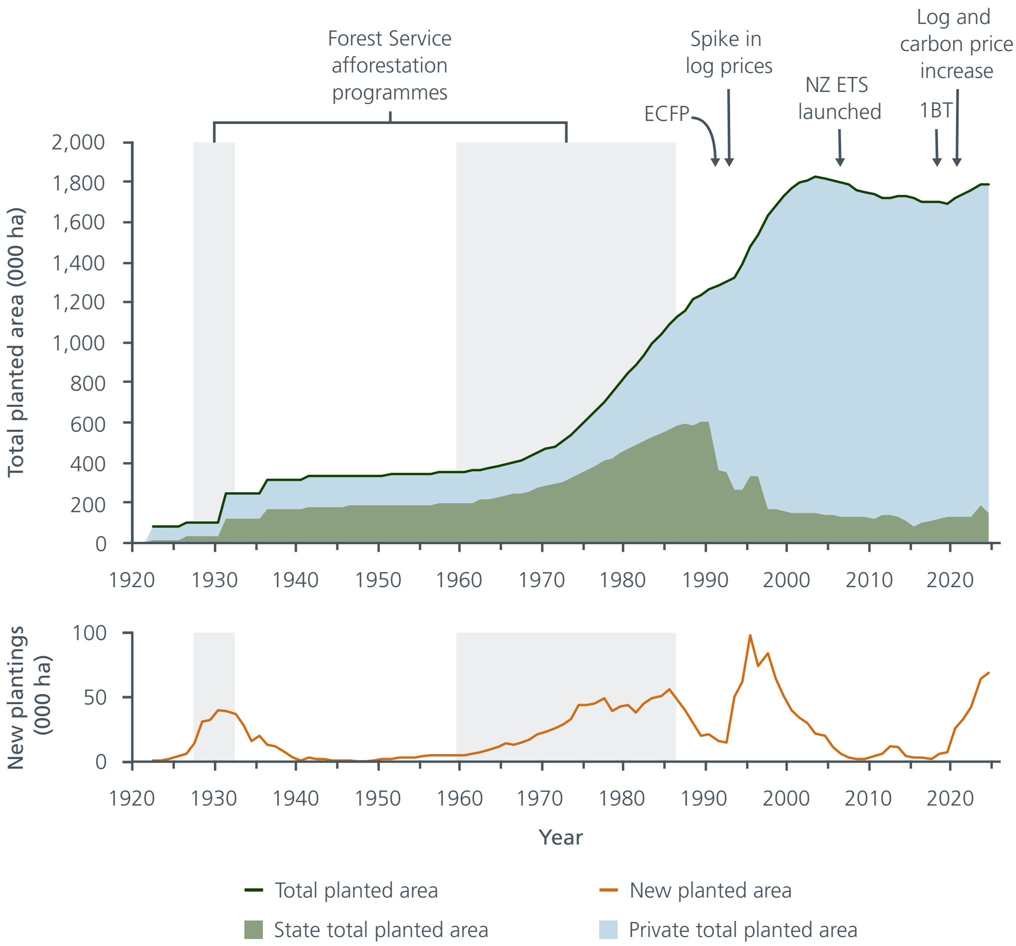
[34] Data from CCC, 2021c, https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/inaia-tonu-nei-a-low-emissions-future-for-aotearoa/modelling/

[35] See Tāne's Tree Trust, https://www.tanestrees.org.nz/projects/national-survey-of-indigenous-plantations-for-carbon-accounting/

[36] Canopy, 2025; Parker, 2019.

[37] MAF, 2009.



Source: Data from MPI et al., 2024

Figure 2.3: New plantings and total planted forest area over time in relation to the introduction of various regulatory and market incentives. ECFP was the East Coast Forestry Project, and 1BT is the One Billion Trees programme.[38]

Several mechanisms have driven afforestation on whenua Māori in the past. As a result of land confiscations and the resulting Treaty settlement process, whenua Māori that was returned to Māori ownership largely consists of marginal unproductive land where afforestation (mostly for carbon credits) was the only opportunity to make an economic return on the land. Crown forest land and other parcels of commercially viable land were also offered as part of redress packages. Additionally, some parcels of previously cleared whenua Māori that are landlocked have been left to regenerate naturally.

More recently, an increasing number of Māori landowners are taking te ao Māori approaches to managing their land and view forestry as one way to protect Papatūānuku by converting land once in pasture to native forest.

[38] Manley, 2024.

Current trajectories for and drivers of afforestation

Current economic and policy settings are expected to continue to drive ongoing land use change, largely through the economics of wood and carbon offsetting.

Short-term trajectories for afforestation

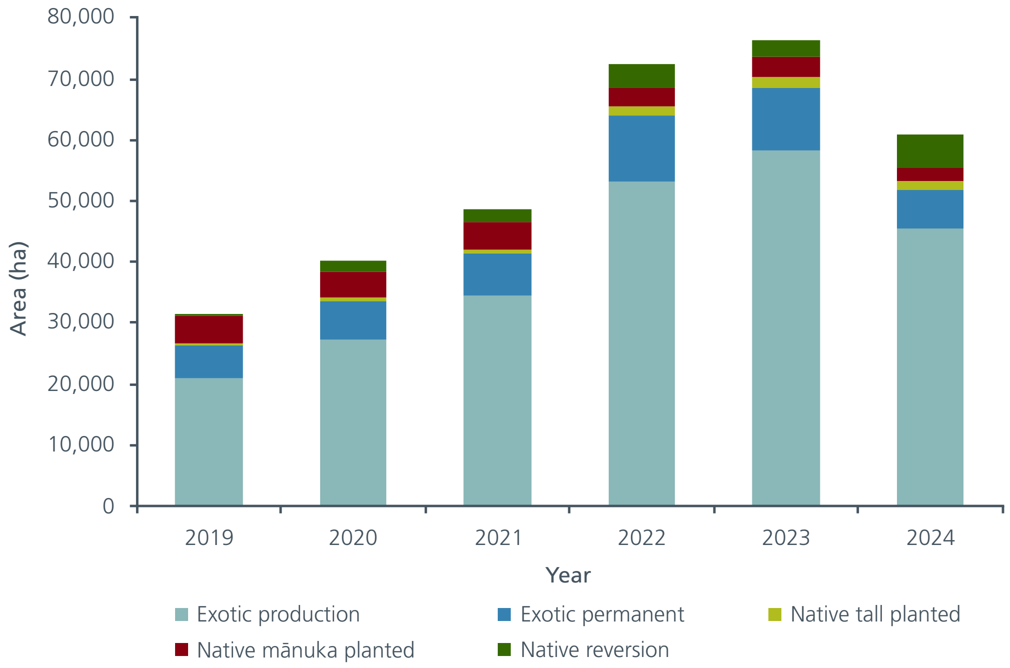
MPI conducts an annual survey of afforestation and deforestation intentions which informs government projections. The survey only reaches known operators involved in afforestation (such as large-scale growers) so will underestimate actual planting rates, but it gives an indication of scale and trends over time. While survey participants are asked for their afforestation intentions out to 2030, greater confidence can be placed on shorter-term intentions. In 2024, total exotic afforestation was expected to be 51,800 hectares with 88% intended for production and 12% intended for permanent forest.[39] This represents a lower exotic afforestation rate than the previous two years but is still a higher rate than occurred in 2019, 2020 or 2021 (see Figure 2.4). Radiata pine remains the dominant plantation species, making up at least 90% of exotic afforestation over the past three years, although there are indications that this may decline slightly in 2024.[40]

Native afforestation remains relatively small scale. The intentions survey indicates that native afforestation may increase to 9,000 hectares in 2024 due to increased natural reversion, although in some cases this reflects intentions to register reverting land in the NZ ETS rather than take action to support new reversion. Reductions in mānuka planting were reported to be caused by a fall in mānuka honey prices.[41]

[39] Permanent forest means forest that is not intended for clear-fell harvest for at least 50 years. This data only includes estimates and intentions from survey participants. Intentions can differ significantly from actual planting rates, e.g. in 2023 the actual area of exotic afforestation (68,500 ha) was much less than intentions stated in the 2022 survey (88,000 ha) (Manley, 2024, p.7).

[40] The intentions survey suggests radiata pine will make up around 86% of exotic afforestation in 2024, whereas the proportion of redwoods and eucalypts will increase slightly (Manley, 2024, p.1).

[41] Manley, 2024, p.2,15.



Source: Data from Manley 2022, 2024

Figure 2.4: Afforestation estimates (2019–2023) and intentions (2024) in hectares for exotic species and native species, split by category.

Longer-term trajectories for afforestation

Longer-term afforestation projections are less certain due to uncertainties around land use restrictions, NZ ETS policy settings and the carbon price.[42] However, the NZ ETS is projected to remain a key driver of exotic afforestation under current settings. When the first emissions budgets were set in early 2022 with an assumed carbon price of $35 per tonne, the Government projected that an average of 32,000 hectares of new exotic forests would be planted per year from 2022 to 2030. Recent carbon prices and exotic afforestation rates have well exceeded these initial projections.[43] In a 2023 Cabinet paper it was reported that the NZ ETS was projected to incentivise between 410,000 and 670,000 hectares of afforestation by 2035, largely through exotic afforestation.[44] The Climate Change Commission's 2023 updated demonstration path to net zero 2050 now includes 500,000 hectares of new exotic forests being planted between 2021 and 2035.[45]

The exotic afforestation projections have been met with scepticism from the forestry industry, which argues that policy and regulatory measures are constraining investment in forestry.[46] While the exact numbers are likely to vary, New Zealand is currently on a trajectory towards establishing large areas of new exotic production and carbon forests. These forests are likely to consist mostly of radiata pine plantations given the species' current dominance and its economic appeal for both wood production and carbon sequestration.

[42] Participants in the intentions survey cite these as the main uncertainties affecting future planting decisions (Manley, 2024).

[43] Since 2022, carbon prices have fluctuated between $37 and $88.50 (Carbon News, 2025).

[44] Shaw, 2023.

[45] The updated demonstration path was included in the Climate Change Commission's advice for the Government's second emissions reduction plan (CCC, 2023a).

[46] For example, see the New Zealand Forest Owners Association submission on the NZ ETS review 2023 (NZFOA, 2023c).

Little native afforestation is projected to occur in response to the NZ ETS, due to lower returns and higher upfront costs. MPI's intentions survey suggests native afforestation will drop to less than 1,000 hectares per year after 2025.[47] While the intentions data typically shows a reduction in planting over time as growers have less certainty looking further into the future, this is a fraction of the rate modelled in the Climate Change Commission's 2021 demonstration path, which assumed native afforestation rates scale up to 25,000 hectares per year by 2030 – three times greater than the highest level achieved in recent years.[48]

Where could new forests go?

There are a variety of estimates of the amount of currently unforested land in New Zealand that could be suitable for afforestation. An analysis by MPI in 2024 identified areas of private land and whenua Māori that are potentially suitable for afforestation by applying the following criteria (as well as several exclusions):[49]

- Low producing grassland and grassland with woody biomass classes from Land Use Mapping (2020).[50]
- Land Use Capability (LUC) classes 6 to 8.[51]
- Erosion Susceptibility Classification (ESC) class of Very High (Red Zone) excluded for production exotics, all ESC classes included for all other trees.
- Areas with mean annual rainfall of 500–2,000 mm for production exotics and areas with over 500 mm for all other trees.

This analysis identified around 2.44 million hectares of pastureland that may be suitable for afforestation. About 1.66 million hectares would be potentially suitable for planting permanent forest or production forest of various species, and another 770,000 hectares would only be suitable for planting new permanent forest (including steep and/or erosion-prone land). LUC class 6 had the largest afforestation potential (Table 2.1).[52]

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47 Manley, 2024, p.15.

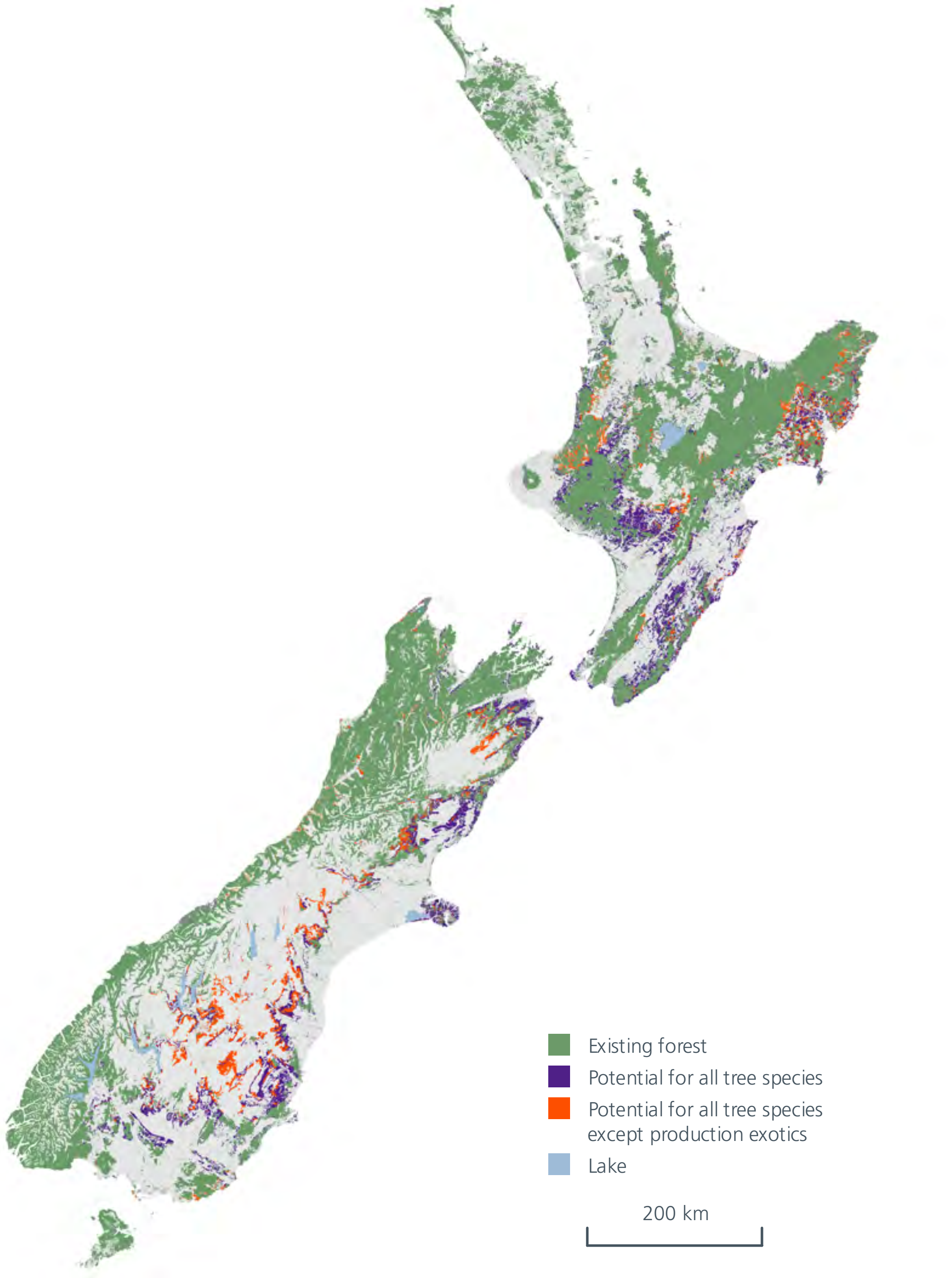
48 CCC, 2021b, p.44. The same assumption was made in an updated demonstration path included in the CCC's advice on the second emission reduction plan (CCC, 2023a, p.304).

49 MPI, pers. comm., 22 November 2024. MPI excluded: land with Environmental Limiting Factors for tree growth; altitudes over 700 m in North Island and 650 m in South Island for production exotics and above 1,250 m for other trees; slopes of over 40°; land cover classes of forest, settlements, orchard, vineyard or other perennial crops, water bodies, permanent snow, ice, sand or gravel, tussock, alpine grasslands, and transport infrastructure; and ecologically sensitive areas provided by DOC. Economic modelling was not included in the analysis.

50 See MfE, 2024b.

51 The LUC class system is an assessment of the land's capability for use, while allowing for its physical limitations, and its versatility for sustained production. There are eight classes with limitations to land use increasing, and versatility for land use decreasing, from LUC Class 1 to LUC Class 8 (Manaaki Whenua – Landcare Research, https://lrp.landcareresearch.co.nz/topics/understanding-luc/an-introduction-to-luc).

52 The area of land identified as suitable for afforestation (based on land use data from 2020) may include some areas no longer available, as around 238,000 ha of new forests were established between 2020 and 2023 (Table 2.1 above). Some of this afforestation may have occurred on land outside the model's parameters (e.g. on high-producing grassland, LUC classes 1–5, etc).



Source: MPI, pers. comm., 15 November 2024

Figure 2.5: Private land potentially suitable for afforestation.

Table 2.1: Area (hectares) of private land with afforestation potential in New Zealand that meets the criteria listed above, broken down by Land Use Capability (LUC) Class, rounded to the nearest 1,000 hectares.[53]

Afforestation potential	LUC Class 6	LUC Class 7	LUC Class 8	Grand total
Potential for all tree species except production exotics (ha)	452,000	297,000	25,000	774,000
Potential for all tree species (ha)	1,232,000	424,000	9,000	1,664,000
Total (ha)	**1,683,000**	**721,000**	**34,000**	**2,438,000**

Other assessments have applied different assumptions and generated different numbers, but all identify large areas of private land that could be well-suited to afforestation.[54] Additionally, the Department of Conservation (DOC) has estimated there may be around 59,000 hectares of Crown land (including public conservation land and land held by the Ministry of Defence and the New Zealand Transport Agency) that could be suitable for afforestation of some sort.[55]

The MPI analysis identified large areas of the South Island that could be suitable for afforestation (e.g. around 476,000 hectares in Otago and nearly 473,000 hectares in Canterbury), but most recent afforestation has taken place in the North Island.[56] Between 2019 and 2023, 73% of exotic afforestation occurred in the North Island, with most planting taking place in central, eastern and southeastern parts of the island. Similarly, 93% of native afforestation over the same period occurred in the North Island, particularly in Hawke's Bay and central and southwestern areas.[57]

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53 MPI, pers. comm., Area suitable for afforestation, 22 November 2024.

54 A 2018 Cabinet paper about the One Billion Trees programme stated there were about 4 million ha of lower producing farmland that could be suitable for afforestation (Jones, 2018). A 2020 report from The Aotearoa Circle estimated there are around 2.8 million ha of unforested private land in LUC classes 6–8 that could support tree species (The Aotearoa Circle, 2020).

55 Based on desktop estimations from 2017 that require ground truthing. A recent request for information (ROI) that sought interest from private parties in planting trees on Crown-owned land included a map of indicative areas that could be suitable for afforestation (New Zealand Government, 2024). The Department of Conservation (DOC) previously noted that exotic forestry is incompatible with the purpose of public conservation land (CCC, 2021a).

56 MPI, pers. comm., 22 November 2024.

57 Manley, 2024, p.1.

3


Monterey pine *(Pinus radiata)*

What could large new areas of radiata pine forests mean for the environment?

Any type of large-scale afforestation (exotic or native) will have a range of environmental effects that depend on the local context, the purpose of the forest and how it is managed. This chapter considers the wider environmental impacts (positive and negative) of radiata pine forests and some of the risks they face.

Sediment and woody debris

Planting radiata pine forests on cleared land can provide soil protection services once the trees are established. That will usually be achieved within eight years of planting.[1] Trees reduce sediment loss by intercepting raindrops on the tree canopy (some of which then evaporate back into the atmosphere) and through root systems that hold the soil in place while allowing water to infiltrate deeper into the ground.[2] Research shows that radiata pine forests have lower overall sediment yields than pasture across a full rotation.[3] During severe weather events, mature pine forests can provide a similar level of soil protection to mature native forests and greatly reduce the risk of landslides, although this depends on local context.[4] For example, a rapid assessment of land damaged by Cyclone Gabrielle in 2023 estimated that land under exotic forest in southern Hawke's Bay and northern Wairarapa was 80% less likely to experience landslides than high-producing grassland, but in Gisborne exotic forest cover was ineffective at reducing landslide risk.[5] More detailed analyses are needed to tease apart the contribution of other factors, such as topography, geology, forest age and land use history.

Clear-fell harvesting removes the soil protection provided by standing trees and any underlying vegetation, which is typically destroyed by the felling operation. There is a spike in sedimentation before, during and after harvest due to disturbance of the soil by earthworks and harvesting itself. Increased sedimentation can last for several years and exceed sediment loss from pasture, even in the absence of extreme events.[6,7] The land remains vulnerable to heavy rainfall for a number

1 Alfeld et al., 2018.

2 Intercepted water that doesn't evaporate from the canopy reaches the soil more slowly, reducing the force of it hitting the ground. Forests also provide shade and leaf litter that supports greater retention of moisture in the soil, reducing surface flows.

3 Fahey et al., 2003.

4 Marden and Rowan, 1993; Gibbs and Woodward, 2017.

5 In comparison, native forest cover reduced landslide risk by 90% in southern Hawke's Bay/northern Wairarapa and 50% in Gisborne (McMillan et al., 2023).

6 Gibbs, 2008.

7 Baillie and Neary, 2015.

of years after harvesting, with maximum vulnerability two to four years post-harvest.[8] This so-called 'window of vulnerability' lasts until a closed canopy and protective root system have re-established. Under extreme conditions, such as very high rainfall on highly erodible soils and steep slopes, land can remain vulnerable to landslides for longer periods.

The impacts of increased sediment yields following harvest are intensified when combined with woody debris, which may be left over from harvest (i.e. slash) or caused by fallen trees and branches and mobilised during severe weather events.[9] If high volumes of sediment and woody debris enter waterways, they can have devastating and lasting impacts on the environment and people's lives.[10]

Carbon forests are not clear-fell harvested, so they don't go through cyclical windows of vulnerability like production forests. Leaving radiata pine trees standing might therefore provide longer-term soil protection than production forests; alternatively, it might lead to large, heavy trees that destabilise slopes. Pine plantations have not, historically, been left unharvested and there has been little research on this topic, so possible impacts are unclear. While carbon forests do not produce slash, they can still produce large volumes of woody debris when the trees die – either naturally or due to events, such as landslides, disease or extreme weather. Wind damage may be particularly relevant in this case, as historically the greatest damage from extreme wind has been concentrated in radiata pine stands over 30 years old.[11]

Box 3.1: Environmental impacts of Cyclone Gabrielle, February 2023

From 12–14 February 2023, ex-tropical Cyclone Gabrielle brought extreme rainfall and winds to the already saturated northern and eastern areas of the North Island, breaking several weather records.[12] Some areas received twice as much rain during the most intense 24-hour period of Cyclone Gabrielle as during the peak of Cyclone Bola in 1988. The extreme conditions caused extensive flooding and as many as 850,000 landslides nationally.[13]

The most severe flooding and damage were seen in Hawke's Bay and Tairāwhiti. The Esk Valley and eastern areas of Wairoa received more than 500 mm of rain, and some areas in Tairāwhiti received more than 400 mm of rain and wind gusts exceeding 90 km/hr. In the Esk River catchment, landslides are estimated to have eroded approximately 5.7 million tonnes of soil, half of which entered waterways and led to an 80 cm-deep layer of sediment on the flood plain.[14] Similar impacts were felt across the East Coast.

[8] It was previously thought that maximum vulnerability to landslides occurred 2–8 years post-harvest (e.g. Phillips et al., 2012), but recent research by MWLR suggests the window is narrower (Manaaki Whenua – Landcare Research, 2024).

[9] 'Woody debris' describes all sources of dead wood, whether 'natural or man-made', including fallen trees, logs, branches, twigs, bark and root balls. It includes material, such as toppled and fallen trees, unrelated to any forest activity. Woody debris occurs in all forests and on land uses that have trees and other woody vegetation. 'Slash' is a type of woody debris and refers to tree waste left behind after commercial forestry activities (MPI, 2024a, p.6).

[10] Parata et al., 2023.

[11] Scion, 2012.

[12] NIWA, 2025a.

[13] University of Canterbury, 2024.

[14] McMillan et al., 2023.

Source: PCE

Figure 3.1: Locals in the Uawa catchment described seeing whole trees being carried by flooded waterways, carving out riverbanks as they went.

Landslides were most common in pasture and recently harvested forests. Areas of mature native forest consistently provided the best protection against landslides compared with other land covers, typically reducing the landslide risk by 90% compared with pasture (albeit with less success on Tairāwhiti hill country where they provided a 50% reduction). The effect of exotic forests on reducing landslide risk was more variable (effective in some regions; ineffective in Tairāwhiti.[15]

During Cyclone Gabrielle, an estimated 1.4 million tonnes of large woody debris were mobilised in Tairāwhiti and around 180,000 tonnes of debris ended up on beaches, in river mouths and around bridges in Wairoa.[16] The combination of woody debris and sediment caused extensive damage to the natural environment, infrastructure, livelihoods and lives.

Two post-cyclone assessments in the Hawke's Bay found the composition of woody debris varied between catchments but that, on average, pine made up the greatest proportion of woody debris (48% according to the Hawke's Bay Forestry Group; 56% according to the Hawke's Bay Regional Council).[17] Willows, poplars, native species and fence posts made up the remainder. Slash from pine plantations made up a small proportion of woody debris (<5%). This suggests that most pine debris came from trees that were damaged or toppled during the storm, rather than material leftover from harvest. Foresters noted that even mid-rotation trees (15–18 years old) previously considered 'safe' were blown over.

[15] McMillan et al., 2023.
[16] Gisborne District Council, 2025; Wairoa Recovery, 2025.
[17] Interpine Innovation, 2023; Roper, 2023.

Water yield and quality

The impacts of afforestation on hydrology within catchments are complex, and there has been little research into the effects of different tree species, silvicultural practices, past land uses and local contexts. In general, any kind of afforestation lowers the average annual water yield from a catchment compared to pasture or tussock grassland. Afforestation reduces maximum flow rates and run-off during heavy rainfall by storing water in the catchment, which is then released hours, days or months later.[18] The evidence for impacts on lower flow rates is less conclusive and an area of active research as part of the Forest Flows research programme at Scion. The impact afforestation has on ecosystems and downstream water users will differ between drier and wetter regions. Under extreme rainfall conditions, forests can play an important role in reducing flood risk. High-resolution data from Mahurangi Forest near Auckland shows that nearly 60% of the rain that fell on the catchment during Cyclone Gabrielle was stored in the radiata pine forest rather than running off into waterways.[19]

International research suggests that fast-growing exotic plantations are often associated with lower annual water yields compared to regenerating native forests.[20] Studies of radiata pine afforestation in New Zealand have found variable reductions (of 20–80%) in annual water yields compared to pasture.[21,22] The impact of silviculture and harvesting on water yields is also variable. A review of international research found that harvesting typically increases annual water yields for a period of time, but its effect on peak and low flows is inconsistent and difficult to predict.[23] One study in New Zealand found that thinning radiata pine forest increased water yields, with clear-fell harvesting leading to water yields that exceeded those from pasture for several years after harvest.[24]

Planting around waterways is a common activity on farms to improve water quality. Afforestation of pasture with radiata pine has been shown to improve water quality in streams by lowering water temperatures and concentrations of nutrients and sediments, which can support the development of sensitive invertebrate communities.[25,26] But clear-fell harvesting reduces water quality by increasing sediment loads, turbidity, light levels, water temperatures and nutrients (particularly nitrogen and phosphorus) for several years.[27] This can result in a shift towards invertebrate communities typically associated with pasture. The impacts of harvesting on water quality can be mediated to some extent by retaining riparian buffers.[28]

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[18] Meason et al., 2019.

[19] Research undertaken as part of the Forest Flows Research Programme (Scion, 2023b).

[20] Jones et al., 2022.

[21] Hughes et al., 2020; Beets and Oliver, 2007; Davie and Fahey, 2005; Fahey and Payne, 2017.

[22] Some older forest hydrology studies did not measure groundwater flow. Recent research in New Zealand as part of the Forest Flow Research Programme at Scion has identified this as an important path for water to leave forested catchments (Scion, 2024b).

[23] Stednick and Troendle, 2016.

[24] Beets and Oliver, 2007.

[25] Although herbicide use during afforestation can lead to short-term contamination of waterways.

[26] Baillie and Neary, 2015; Meason, 2024.

[27] Larned et al., 2020.

[28] Larned et al., 2020.

Biodiversity

Meeting New Zealand's domestic structural timber needs through fast-growing exotic species removes the need to log remnant and secondary native forests, leaving these areas available for biodiversity conservation (although the expansion of plantation forestry has been an important driver of recent native deforestation).[29]

Pine forests can also foster indigenous biodiversity directly, albeit less than native forests. While exotic grasslands support little native biodiversity, radiata pine production forests can support healthy populations of native species, particularly where pests are well-managed.[30] A number of studies have demonstrated that radiata pine forests managed for timber production can support abundant natural native regeneration, although this varies greatly between sites.[31] Plantations can support high densities of kiwi. Research from the 1980s found kiwi in Waitangi Forest in Northland were among the heaviest recorded at the time, suggesting ample food availability.[32] Breeding populations of kārearea (New Zealand falcon) have been found in high densities in pine plantations – Kaingaroa Forest supports the highest-known density of the species. Both of New Zealand's endemic bat species have been found in plantation forests, although little is known about how forestry activities affect them. Recent research has shown that pine plantations can support a high diversity of beetles across multiple rotations, although this is about 30% lower than native forests.[33] Pine forests can also provide important habitats for breeding Hooker's sealions on mainland New Zealand.

Although exotic afforestation can offer biodiversity benefits over exotic grassland, tussock grasslands can support considerable native biodiversity. Exotic afforestation in these native ecosystems could lead to losses in local biodiversity and the development of a closed canopy in some areas that may not have been dominated by forests in the past.[34,35]

Clear-fell harvesting a plantation represents a major disturbance to biodiversity by removing the mature pine canopy and destroying any understorey that has developed. While the understorey may recover during the subsequent rotation, forest-dependent species that rely on closed-canopy conditions will be displaced or killed during the immediate harvesting process. Mobile species (such as birds and bats) may be able to move or be relocated to nearby unharvested areas, particularly in larger plantation forests with different aged stands. Some species, such as kārearea, benefit from the openings created by harvesting radiata pine stands as they provide foraging and nesting habitat. Kiwi have been found using slash piles and cutover areas, but little is known about how

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29 Almost half (45%, ~16,000 ha) of the 35,000 ha of native forest that was converted to other land classes between 1996 and 2018 went into exotic forest. ~15,000 ha (42%) went into exotic grassland. Most of the converted native forest was lowland scrub communities (dominated by broadleaved hardwoods) rather than tall forest. For more information, see the Stats NZ website (https://www.stats.govt.nz/indicators/indigenous-land-cover).

30 Although native forests provide the greatest biodiversity benefits (Allen et al., 2013).

31 Brockerhoff et al., 2003.

32 Kleinpaste and Colbourne, 1983.

33 Scion, 2023c.

34 Day et al., 2023.

35 From 1996 to 2018 around 18,000 ha of tussock grassland was converted to exotic forest (276,000 ha of exotic grassland was converted to exotic forest over the same period). There is about 2.34 million ha of tussock grassland in New Zealand (Stats NZ, 2021).

kiwi behaviour and survival is affected by clear-fell harvest in radiata pine forests.[36,37] Research is currently underway to explore this, led by Save the Kiwi.[38]

Plantation forests can also contain significant areas of native habitat, such as remnant or secondary native forest and wetlands. Forest Stewardship Council (FSC) certification requires that at least 10% of certified forests are set aside as reserves that are managed for pest control and restoration.[39] The New Zealand Forest Owners Association estimates that, on average, 13% of land managed by its members is set aside in reserves.[40]

Almost all research into biodiversity in pine plantations in New Zealand has occurred in forests managed for timber production. It is unclear to what extent this research could apply to carbon forests. The absence of periodic clear-fell harvesting could support long-term biodiversity values. However, planting and maintaining forests at higher stocking rates to maximise carbon sequestration could reduce sub-canopy light levels and restrict development of a native understorey until the forest naturally self-thins.

Source: PCE

Figure 3.2: Radiata pine production forests can support healthy populations of native species, particularly where pests are well-managed. Kiwi, kārearea, native bats and even Hooker's sea lions have all been found in pine plantation forests.

[36] Best practice guidance recommends avoiding harvest during breeding periods to mitigate impacts on kiwi. See Sporle, W., 2016, https://rarespecies.nzfoa.org.nz/site/assets/files/1088/final_forestry_guidelines_kiwi.pdf

[37] Research from the 1980s found that clear-felled areas were vacated by kiwi for 6–9 weeks, likely due to changes in food availability (Kleinpaste and Colbourne, 1983).

[38] See Sporle, 2016.

[39] FSC certification signifies that the wood product comes from environmentally and socially acceptable sources and improves access to international timber markets. Approximately 55% of plantation forests in New Zealand are FSC certified (https://www.nzfoa.org.nz/plantation-forestry/certification; https://fsc.org/en/newscentre/general-news/fsc-forest-stewardship-standard-for-new-zealand-published).

[40] NZFOA, pers. comm., 25 November 2024. The NZFOA represents owners of production forests in New Zealand.

Spread of mammalian pests and weeds

Without adequate pest control, forests of any sort can act as corridors and refuges for introduced mammals (like deer, goats, pigs and possums) and weeds (like old man's beard, wandering willie and wild ginger). This can have negative impacts on the forest itself and on the wider landscape. However, with adequate pest control, forests can have low pest densities. The risk of forests supporting pests and weeds will depend on pressures in the surrounding landscape and the management of the forest.

Exotic trees can act as a source of weeds themselves. Pine plantations can cause serious issues by self-seeding outside of planted areas, a behaviour known as 'wilding'. In New Zealand, wilding conifers cover 1.8 million hectares (a similar area to the entire plantation forest estate) and are challenging to get rid of once established.[41] Many of the wilding conifer infestation issues today are the result of legacy plantings of high-risk wilding species. This includes lodgepole pine (*Pinus contorta*), which can self-seed at three years old, and Douglas fir, which is shade-tolerant and can invade native forests. Radiata pine has a lower wilding risk than some conifer species due to its lower spreading vigour and higher palatability to browsers.[42] However, radiata pine invasions have been observed in open areas where grazing pressure is low and in uncommon ecosystems with low statured vegetation, including geothermal areas, gumlands and inland cliffs, scarps and tors.[43] The siting of any new radiata pine plantations (or those comprising other wilding risk species) is therefore critical, as is the ability to regularly monitor and manage any potential spread. As carbon forests are often established in inaccessible areas unsuitable for production forestry, monitoring these plantations for early signs of wilding spread may be particularly challenging.

Controlling pests and weeds within forests requires an ongoing source of revenue – something that exists for production forests, but not for carbon forests once the maximum carbon stock has been achieved (which will vary depending on how the forest is managed). Ongoing pest animal control may be important for permanent pine carbon forests, as browsing pressure could reduce regeneration to a level that is insufficient to counteract carbon losses from natural aging and mortality. The long-term consequences of browsing pressure on forest carbon are complex and difficult to predict.[44]

Pests and diseases of radiata pine

As the dominant plantation species in New Zealand, radiata pine receives high levels of investment in research and development, including biosecurity surveillance, readiness and response.[45] Therefore, it could be argued that afforesting with radiata pine has a lower biosecurity risk than with some other species. But planting large areas with a single tree species increases the potential damage and rate of spread should a serious pest or disease establish in the country.

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[41] DOC, 2025.

[42] According to the Wilding Risk Calculator, radiata pine scores 1 (out of a maximum of 5) for spreading vigour and 1 (out of 4) for palatability. Douglas fir scores 4 and 3, and lodgepole pine scores 5 and 2, respectively. A lower score means lower spread risk. Siting, grazing pressure and downwind vegetation also affect spread risk (Paul, 2015).

[43] Bellingham et al., 2022.

[44] Peltzer and Nugent, 2023.

[45] The Forest Growers Levy is a levy on national timber sales that generates funding for research, development and promotion of New Zealand forestry. It imposes a levy of 33 c per tonne of harvested wood products and raises around $10 million per year. In 2024, roughly $1 million was spent on forest biosecurity (Forest Growers Levy Trust, 2024; https://fglt.org.nz/the-levy/levy-vote-2024).

Pest insects are regularly intercepted at New Zealand's borders, and incursions do occur. While most pest insects have had little effect on radiata pine in New Zealand, some (such as the European sirex wood wasp) have caused serious damage. The risk of new, more damaging insect pests arriving is ever-present. Of particular concern are the various species of bark beetles that are causing severe damage to pine plantations overseas, such as the red turpentine beetle (*Dendroctonus valens*) in China, the five-spined bark beetle (*Ips grandicollis*) in Australia and the mountain pine beetle (*Dendroctonus ponderosae*) in Canada.[46,47]

Currently, the greatest health issue for radiata pine in New Zealand is disease management. Several needle diseases are present in New Zealand, such as red needle cast (caused by a *Phytophthora* pathogen) and needle blight (caused by *Dothistroma septosporum*). Red needle cast was first recorded in New Zealand in 2008 and now affects most areas of the North Island and many parts of the South Island, with the most severe damage being reported in central and northeastern regions of the North Island.[48] The severity of the disease is strongly driven by climate – prolonged wet conditions in recent years have provided favourable conditions for the pathogen, leading to widespread and persistent infections.[49]

A disease of serious concern overseas is pine pitch canker, a fungal infection caused by *Fusarium circinatum* that has led to extensive dieback in radiata pine and other pine species, and has been reported in the United States, Chile, South Africa, Spain and Japan. It has been described as a significant threat to the exotic forest industry in New Zealand.[50] Another disease, brown spot needle blight (caused by *Lecanosticta acicula*), has caused severe damage to radiata pine forests in North America and Europe, with both severity and spread increasing in response to climate change.[51] Pathogens such as these have made radiata pine uneconomical in some traditional planting regions around the world.[52]

Stressed forests are more vulnerable to damage from pests and diseases. Other pressures, such as flooding, prolonged drought and wind damage, can stress forests. Overcrowding can also stress trees, as was seen during the sirex wasp outbreak in unthinned radiata pine plantations during the mid-twentieth century.[53] The high stocking rates associated with radiata pine carbon forests may therefore make them more susceptible to health issues.

Even if pests and diseases don't kill trees, they can affect the positive environmental benefits that forests provide and have economic impacts through reducing wood quality or a forest's carbon storage capacity.

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[46] The mountain pine beetle has attacked 50% of the total volume of commercial lodgepole pine in British Columbia since the 1990s (Natural Resources Canada, 2025).

[47] In Australia, healthy radiata pine trees have been killed by mass attacks of five-spined bark beetle. The red turpentine beetle has also been recorded as attacking radiata pine. The effects of the mountain pine beetle on radiata pine are unclear, but it affects at least 13 other pines and it is likely that radiata is a suitable host (Brockerhoff and Bulman, 2014, Scion, 2023d).

[48] Watt et al., 2024.

[49] Copper fungicide is emerging as a potential control treatment for red needle cast and has been used to control Dothistroma since the 1960s.

[50] MPI, 2022d.

[51] Ogris et al., 2023.

[52] NZFOA, 2023.

[53] The sirex wood wasp was first detected in New Zealand in 1900 and caused severe damage to overstocked radiata pine plantations between 1946 and 1951, particularly during drought conditions. Biological control agents, silvicultural methods and appropriate siting have been effective at reducing the impact of the wasp and it is now considered a minor pest (Bain et al., 2012).

Source: Ross Younger, Flickr

Figure 3.3: Multiple fires burnt in the Port Hills above Christchurch in 2017. Fires in forests can be more intense that those in grasslands due to greater fuel availability.

Wildfires

Naturally occurring wildfires (e.g. caused by lightning strike) are rare in New Zealand. Humans have been responsible for most of the wildfires that have occurred over the past 30 years. Most wildfires start in grasslands, which are more flammable and have a greater rate of fire spread than scrublands or forests. The leading cause of wildfires over recent decades has been prescribed pile burns that have escaped.[54] Infrastructure and machinery, such as powerlines and motors, can also cause wildfires.[55] This makes the surrounding landscape an important determinant of fire risk (likelihood of ignition) of forests. Most wildfires in plantation forests do not originate from forestry activities but come from external sources. Human activity within forests can cause fires, through:

- forestry-related activities, such as pile/slash burning, the use of equipment (e.g. machinery, chainsaws, vehicles) and spontaneous combustion of decomposing slash piles[56]
- non-forestry related activities, such as non-permitted activities in forests (e.g. bonfires, fireworks), and other industries, such as farming and beekeeping.[57]

As people are often the direct source of ignition, increasing public access to forests can increase fire risk.[58]

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[54] Pile burns are the burning of cut and stacked vegetation.

[55] Powerlines were the leading cause of the area burnt from wildfires in 2020/2021, causing fires that burned 5,647 ha of land (forest and non-forest), 66.7% of the total area that year (Gross et al., 2024a).

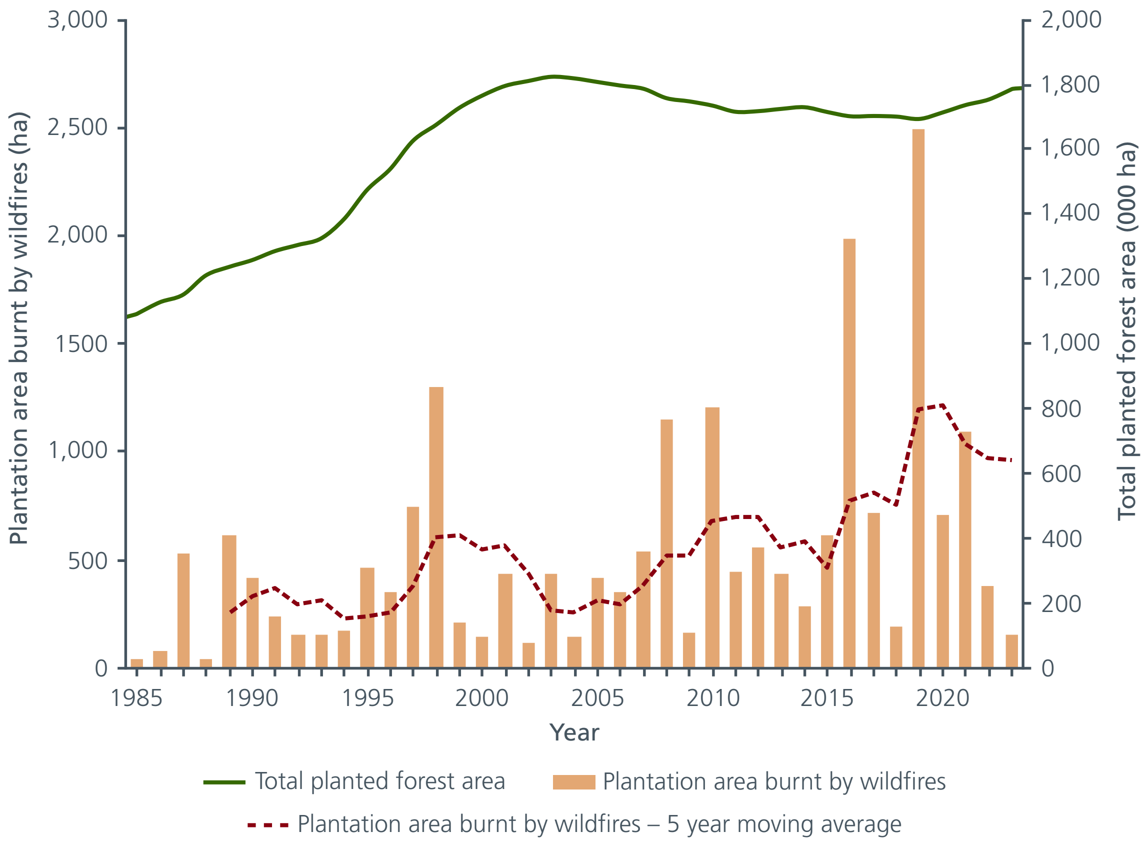
[56] Spontaneous combustion of slash piles is caused by bacteria generating heat during the decomposition process. Moist conditions promote bacterial growth – fires are more frequent following rainfall and high humidity (Clifford et al., 2020).

[57] The Pigeon Valley wildfire (2019) that burnt 2,300 ha of plantation forest was started by a tractor blade sparking on a rock (Cowan, 2019).

[58] Gross et al., 2024a; Gross et al., 2024b.

If a fire occurs in a forest, the rate of spread and fire intensity (the fire hazard) depends on the weather, topography, and the type, availability and continuity of fuel (burnable material) within the forest. The fire risk and hazard of a forest varies with forest stage and management approach (see Box 3.2). If the conditions are conducive, fires in forests can be much more intense than those in grasslands due to greater fuel availability (although scrub tends to produce the highest-intensity fires most easily).[59] When high-intensity forest fires do occur they can be devastating, as was seen during the 2017 Christchurch Port Hills fires, the 2019 Pigeon Valley fire and the 2020 Lake Ohau fire (noting that the last event included large areas of wilding conifers).

The losses to forestry plantations from wildfires have steadily increased since the 1980s: between 2015 and 2021, the average annual loss was 1,159 hectares compared to 321 hectares from 1985 to 1991 (a roughly 3.6-fold increase).[60] The area lost to fires has increased at a greater rate than the total area of plantation forest in New Zealand, which increased from around 1.1 million hectares to 1.7 million hectares over the same timeframe (a roughly 1.5-fold increase).[61]



Source: Dudfield, 2023; MPI, 2024b

Figure 3.4: Graph showing the area of plantation forest damaged by wildfires over time (grouped into six-year periods).

[59] Gross et al., 2024c.

[60] Dudfield, 2023.

[61] MPI, 2024b.

The flammability of a plant is affected by its moisture content (which varies depending on environmental conditions), its chemical composition and the structure of the plant. An assessment of the shoot flammability of 60 tree and shrub species found that radiata pine is moderately flammable with a flammability similar to species, such as red beech, tawa and pūriri, and lower than that of some species, such as mānuka, kānuka, silver beech, rimu and gorse.[62,63] However, at a stand level, exotic plantations tend to be more flammable and have higher-intensity fires than mature mixed-species native forests which typically have moister microclimates and diverse, low-flammability understories (noting that some exotic plantations can develop these conditions too).[64] Notably, even typically low-flammability vegetation can burn during extreme conditions, such as prolonged drought.

Various methods are employed to manage fire risks and hazards in plantation forests. This includes reducing ignition opportunities, carrying out fire surveillance and preparedness activities, and altering the amount and continuity of fuels in the forest.[65] Pruning reduces the availability of 'ladder fuels' which allow fires to climb from the forest floor into the canopy, and thinning can reduce the risk of a continuous crown fire. Forests with high stocking rates are more susceptible to crown fires.

Certain areas of the country are more prone to climate and weather conditions that cause high fire risk, particularly those that experience prolonged dry periods. Plantations in these areas have a higher fire risk and hazard than wetter areas of the country.[66] Parts of the Otago, Canterbury, Marlborough, Hawke's Bay and Wairarapa regions typically experience periods of high to extreme fire severity risk in most years.[67] When climate and weather conditions align (such as in 2012–2013), the entire country can be at high risk of wildfires.

62 Wyse et al., 2016.

63 Assessing shoot flammability can provide some insights into relative flammability of species, but there are challenges in extrapolating up to the whole plant level as plant structure and the retention of dead material also affect flammability. Environmental conditions are also crucial.

64 Gross et al., 2024c.

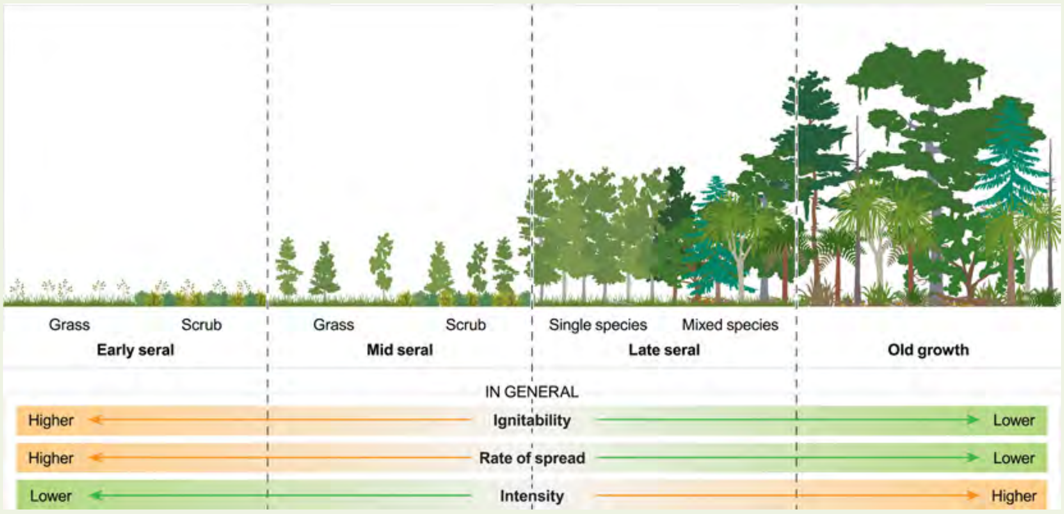
65 For example, restrictions on work practices and limiting public access during periods of higher fire risk; fire patrols; use of fire breaks; and reducing fuels within stands through thinning, pruning, grazing, weed control or controlled burns. A handful of plantations have their own firefighting equipment; most have access roads for emergency vehicles (Gross et al., 2024b).

66 Establishing native vegetation in dry areas is challenging, so afforestation options may be limited.

67 Clifford, 2023.

Box 3.2: Wildfire risk and hazard of forests over time[68]

The fire risks and hazards of any forest are affected by a number of factors, including the stage of forest development.



Source: Scion, 2024

Figure 3.5: The infographic shows how fire behaviour changes with forest development. Generalised fire behaviour is displayed using arrows representing lower to higher ignitability, rate of spread and intensity. Actual fire behaviour will be dependent on landscape context, weather, species composition and forest structure.

Grasses or scrub with young tree seedlings

Tree seedlings planted at open sites are exposed to weather conditions, such as sun, wind and rain, which can rapidly change moisture levels. This makes them more prone to fire than closed canopy forests. Often grasses or flammable scrub species (such as gorse, mānuka and kānuka) are also present, which ignite easily. Grass fires tend to be low intensity but spread rapidly (typically 10 km/hr) and are very responsive to changes in wind speed and direction. Scrub fires tend to spread more slowly (up to 5 km/hr) but become high intensity more easily.

Young forest with grass or scrub understorey, open tree canopy

As seedlings grow into young trees they reduce wind speeds, lowering the rate of fire spread on the forest floor (surface fires). In the absence of grazing, underlying grasses can remain and act as the main fuel for surface fires. A relatively open tree canopy means dry conditions can still rapidly develop. An understorey of scrub can help maintain moister conditions than grasses, but can also supply large amounts of dead, elevated, fine fuel that is highly flammable. Young trees increase fuel availability for surface fires by generating leaf litter and woody debris, fuelling more intense fires than grasses alone.

[68] Gross et al., 2024c.

Surface fires can spread into the crowns of trees, particularly in unthinned or unpruned stands, causing intermittent crown fires. While thinning and pruning reduces the risk of crown fires, the cut material can temporarily increase fuels on the forest floor if not removed.

Mature forest, closed canopy

Once the tree canopy closes, grasses and scrub species are shaded out and the sub-canopy environment becomes cooler, reducing the fire risk. The rate of spread of any surface fires typically reduces as moisture increases and wind speed drops. Fuel availability depends on the understorey and canopy species present, the forest structure and weather conditions. Typically, the litter layer is the primary carrier of any fires that occur. Prolonged dry conditions can cause high-intensity fires that spread into the canopy. If crown fires do occur, they can spread rapidly through the closed canopy and create embers that spread beyond the fire front in windy conditions, sparking new fires. Long-lasting underground burns can occur in the deep organic layers, slash piles, stumps and root systems.

Climate mitigation

Forests of fast-growing exotic tree species, including radiata pine, can rapidly sequester and store large amounts of carbon from the atmosphere over the short-term to medium-term in their roots, shoots and branches.[69] The carbon sequestration rate of a radiata pine forest depends on location, silvicultural regime, rotation length and forest health. Radiata pine plantations in the North Island sequester carbon more rapidly than those in the South Island. The highest regional carbon stocks are achieved in Gisborne, where radiata pine forests store over 800 tonnes of CO_2 per hectare by year 28 and almost 1,350 tonnes of CO_2 per hectare by year 50.[70] Native species and most other exotic species are slower growing than radiata pine so sequester less carbon over the first 50 years or so, except in areas where radiata pine grows more slowly, such as Canterbury and the West Coast.[71,72]

When forests are managed under rotational harvest regimes, it is more appropriate to consider the average carbon stocks of the forests over time, rather than repeated peaks and troughs. A typical radiata pine production forest managed under a clear-fell regime reaches its average carbon stock at 16 years, by which time the forest can have sequestered around 400 tonnes of CO_2 per hectare in good growing regions. Changing the harvesting regime by lengthening the rotation or reducing the area harvested at any one time are ways of increasing the average carbon stocks of a forest.

While rapid sequestration is beneficial from the point of view of carbon accounting, storage is not permanent. Carbon is only sequestered while trees are growing. When trees decay or any harvested wood products reach the end of their life, carbon is released back into the atmosphere. In order to fully offset fossil carbon emissions (which have a near permanent warming impact)

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69 Soils also typically store a considerable amount of carbon (~360 tonnes of CO_2/ha for most soils) but this does not change much between land uses in New Zealand (MfE, 2024).

70 Climate Change (Forestry) Regulations 2022, Schedule 4.

71 According to the NZ ETS look-up tables, exotic hardwoods store more carbon by year 30 than radiata pine in Canterbury and the West Coast. The exotic hardwood rate is generalised across the country and based on *Eucalyptus nitens* (Climate Change (Forestry) Regulations 2022).

72 Redwood can outperform radiata pine on warm, wet sites in the North Island, particularly under high stocking rates over 40 years or more (Watt and Kimberley, 2022).

through afforestation, a forest needs to maintain its carbon stocks in perpetuity. But there is no guarantee that a forest planted today will still be standing 100 or 1,000 years from now. This issue of permanence is discussed more in Chapter 9.

Forests affect the climate system in additional ways such as through the emission and absorption of gases, e.g. methane, and the release of volatile organic compounds that can affect cloud formation and alter the breakdown of methane in the atmosphere.[73] Forests can also affect land surface reflectance (albedo).[74] The cooling effect that results from carbon sequestration by new pine forests may be negated to some extent by the warming effect of moving from a light-coloured landscape (e.g. grass) to a dark-coloured one (pine forest). Dark-coloured surfaces reflect less sunlight, absorbing more solar radiation and leading to greater warming than light-coloured surfaces. The reflectivity changes that result from converting pasture to pine forest in New Zealand have been estimated to cancel out the cooling effect of increased carbon storage by 17–24%, and recent research suggests this negating effect could be even greater.[75,76]

However, the impacts of forests on albedo are complex and remain a topic of research.[77] Likewise, the way in which forests alter complex atmospheric chemistry processes is far from clear and remains the topic of much debate.[78]

Figure 3.6: A typical radiata pine production forest managed under a clear-fell regime, like this one near Taupō, reaches its average carbon stock at 16 years, when the forest can have sequestered around 400 tonnes of CO_2 per hectare in good growing regions.

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[73] Weber et al., 2024; Gauci et al., 2024.

[74] Albedo is the fraction of light that a surface reflects. If it is all reflected, the albedo is equal to 1. If 30% is reflected, the albedo is 0.3. The albedo of the Earth's surface determines how much incoming light is reflected back to space.

[75] Kirschbaum et al., 2011.

[76] Hasler et al., 2024.

[77] For example, increased cloud formation over forests can increase reflectance and lead to a cooling effect (Ellison et al., 2024).

[78] Blichner and Weber, 2024.

Climate change as a risk modifier

Climate change is often asserted as a reason to establish new forests, as afforestation can both increase sequestration of carbon from the atmosphere and recloak erodible landscapes to protect them against extreme weather events. However, climate change is altering the risk profile of new and existing radiata pine (and other) forests by increasing many of the risks that arise from or threaten these forests.

Extreme rainfall events are becoming more common and this trend is expected to continue.[79] An increasing frequency of heavy rainfall events means greater risk of sediment and woody debris mobilising from recently clear-felled areas and young plantations on steep, erodible landscapes. Grazed, erodible areas will also be vulnerable. Permanent forest cover will offer the best protection – but the efficacy will depend on the species and how the forest is managed.

Many regions will experience more extreme winds, particularly the South Island and the southern half of the North Island.[80] Extreme winds can cause wind throw of standing trees, especially mature stands, as was seen in Taupō plantations during Cyclone Gabrielle.[81] The greatest wind damage event to affect planted forests to date was Cyclone Bola in 1988 when some 27,000 hectares were destroyed.[82] Radiata pine is more susceptible to wind damage than many other species, particularly in saturated soils and at older age classes (>30 years).[83] The existing vulnerability of radiata pine to wind damage is compounded by a projected increase in radiata pine growth rates, which will cause trees to become taller and more slender, increasing their susceptibility to windthrow.[84] Trees under carbon forestry regimes may be particularly vulnerable to windthrow if planted at high stocking rates that drive the growth of tall, slender trees. Selecting for trees with a greater wood density could reduce wind damage risk, although this may lead to reduced growth rates.[85]

Climate change is projected to reinforce existing regional differences in precipitation: regions in the south and west of the country will become wetter, and regions in the north and east of the North Island and inland South Island will become drier and more prone to drought.[86] Prolonged periods of wet or dry conditions can stress trees, making them more susceptible to other pressures. These climatic conditions can also affect the distribution and severity of diseases and damage from insects in different regions. For example, needle diseases are projected to reduce in severity in the major plantation areas of the North Island due to increasingly dry conditions but increase in the South Island as conditions become wetter.[87] The potential distribution of the as yet unintroduced pitch canker is predicted to expand from northern coastal areas under the

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79 NIWA, 2025b.

80 NIWA, 2025b.

81 Around 6,500 ha of trees were snapped or blown over (with their root-balls still attached) in the Taupō region when Cyclone Gabrielle hit in February 2023, with most being 20 years or older. This includes 4,200 ha within a single plantation (Thorp, 2023).

82 Other notable storms include Cyclone Ita in 2014, which caused wind damage to 40,000 ha of natural native forests on the West Coast (Watson, 2017), and the northwest gales in 1975 in Canterbury that affected 11,000 ha of planted forests (Moore, 2014).

83 Scion, 2012.

84 Radiata pine growth rates are projected to increase in New Zealand due to increased CO_2 levels (Watt et al., 2019).

85 Smaill et al., 2024.

86 Drought severity is projected to increase for most parts of the country (NIWA, 2025b).

87 Watt et al., 2019.

current climate to cover almost all of the North Island, but only eastern and coastal northern parts of the South Island by 2080.[88]

The average fire season length is predicted to extend, particularly in eastern areas with existing high fire risk (including Tairāwhiti and Canterbury) and some areas of currently low fire risk (including Wellington and Dunedin).[89] Across New Zealand, the average number of days with 'very high' or 'extreme' fire risk is projected to increase by 71% by 2040, with substantial variation between regions.[90] Late winter and early spring wildfires are already occurring regularly in some areas, such as the Mackenzie district, suggesting that continuous fire seasons may occur in future.[91] While the frequency and intensity of wildfires is increasing under climate change, so too is the likelihood that forests are vulnerable to fires, as stressed forests have a higher fire risk and hazard.[92] This means fire management interventions and appropriate siting of forest species is increasingly important.

The climate risks of radiata pine production forests and carbon forests are inherently different due to different management regimes and different timeframes. Trees planted in a forest today for timber will need to withstand changing environmental conditions over at least the next 25 years. Trees planted for long-term carbon storage will need to withstand changes over many more decades and form a self-sustaining forest that remains in perpetuity.[93] If this doesn't occur, the forest will become a net source of carbon emissions. Given the many risks associated with radiata pine, planting monocultures of the species for long-term carbon mitigation purposes is unlikely to result in permanent, resilient forests.[94]

Loss of social licence

Over the past decade or so a divisive debate has been brewing in rural communities about the role of exotic forestry. While concern extends to all types of exotic plantation forestry, there is particular concern around permanent carbon forestry.

Many rural communities, particularly those dominated by sheep and beef farming, where forestry is the main competing land use, worry about the role afforestation will play in the survival of their communities. Competing narratives exist about the consequences of farm-to-forest conversion. The farming sector has argued that afforestation removes more jobs than it provides, with only sporadic employment from planting to harvest.[95] Production foresters dispute the numbers and argue that not only does forestry add more Full Time Equivalents (FTEs) and value than sheep and beef across the value chain, but that it adds more value per FTE.[96] Some also claim that rural communities have changed a lot in recent years anyway. What is clear is that carbon forestry provides less employment than production forestry or sheep and beef farming.[97]

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[88] Ganley et al., 2011.

[89] The biggest projected increases occur in Wellington (from 17 to 32 days) and Dunedin (from 6 to 18 days). Canterbury and Tairāwhiti will continue to experience the greatest number of very high or extreme fire risk days (45 days and 41 days respectively). Some regions (like the West Coast, Southland and central North Island) will continue to experience few days per year with very high or extreme fire risk (Watt et al., 2019).

[90] MfE, 2018.

[91] Gross et al., 2024c.

[92] Gross et al., 2024c.

[93] Unless they are manually replanted.

[94] Unless the pine forests are successfully transitioned to some other state, such as native forest.

[95] MC, 2023, p.13.

[96] PwC, 2020, p.5.

[97] Noting that continuous cover production forestry involves low intensity harvest and is distinct from permanent unharvested carbon forestry. Detailed analyses of the number of FTEs supported by alternative management regimes are lacking.

The risks associated with forestry – and who is asked to bear them – certainly mould the way communities feel about the industry. The term 'social licence to operate' has featured strongly in the discourse around exotic forestry practices following the devastation caused by extreme weather events in recent years. Post-harvest erosion, land mobilisation and downstream damage caused by sediment and woody debris during storms have placed clear-fell regimes under the spotlight.

In some cases, there is no question that existing practices need to change. Following the large-scale devastation of Cyclone Hale (and later Cyclone Gabrielle) in 2023, the local community in Tairāwhiti mobilised, triggering the Ministerial Inquiry into Land Use in Tairāwhiti and Wairoa. The inquiry resulted in the production of the *Outrage to Optimism* report with 49 recommendations, including one to restrict all large-scale clear-felling on the East Coast in favour of coupe harvest.[98] While there are differences of opinion about the best way forward, there is broad agreement that forestry on the East Coast is going to change.

Accountability mechanisms, such as the international FSC, have also been successfully petitioned by local communities to provide greater scrutiny of forestry operations, in some cases triggering the suspension of certification.[99]

Source: Greg Briner, PCE

Figure 3.7: Rural communities, particularly those dominated by sheep and beef farming, worry about how pine afforestation will affect their communities. Currently pine forestry is the main competing land use.

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[98] Parata et al., 2023.

[99] Two forestry companies, Ernslaw One and Aratu Forests, lost their FSC certification in 2024 following an independent audit of the certifiers for these companies. The audit identified major non-conformities, including failure to detect practices in 2018 for which both Ernslaw One and Aratu had been previously fined by Gisborne District Council. These included discharges of forestry waste and silt into waterways and damage resulting from landslides and slash mobilisation during the Queen's Birthday weekend storms of that year (ASI, 2024a; ASI, 2024b).

3 What could large new areas of radiata pine forests mean for the environment?

4


Blackbutt *(Eucalyptus pilularis)*

What are the alternatives?

The previous two chapters of this report talked about the current state of forestry in New Zealand and its significance from an environmental perspective. The next three chapters discuss what we know about alternative forestry systems – specifically native afforestation, transitional forestry and alternative exotic species. Other approaches will be woven throughout these chapters, such as mixed-species forests and alternative management regimes, including continuous cover forestry, agroforestry and management using te ao Māori principles.

This chapter introduces these alternative forestry systems.

Why is there interest in alternative forestry systems?

Current market signals and NZ ETS regulatory settings make it likely that the current trends that overwhelmingly favour the planting of radiata pine will continue.

Concerns about the impacts of large-scale afforestation with a single exotic species and a clear-fell regime are coupled with increasing demands for land use change that prioritises other values. This has led to calls from various groups for alternative forestry systems to play a bigger role in afforestation. The motivations behind these calls include:[1]

- restoring biodiversity and the mauri of the whenua
- establishing more resilient forests for long-term carbon sequestration and storage
- providing long-term soil protection and improved water regulation
- developing alternative approaches to clear-fell harvest, particularly on erosion-prone land or where forests are established for multiple purposes
- developing a production forest estate that is more resilient to pressures, such as pests, diseases and climate change
- developing alternative timber and fibre products and markets and supporting domestic processing
- interest in non-timber products (such as honey, rongoā, bioactives and food)
- enhancing the social values of forests (such as tourism, amenity and recreation).

[1] The purpose of a forest is crucial when it comes to identifying the most appropriate forestry system. A range of functional forest types for New Zealand have been described (Payn, 2021).

A medley of native forests

The term 'native forest' may conjure images of old-growth forests in New Zealand: perhaps the diverse understorey and dense canopy interspersed with emergent podocarp giants (like rimu, tōtara or kahikatea) that are found in healthy broadleaf-conifer forests, or the more open structure and simpler species composition typically associated with a southern beech forest. It might be assumed that the desired outcome for all new native forests is to get as close to this natural state as possible and for the forest to be solely managed for conservation purposes.

Although true in many cases, there are other reasons why a landowner might choose to establish native forests. This is reflected in how the term 'native forest' has been used (not without contention) to describe a wide spectrum of forest types, including:

- old-growth forests and secondary forests managed for conservation or non-extractive purposes, including diverse forests and those that are naturally near-monocultures, such as many beech forests
- naturally regenerated or planted mixed-species assemblages managed for conservation and/or low-level harvest of timber or non-timber products
- monocultures of naturally regenerated or planted native species managed for timber or non-timber products (e.g. tōtara for timber; mānuka/kānuka for honey and oil)
- forests with only native trees
- forests with native trees and some exotic trees
- ngahere that includes its people and has balanced or thriving mauri.

Under the Forests Act 1949, indigenous forest land is defined as "land wholly or predominantly under the cover of indigenous [native] flora".[2] The Forests Act differentiates between planted and natural native forest when it comes to harvesting, the consequences of which are discussed in Chapter 10. Similarly, under the NZ ETS a native forest is one where native tree species are 'predominant', which means native tree species make up the greatest total basal area compared to other forest types within a particular area of forest land while also meeting other requirements for a 'forest' (i.e. minimum area, height, crown cover and width requirements).[3] In neither case is any reference made to the species diversity of the native forest or its purpose.

Such definitions often don't provide a picture of the entire ecological community that makes up a forest. Trees are not isolated from all the other species that make the forests their homes. There are vital relationships that reach across different levels of the forest, from the biota in the soil (including fungi, pathogens and insects) to the birds in the trees. For example:

- Mycorrhizal fungi pass nutrients to plants through their roots and in return receive nourishment from the plant.
- Insects can influence succession and forest composition by consuming seedlings of some trees and leaving others.
- Birds disperse seeds across large areas and can digest the outer coating of seeds, making it easier for them to germinate once dropped in soil.

[2] Forests Act 1949 s2.

[3] Climate Change (Forestry) Regulations 2022. In order to qualify as forest land under the NZ ETS, a forest must cover at least 1 ha in area; contain species that can reach at least 5 m in height when mature in that location; have (or be expected to reach) crown cover of more than 30% in each ha; be at least (or expected to reach) 30 m across on average (Climate Change Response Act 2002).

When referring to native forests in this report, the term is used broadly to capture the full spectrum of native forest types listed above, referring to different types of native forest where relevant.[4]

Alternative exotic species

Alternative exotic species are those other than radiata pine that show potential for larger-scale use in New Zealand. As there are hundreds of potential species that could be discussed, this report has focused on some of those that have received the most investment to date and have shown the most promise. Alternative exotics are discussed in Chapter 7, with particular species, including redwoods, cypresses, eucalypts, poplars and alternative pine species, discussed in more detail in Appendix 1.

Box 4.1: Can genetic technology help weed out wilding genes from Douglas fir?

The exclusion of Douglas fir from the list of alternative exotic species explored in more detail in Appendix 1 might seem surprising. After all, it is a well-developed and widely recognised exotic species known for producing high-quality structural timber, which enjoys a strong international reputation and has established markets both domestically and globally. It is also the second most common plantation species in New Zealand and grows well in high-altitude sites that are less suited to radiata pine.[5] However, Douglas fir is a high wilding risk species when planted in the wrong place due to its spreading vigour, low palatability and shade tolerance, which enables it to invade existing vegetation, including native forests. Concerns around its wilding risk and consequent restrictions on where it can be planted have led to reduced planting in recent years.

The Government's decision to ease regulatory hurdles on gene technology outside of laboratories opens up the opportunity to develop and commercially deploy sterile Douglas fir plantations in New Zealand.[6] This would remove the risk of wildings spreading from new plantings of Douglas fir. The legislative changes that would enable this are due by the end of 2025, but scientific developments are also needed before sterile Douglas fir becomes commercially available. Scion has already completed some research to support this ambition.[7] This includes developing mechanisms to alter genes without transferring genetic material from another species – as so-called 'transgenics' won't be deregulated – as well as identifying genes that, when inactivated, may cause sterility in conifers. Due to current regulatory restrictions, Scion hasn't yet been able to test whether such gene editing leads to sterile Douglas fir but the proposed changes would enable testing to occur. Still, it is likely to be at least a decade before sterile Douglas fir is available for commercial use.

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[4] Although this report takes a wide view of native forests, it does not include mangroves. The northern part of the North Island is home to a single species of mangrove (*Avicennia marina* subspecies *australasica*, also known as manawa). Growing at the southernmost extent of the range for its genus, the plant is stunted compared to its relatives in warmer climates. These highly-adapted plants occupy the extremely dynamic intertidal boundary between land and sea in sheltered estuaries where they perform a valuable role, providing habitat for many species, filtering water, buffering storms and storing large amounts of carbon in the sediment they trap (Waikato Regional Council, 2016).

[5] Scion, 2021.

[6] Collins, 2024.

[7] Scion, 2025a.

Source: benteele, iNaturalist NZ

Figure 4.1: Douglas fir is the second most common plantation species in New Zealand. It produces high-quality structural timber that is supplied to established domestic and international markets. In recent years, it has been subject to planting restrictions as it has a high wilding risk.

There is growing interest in the forestry industry in identifying a high-volume timber contingency species for resilience purposes, should any major issues affecting radiata pine arise. But there is also interest in alternative exotics for the other qualities they could provide. These include different wood properties (e.g. strength, durability, appearance, workability), better site matching (e.g. tolerance of harsh conditions, greater erosion control) and suitability to alternative management regimes (such as continuous cover forestry).

Mixed-species forests

It could be argued that some pine plantations form 'mixed-species' forests since, in some instances, a diverse understorey of other species can develop. However, here we use the term to describe forests that have two or more tree species that form a dominant part of the canopy. These could be native species, exotic species or a mixture of both, and could be interplanted or planted in small single-species coupes within a mosaic of other species.

Many naturally formed forests have multiple canopy species, but mixed-species forests can also be purposefully established. Motivations behind mixed-species forest establishment can be environmental, cultural and commercial. Mixed-species forests are typically more structurally diverse than single-species forests, providing a wider variety of habitats and microclimates that support other species. When composed of locally appropriate native species, newly established mixed-species forests can contribute towards local biodiversity restoration efforts. Mixed-species forests are generally more resilient to extreme weather and outbreaks of specialist pests and diseases, as a single event is unlikely to affect all species present.[8] Forests composed of multiple species with complementary traits can also be more productive (in terms of both carbon and timber) than monocultures because the species occupy different niches and therefore use resources more efficiently.[9] These benefits have led to a growing interest in mixed-species forests internationally and domestically.[10,11]

Many native afforestation efforts in New Zealand focus on establishing mixed-species forests for conservation purposes. Mixed-species forests involving exotic species are less common, although examples do exist.[12]

Box 4.2: Horowai Forest – continuous cover mixed-species forestry[13]

Horowai Forest is a 150-hectare mixed-species plantation in Northland, which was previously in pine forest and farmland. The forest is being managed under a continuous cover regime (single-tree harvest) with the aim of producing diverse products from naturally durable high-quality timber.

The land has low fertility soils and can be very wet in places. Different species have been trialled in small woodlots, with varying success. Failures included poplars, some eucalypts (e.g. *E. cladocalyx, E. quadrangulata*), some acacia species and native species (tōtara and kauri). However, others have shown promise, including several other eucalypts, particularly red mahoganies (*E. scias,* subspecies *callimastha*, and *E. notabilis*) and some stringybarks (*E. sphaerocarpa* and *E. muelleriana*). These have been successfully interplanted with other species, such as cypresses. Even with the successful species, careful soil and site matching has been crucial.

The forest manager, Dean Satchell, has found that high-density planting (1,666–2,000 stems per hectare) works well for eucalypts and cypress. While there are higher upfront costs, there are lower silvicultural costs later on (as the trees self-prune) and more trees to choose from for harvest, which improves timber quality. Poorly formed trees are thinned out through ring-barking to make room for the better quality trees to grow.

Challenges have included finding staff with the right expertise, and not having the right tools for efficient single-tree harvest with minimal understorey damage (the current approach involves a small tractor with a winch and 'nose cone' fitted to the log). Harvesting is at a small scale currently but markets are being developed in preparation for trees maturing. Dean Satchell is developing an integrated forestry operation – logs will be milled and dried onsite, and timber sold at the farmgate. The aim is for a constant supply of timber to sustain a mill suitable for the scale of harvest.

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8 Jactel and Brockerhoff, 2007; Jactel et al., 2017; Roberts et al., 2020; Barrere et al., 2024.

9 Jactel et al., 2018; Liu et al., 2018; Feng et al., 2022; Warner et al., 2023.

10 FORMIX, 2023; Ghent University, 2024.

11 Scion, 2024a.

12 For example, Woodside Forest in Canterbury and Horowai Forest in Northland.

13 Dean Satchell, pers. comm., 15 November 2024.

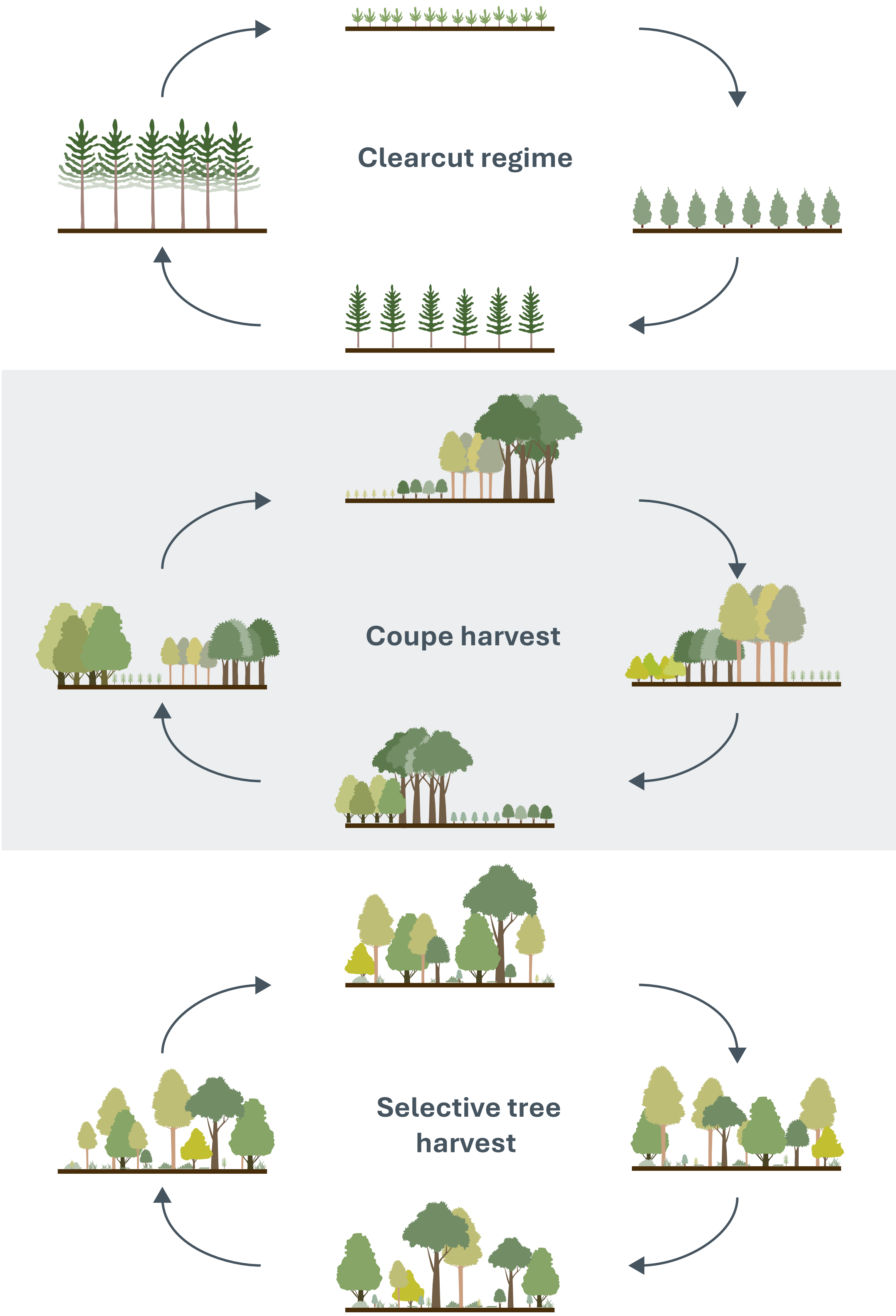
Alternative management regimes

Currently, most exotic forests are managed for high-volume timber production through clear-fell harvest or rapid carbon sequestration by leaving the trees unharvested. Most native forests are managed for conservation purposes only, rather than commercial purposes. But other forest management approaches are being applied overseas and at a smaller scale in New Zealand, including continuous cover production forestry, agroforestry and exotic-to-native transition forests.[14]

Continuous cover production forestry

A continuous cover production forest is one that maintains a canopy at all times but will undergo some low-intensity harvest, such as single tree harvest, strip-felling or small coupe harvest. The continuous cover management approach leads to the development of mixed-age forests that are more structurally representative of most natural forests than single-age stands. See Figure 4.2 for an illustration. Due to the more selective harvesting approach (rather than clearing large areas in one go), continuous cover production forestry is suitable for mixed-species forests where different species may grow at different rates and occupy different niches.

[14] To date, New Zealand has typically employed a 'land-sparing' approach to forestry, featuring intense high-yield production systems and conservation land with minimal resource extraction, but little in between. Some alternative forestry systems, such as continuous cover production forestry, take more of a 'land-sharing' approach where multiple objectives of forests, such as wood production, grazing and biodiversity, are prioritised in a single land use (Harris and Betts, 2023).



Source: Adapted from The Connective et al., 2023

Figure 4.2: A comparison of the age structures that occur under different management regimes.

Rather than focusing on **high-volume** timber production, a continuous cover production forest is managed for multiple values, such as **high-value** timber production, recreation and other ecosystem services. Proponents of continuous cover forestry often seek to minimise disturbance during harvesting operations to minimise harm to forest understorey species.

Compared to a clear-fell regime, continuous cover production forestry typically requires greater investment in silviculture, expertise and harvesting, and involves more regular but lower-intensity management.[15] Harvested trees are often replaced through natural regeneration, which can reduce the costs of re-establishment.

A small number of exotic, native and mixed-species forests in New Zealand are being managed under continuous cover production systems. These include Woodside Forest in Canterbury, a 120-hectare farm-forest with stands of black beech and radiata pine. The owners carry out the establishment, tending and maintenance of the forests themselves, but bring in contractors for harvesting and roading. Trees are selectively harvested when they reach a target diameter size, which maximises the proportion of high-value logs and provides a regular cashflow.[16] A preliminary economic assessment of the radiata pine component of the Woodside continuous cover system found it provided a modest income for the forest owners (comparable to what they would receive from a clear-fell regime) but not a commercial rate of return.

Radiata pine isn't an obvious candidate for continuous cover forestry, as its light-demanding nature means that low-stand densities are needed to support regeneration.[17] Traits such as shade tolerance and coppicing ability are advantageous for continuous cover regimes.[18] A modelled comparison of various hypothetical management approaches for coast redwood (a shade-tolerant, coppicing species) in New Zealand, suggests that under a continuous cover system the revenue from carbon (while the forest is growing) and high-value timber (once the forest matures) could provide good investment returns, particularly in the central North Island where redwood is more productive.[19]

Continuous cover systems are more common overseas. A recent report summarising national and international examples of continuous cover production forestry found they typically have complex business models and multiple revenue streams.[20] Internationally, government support is often provided to forest owners using continuous cover practices in recognition of their wider ecosystem benefits.

The report included a case study of Slovenia, where clear-fell harvest has been banned since 1949. The forests are instead managed to form mixed-age stands, which are recognised for the wider public benefits they provide. Commercial revenue comes from high-value timber production and other sources, such as recreation. Forests are actively managed to support regeneration and biodiversity, with grants provided for silviculture and conservation work. The country has one of the highest levels of forest cover in Europe (covering 58% of the country's land area), of which 95%

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[15] The Connective et al., 2023; Evison et al., 2024.

[16] Windthrown radiata pine contributes a moderate component of the total recovered timber volume, enabled by a good roading system and annual harvests that provide an opportunity to extract windthrown trees. Between 2002 and 2021, 28% of timber was harvested from windthrow events (Evison et al., 2024).

[17] Evison et al., 2024.

[18] The Connective et al., 2023.

[19] Bown and Watt, 2024.

[20] The Connective et al., 2023.

is now managed under a 'close to nature' approach. Similarly, in Ireland, continuous cover forestry is now a key part of the country's national forest policy, following a growing resistance to exotic monocultures and clear-fell harvest. Other examples of continuous cover production forestry exist in Germany, the United States of America and Canada.[21]

Box 4.3: From clear-fell pine to continuous cover mixed forestry

Nelson City Council is transitioning its 600-hectare commercial forestry estate from a clear-fell radiata pine regime to continuous cover forest systems, mostly of mixed species, as recommended by the Right Tree Right Place Taskforce that was set up to advise on the matter. The purpose of the transition is to improve environmental, climatic and social benefits from the land following poor returns on investment from the current approach and concerns around long-term forest resilience. The taskforce suggested that different approaches could be taken within different parts of a single catchment. For example, in the Roding Forest block the lower slopes were identified as being well-suited to mixed stands of high-value timber species for future selective or coupe harvest; the upper slopes that are vulnerable to windthrow should be harvested and then allowed to regenerate into native cover; and some low-risk, distant areas could remain in ongoing pine forestry (with smaller harvest sizes).

Challenges emerged as the council started to implement some of these transitions. In the Maitai Valley there was an urgent need to reforest 20 hectares of steep harvested land above a drinking-water supply pipeline that was damaged when the land slipped in 2022. Urgency came from the need not only to secure the land but also to avoid potential deforestation liabilities under the NZ ETS (costing close to $1 million). Redwoods were selected due to their erosion control benefits, suitability for planting late in the season and lower cost compared to native species. The species selection sparked pushback, with some arguing natives would have been more appropriate.[22] A governance group and forestry systems manager role have since been established, which may foster greater community support for future forestry decisions.

[21] The Connective et al., 2023.

[22] Jones, 2024.

Agroforestry (silvopastoralism)

Agroforestry is the incorporation of trees within agricultural landscapes. This can include riparian plantings, shelterbelts and widely spaced trees within grazed areas – the latter is also known as silvopastoralism. The integration of appropriate trees within pasture can reduce erosion in hill country and improve animal welfare through the provision of shade and shelter.[23] Depending on the tree species, agroforestry can also provide fodder during periods of drought and feed shortage. Silvopastoralism typically involves space plantings of poplars or willows, although some native species can also be appropriate. If certain criteria are met, widely spaced trees can be eligible for registration in the NZ ETS.[24]

Exotic-to-native transitional forestry

Exotic-to-native transitional forestry is a management approach that aims to shift from exotic forests to native forests gradually over time.[25] Rather than clear-felling the exotic forest and planting or regenerating native plants on the cleared site, native tree establishment is encouraged through various management interventions under an exotic forest canopy. This is a relatively new management approach in New Zealand but is gaining interest for economic and environmental reasons. Transitional forestry is discussed in detail in Chapter 6.

Forestry using te ao Māori principles

Many Māori are thinking about the impacts of historical land use and the potential to change future land use to forestry (and other land uses) by applying important Māori values like rangatiratanga, kaitiakitanga, mauri, whakapapa and ahikāroa. This means using te ao Māori principles and decision-making frameworks. Hēnare (2014) describes an example where a Māori landowner collective in Te Taitokerau used a Māori well-being framework to determine the best use of their land. This framework included spiritual, environmental, kinship and economic values to assess different future forestry options. They decided that their land should be developed into a mix of heritage and production forestry. Heritage forests planted in endemic and native rākau would provide owners with connection to culturally important rākau and improve cultural identity. Production forests would be developed with native, endemic and exotic species, including radiata pine, for economic and commercial purposes.

The outcome for those utilising these decision-making frameworks is that these forests are being managed to support multiple Māori values – not just commercial or purely environmental values. This could include, for example, harvesting or hunting by the whānau within the forestry block or utilising the improved mauri of a regenerating ngahere to support other uses like beekeeping or harvesting pharmaceutical plant species.[26]

[23] Mackay-Smith et al., 2024.

[24] See Chapter 9.

[25] Forbes Ecology, 2021.

[26] Lyver et al., 2017.

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Mataī *(Prumnopitys taxifolia)*

Establishing and maintaining new native forests at scale

Key points in this chapter:

- Native afforestation at scale is challenging as little is known about how to do this. Human-induced pressures mean that even relatively passive regeneration projects often require some level of human intervention.
- Interventions will range from passive (assisted native regeneration) to highly intensive (planting of species) and will depend on the site condition, available resources, scale and desired outcome.
- Challenges to native afforestation include seed sourcing and viability, costs of seedling production and planting, and the need for long-term pest and weed control. Trees need to be carefully managed for the first few years to ensure survival.
- Native tree breeding programmes, seed collection and eco-sourcing should consider tikanga and the role of mana whenua as kaitiaki.
- Native forests can provide significant benefits for biodiversity, erosion control, water quality and long-term carbon sequestration. Benefits will vary depending on the forest composition, location and ongoing management.
- Where forest restoration is the aim, it could take centuries for tall, diverse native forests to develop. Beneficial though they may be, these forests will never be able to mimic the forests we once had.

There are many reasons why someone might wish to establish a native forest, and the purpose and location will affect what type of native forest is most appropriate. Depending on their composition and how they are managed, native forests can provide many benefits[1], including:

- biodiversity values and improving mauri
- regulating services, such as water regulation, soil erosion control, fuel breaks, pollination services, nutrient regulation

[1] More detail is provided in Aimers et al., 2021

- social and cultural values, such as amenity values, recreation, kaitiakitanga, rongoā practice, hunting
- revenue from timber, carbon credits, honey, oil, pharmaceuticals, wild game, animal fodder, tourism
- animal welfare, such as shelter, shade provision, food
- long-term carbon sequestration and storage, contributing towards climate mitigation efforts
- strengthening whakapapa (connection) to the land.

Establishing large tracts of new native forests across the country has not been attempted before. From the restoration efforts that have been made, we know that trying to do so is likely to be difficult. Aotearoa New Zealand has been subjected to a wave of upheavals in land cover and land use. Pests and weeds run rife. Seed sources have been reduced and so have the populations of many of the birds that disperse them. The large-scale establishment of new native forests that closely resemble the mature forests that would have originally existed is unlikely to occur 'naturally', particularly within short to medium timeframes. Interventions will be needed.

Notwithstanding that, it is helpful to understand how forests were naturally established before humans arrived to inform any attempts to grow new native forests. This chapter discusses how a forest might establish and mature through natural regeneration in the absence of any human-introduced pressures. It then describes the various approaches being employed today to establish native forests in a human-altered world, ranging from assisted natural regeneration through to intensive planting of native trees. A more recently developed approach that seeks to transition exotic forests into native forests is discussed in the following chapter.

How do native forests naturally establish?

Prior to human arrival, the establishment and longevity of forests in New Zealand was driven by natural processes, including plant colonisation, succession, natural regeneration and disturbance.

Colonisation describes the process by which plant species first arrive and grow at a site and **succession** describes the change in the composition of the plants over time. Succession can occur after colonisation of bare ground or following disturbance within an existing plant community. While seeds might reach a site via wind or animal-based dispersal, germination and plant establishment will only occur if the environmental conditions are suitable.[2] Existing vegetation can alter local conditions to benefit other species, facilitating their colonisation and leading to progressive evolution of the ecological community.

Natural forest regeneration is the process through which forest species establish from naturally dispersed seeds or soil seedbanks. Natural regeneration affects the composition, structure and health of forest ecosystems. Classical forest ecology describes a natural succession of species from early pioneer species that are typically rapid growing and light-demanding, through mid-successional species that outgrow or outlive the pioneers, to late-successional or old-growth species that are long-lived and can push up through the existing canopy when the opportunity arises.[3]

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[2] Such as temperature, soil microbiome, moisture levels, oxygen availability and light conditions.

[3] Successional trajectories in New Zealand forests are described in Wyse et al., 2018.

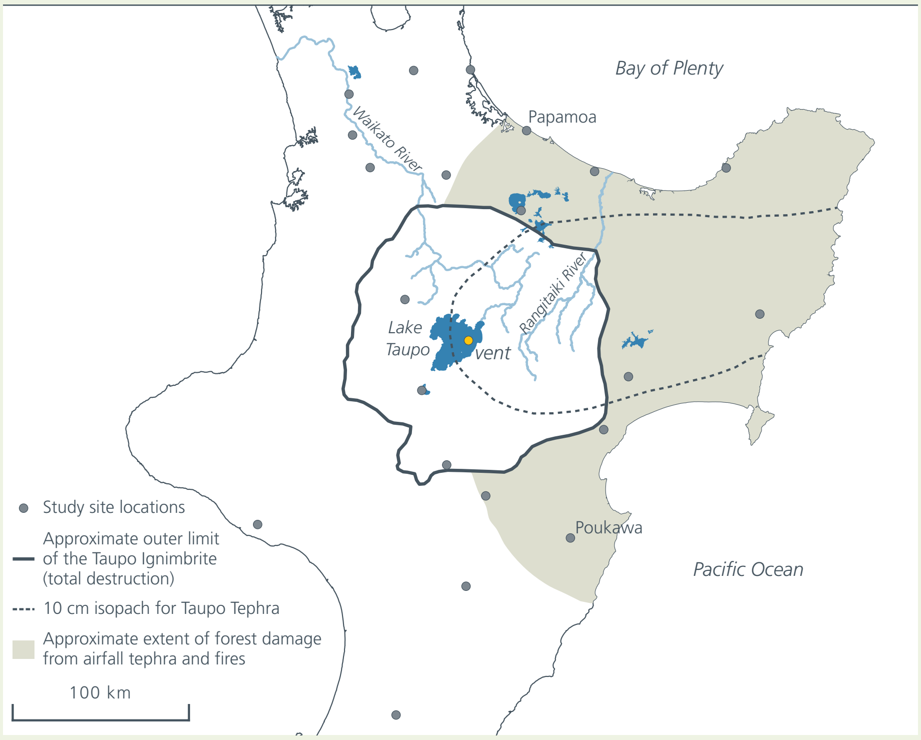
Many tree species in New Zealand require some level of **disturbance** before they can even get a foothold on the forest floor. Forests are dynamic systems that respond to shocks, such as storms, or more subtle changes, such as changing temperature or weather patterns. As an elongated, geologically active fragment of the earth's crust in a marine environment, New Zealand frequently experiences disturbance events. Earthquakes, volcanic eruptions and landslides can set in motion rapid changes. Despite New Zealand's relative isolation, new insects and pathogens were arriving long before humans increased the flow of species. These arrivals too constitute a disturbance. Disturbances can temporarily or persistently reshape the ecological state of the forest (Box 5.1).

Box 5.1: Lasting impacts of the Taupō eruption on Central North Island forests

The Taupō eruption in about AD 230 was one of the largest eruptions globally over the past 5,000 years. The eruption destroyed or damaged some three million hectares of native forest in the central North Island through ashfall and recurring outbreaks of fire. The area of vegetation damage ranged from Pāpāmoa in western Bay of Plenty to Poukawa in southern Hawke's Bay. Pollen records show varying levels of disturbance but generally sharp declines in tall podocarp and beech species immediately after the eruption.[4] Revegetation with bracken fern, grasses and other early colonisers was rapid and, in some cases, these flammable species persisted for decades due to the recurrence of fires. In the absence of further fire, shrubs and small trees then reappeared, followed by tall forest within 125–225 radiocarbon years of the eruption. Forest regeneration was fastest in higher rainfall areas.

Dense, contemporary podocarp forests near Taupō, such as Whirinaki, are the result of the intensity and legacy of the catastrophic disturbance and huge deposits of pumice caused by the eruption. The large areas of fresh substrate combined with high light levels and limited competition are likely to be what promoted the establishment of such dense podocarp forests. Over time, they may become increasingly dominated by broadleaf trees because of their superior ability to regenerate in gaps and under shaded canopies.[5] An analysis of change over 50 years suggests this may be happening, but it's hard to say for certain as these permanent plots span only a fraction of the time since the eruption or the lifespan of a mataī.[6]

[4] Wilmshurst and McGlone, 1996.
[5] McKelvey, 1963.
[6] Smale et al., 2016.



Source: Adapted from Wilmshurst and McGlone, 1996

Figure 5.1: Map showing the approximate extent of forest damage from the Taupō eruption.

Disturbances play out differently in different forest types. Large canopy-loss events caused by weather or geological events are an important driver of beech regeneration.[7] Indeed, in the absence of extreme events, beech trees can 'over-mature' and synchronously die back over large swathes of the forest, opening the way for renewal. Broadleaf-conifer forests contain many shade-tolerant species that can regenerate in small canopy openings.[8] But larger canopy openings caused by events such as landslips will see a lengthy succession of species colonising the site, ranging from short-lived, light-demanding shrubs and trees followed by slower-growing, shade-tolerant podocarps and broadleaf trees that emerge through the canopy.[9] While a broadleaved canopy of intermediate stature may develop within 100 years or less, it can take many centuries with little disturbance for tall, late-successional tree species to emerge.

The arrival of humans

Following the arrival of Māori in Aotearoa, areas of native forest were cleared. Māori brought with them a belief system in which care for natural resources was deeply embedded but it had been developed in a completely different island setting. New learnings had to be generated about the limits the Aotearoa environment could handle. Forests were cleared to make way for kāinga, pā and other living areas, like māra kai (vegetable gardens). The use of fire to catch large

7 Wyse et al., 2018.

8 See Beveridge (1973) for a description of podocarp regeneration following different disturbance events in the central North Island.

9 Wyse et al., 2018.

flightless birds like moa was utilised with devastating effects. In combination with natural drivers of deforestation during that period – including climatic changes, volcanism and natural fires – it is estimated that forest cover was reduced from 82% to 68% of land area, with about half of the lowland forests destroyed.[10] Dry, open forest types, such as those that existed in the drier eastern regions of both islands, were particularly vulnerable to fire and did not persist in the face of human-induced burning. With the arrival of Europeans, the clearing of forests increased on a massive scale and over a much briefer timespan. Forest cover was further reduced to roughly 23% of land area.[11] The ability of the ngahere to regenerate was severely diminished as other pressures, such as browsing animals and weeds, were introduced and spread.

Establishing native forests in a human-altered world

It is generally acknowledged that establishing and maintaining diverse new native forests in most parts of New Zealand will require some form of intervention. Human-induced pressures have disrupted natural processes and human intervention will be required to repair them. In such a modified environment, leaving areas entirely to 'natural' processes risks ending up with an assemblage of weedy exotic species and a narrow range of unpalatable native species.

A spectrum of passive-to-active approaches can be undertaken to support native afforestation, including:[12]

- more passive approaches that predominantly focus on facilitating natural successional processes, such as weed control or reducing browsing pressure from stock or animal pests
- moderately intensive approaches, such as planting a nurse crop to support natural regeneration or enrichment plantings to supplement regeneration
- highly intensive approaches, such as planting and tending a diverse range of native tree species.

Key considerations when assessing whether to take a more active or passive approach include:

- how likely is it that relying predominantly on natural processes will lead to the desired outcome within the desired timeframe? For example, those with a production mindset may seek forest establishment within a few decades, while those with an intergenerational mindset may be comfortable with the process taking a few hundred years. Different timeframes will raise different pressures that need to be considered (see Box 5.2 for a Māori approach to passive afforestation with a long-term outlook)
- what resources – time, funding, workforce – are available to support the development of the forest? How secure are these resources over the relevant timeframes, bearing in mind that even a 'permanent' forest will need some long-term management?
- what are the desired uses of the forest and how could they be affected by the establishment approach (such as through regulations on natural forest harvest)?[13]

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[10] Ewers et al., 2006.

[11] Perry et al., 2014.

[12] Forbes et al., 2023.

[13] The Forests Act 1949 includes rules around harvesting of natural forests that are relevant when choosing between planting or natural regeneration of native forests for timber production. This is discussed more in Chapter 10.

Box 5.2: Taking a long view of native forest restoration

The whānau-run Prime Holdings farm in Motatau, Northland, led by Kevin Prime and his son Peter, is taking an intergenerational approach to restoring native forest on their whenua. About 50% of their 1,000 hectares is currently pine plantations of varying ages. Owner Peter Prime explains:

> "We are guided by the philosophies of our ancestors, one of whom once said, 'Kaua e turaki ngā rākau i ngā tahataha wai', which loosely means, 'Don't cut down trees next to water'. For context she died in 1947, long before modern research was readily available for landowners. This is abundantly clear to us now, as areas where trees were left standing show superior water quality and minimal local sedimentation. Earlier adherence to this would have prevented many of the issues we experience today, such as sedimentation, slash and water quality."

From 2013 to 2019 as each pine stand was harvested, the land adjacent to the waterways – approximately 50 m either side – was planted in native rākau and set aside as a permanent reserve. This contributed to restoring and protecting the quality of the water.

The scale of the task is no mean undertaking, but the whanau are comfortable that the restoration will eventually be a success, even if it takes centuries. The Prime whānau have a 750-year vision for their whenua. This intergenerational mindset allows the challenges that occur throughout the process, such as wilding pine, 'weeds' and storm damage, to be just that – part of the process. This doesn't mean they are completely hands off, as plants such as pampas have demanded attention. According to Kevin Prime:

> "We have a firm belief that Papatūānuku will eventually correct our activities, activities that have drastically changed this landscape in a relatively short period of time."

The whānau utilises kōrero tuku iho (knowledge passed down) to guide them, coupled with modern learnings from research and examples throughout the land to assist this vision. They have trialled various approaches to establish native species and have had great results from planting kahikātoa (tea tree) at 2x2 metre spacings as they rapidly establish a canopy.

> "We think it is important to point out that it took us over 100 years to clear the debt on our land. We were on the land before the 1909 Native Lands Act dispossessed us of it. Our tupuna took loans to purchase back our ancestral land which committed it to its present state. Hence, the decision by our collective whānau to return forestry land to a reserve is made easier with the knowledge that we are forfeiting economic profits for intergenerational benefits, such as drinkable and healthy water.
>
> "Had we not cleared the land debt, this decision would not be so straightforward. As we often say, 'It's hard to be green when you're in the red [i.e. without resources and money], but it's hard to be green when your eyes are green' [i.e. driven entirely by profit and prioritised overall]. Throughout our organisation's history, we have sat on both ends of the spectrum."

Source: PCE

Figure 5.3: A view of the Prime Holdings farm in Motatau, Northland.

Some different approaches that can be used to establish new native forests follow.[14]

Assisted natural forest regeneration

Assisted natural forest regeneration aims to enable and accelerate natural processes that lead to the development of native forests by removing barriers and addressing pressures within the landscape. It occupies a middle ground between unaided natural processes, such as reversion to mānuka or kānuka on pastoral hill country, and high-intensity interventions like large-scale tree planting. Assisted natural regeneration can be carried out at large scales and generally costs less than more intensive approaches, with nature doing most of the work 'for free'. Some costs are still likely through interventions, such as weed control ($15–$700 per hectare) or animal pest control ($2–$200 per hectare), fencing ($595 –$7,430 per hectare) or enrichment planting ($6,900 per hectare for 1,500 stems per hectare).[15] Under the right conditions, simply excluding stock or controlling animal pests and weeds can enable palatable forest species to regenerate from residual soil seedbanks or seeds dispersed by wind or birds. In other places, low-level grazing by stock can sometimes support the establishment of unpalatable tree species, such as mānuka, kānuka or tōtara.[16]

Assisting natural processes in this way is cheaper and more practically feasible than large-scale planting, which brings the additional costs of purchasing, transporting and planting thousands of native seedlings per hectare. It may also lead to more diverse and resilient forests that reflect naturally present, locally adapted species. While new native forests established through planting have tended to be relatively small, there are examples of natural forest regeneration occurring over much larger areas. Examples include Hinewai Reserve on Banks Peninsula (>1,000 hectares), marginal pastoral hill country on the East Coast of the North Island, and hillsides in other parts of the country.[17]

[14] Dungey et al., 2025.

[15] Forbes Ecology, 2022. Costs are highly variable with site-specific circumstances.

[16] Bergin and Kimberley, 2014.

[17] Bergin, 2003.

However, assisted natural regeneration won't work everywhere.

At a regional scale, we know which areas of the country are most suited to natural forest regeneration and where active planting is likely to be needed.[18] Natural regeneration is more likely in warmer, wetter areas and those with more local woody cover than in colder, drier, more sparsely forested areas. In general, the North Island is better suited to natural forest regeneration than the South Island.[19] In very dry areas, such as southern Marlborough, establishing naturally regenerated or planted natives can be very difficult.

At a local scale, the likelihood of natural regeneration requires careful site-specific assessment. While many landowners have detailed knowledge of their land and a good understanding of where natural regeneration is most likely to be successful, technical expertise may be needed to identify the most effective approaches to use within a site.[20] Besides temperature, rainfall and local woody cover, other macro-scale and micro-scale factors affecting natural regeneration potential include:

- the proximity of seed sources and the presence of seed-dispersing birds
- topography, slope and aspect, e.g. lower slopes tend to be more nutrient rich; southern facing slopes are cooler and moister so are more likely to regenerate
- soil properties, such as moisture content, nutrients, soil type and microbiome
- how land has previously been used and how long since it was deforested. The best approach to support regeneration of a site previously in pasture might differ from cutover areas due to differences in soil chemistry, compaction, fungal communities and nutrient levels
- the presence of pests, weeds and other exotic species within the surrounding landscape (noting that some exotic 'weeds' such as gorse can be turned to advantage for forest restoration).

Natural regeneration of early-mid successional species can occur fairly rapidly in suitable areas simply by excluding browsers. The earliest arriving tree species in retired pasture tend to be unpalatable, light-demanding and dispersed by wind or water.[21] Where diverse mature native forest is the goal, interventions may be needed to stimulate or accelerate the arrival of later-stage species.

Interventions that accelerate the development of a mature native forest include planting later-stage tree species or plants that attract birds, herbivore exclusion or control, and mimicking disturbance events that trigger germination and the growth of target species. Enrichment planting is particularly important if native tree seed sources are scarce in the surrounding landscape. But taking too much of a 'scatter-gun' approach to planting within developing shrubland is labour intensive, challenging to maintain at scale and likely to yield poor results.[22]

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[18] Mason et al., 2013.

[19] A 2020 report by The Aotearoa Circle estimated the area of private land that could be suited to natural regeneration (excluding areas suited to exotic production forests, ecologically sensitive areas, extreme slopes and environmental limiting factors for tree growth) was 260,000 ha in the North Island and 480,000 ha in the South Island. If those exclusions were removed, they considered the majority of the North Island could naturally regenerate, whereas the South Island had about 1 million ha suited to natural regeneration (The Aotearoa Circle, 2020).

[20] Forbes et al., 2023.

[21] Mason et al., 2023.

[22] Tāne's Tree Trust, pers. comm., 7 January 2025. More strategic approaches include planting and maintaining small groves or 'seed islands' of native tree species in good-quality, accessible areas across the landscape.

Accelerating forest development reduces the risks of arrested succession, where plant communities remain in an early stage of development for prolonged periods. For example, historical fires in the Waikere River catchment in central Te Urewera cleared the original podocarp-tawa forest and initiated forest successions. Browsing pressure from introduced mammals has prevented re-establishment of tall canopy tree species and has maintained the land in an early-successional state, characterised by kānuka giving way to tree ferns, which additionally shade out any seedlings growing underneath.[23] Without intervention, it is likely that a short-statured tree fern and shrub community will persist.

Early-successional species, such as mānuka and kānuka, are also more flammable than diverse native forests and therefore more vulnerable to wildfires, which can reset forest development and keep the land in a vulnerable state for longer.[24]

Could disturbance treatments assist regeneration of podocarp forests?

Historically, there are examples of both natural (see Box 5.1) and human-induced, large-scale disturbance events that have triggered the regeneration of podocarps. Early Māori fires around kāinga and gardens in both Whirinaki and Te Urewera – before the introduction of deer to those forests – created ideal conditions for podocarp regeneration.[25] Logging in Westland created soil disturbance and high light environments that favoured rimu.[26] Similarly, heavy logging in the central North Island in the twentieth century sometimes resulted in the emergence of a podocarp canopy 40–60 years later.[27]

These observations suggest that disturbance treatments could be used to stimulate podocarp regeneration. However, there is a much greater abundance of early colonising weeds and browsing mammals today than during historical disturbances, which could limit podocarp establishment if left unmanaged. Furthermore, the exact mechanism through which large-scale disturbance supports podocarp regeneration is unclear. High light levels, increased soil fertility, reduced competition or ability to disperse into sites are all possibilities. This makes the development of suitable silvicultural treatments to mimic disturbance and promote podocarp establishment challenging.[28] There also appears to be a continuum of shade tolerance within podocarps that precludes a one-size-fits-all treatment.[29]

[23] Richardson et al., 2014.
[24] Wyse et al., 2016.
[25] Cameron, 1960; McKelvey, 1963.
[26] James and Franklin, 1978.
[27] Beveridge and Bergin, 1999.
[28] Manaaki Whenua – Landcare Research, pers. comm., 28 November 2024.
[29] Beveridge and Bergin, 1999; Carswell et al., 2007.

Source: Jon Sullivan, Flickr

Figure 5.4: These kahikatea seedlings have established themselves on the forest floor in Canterbury, but to survive in the human-altered environment, they are likely to need human assistance, specifically weed and pest control.

Planting new native forests

Planting can accelerate native forest establishment and provide the landowner with more control over what type of forest develops and how it is used in future.[30] However, while there have been many successful small-scale native plantings, there are few examples of success being achieved at a larger scale. Large-scale plantings of native species did occur in the late nineteenth and twentieth century to replace native forest that had been cleared. But a lack of maintenance meant these plantings largely failed. See Box 5.3 for an example.

[30] Such as keeping harvesting options open.

Box 5.3: Learning from the past: the risks of planting without maintenance

From the 1930s to the 1960s, the New Zealand Forest Service carried out sporadic planting of kauri seedlings in recently logged kauri forest and other areas with low levels of regeneration.[31] But a lack of follow-up care, such as releasing the saplings from weeds and nurse crops, meant more than half the plantings failed (either partially or completely) and poor record keeping meant many couldn't even be relocated. Interest in kauri forests faded due, in part, to these low success rates but also because of propagation issues, high costs and uncertainties about the future of kauri forest management.

Planting scaled up in the 1970s with the formation of the Kauri Management Unit, and between 1974 and 1983 some 290,000 kauri seedlings were planted over 780 hectares in Northland and the Auckland and Rotorua Conservancies.[32] Some early releasing occurred, and initial survival and growth rates were encouraging (albeit variable), but large areas remained untended. Once again, a lack of systematic monitoring and ongoing tending often ultimately resulted in poor performance and missed learning opportunities.[33]

The lack of tending wasn't restricted to state forests. A national survey in the 1980s of native plantings on private land and those administered by local bodies found that little weed control occurred beyond the early years after planting, and this was the main cause of poor survival and growth rates.[34]

The Government's One Billion Trees programme provided direct grants for 420 projects focused on planting natives (covering a total area of 13,861 hectares).[35] Intended or not, the programme became a large, but unplanned, experiment in finding out what works and what doesn't when it comes to growing new native forests.[36] There have been both successes and failures. In some cases, these have led to amendments to projects. Planting failure was the most commonly stated reason for native plantings being withdrawn from the programme.[37] Given the unplanned nature of the experiment, it is unsurprising that little detail into the causes of these planting failures was captured.[38] This speaks to a deeper policy problem with environmental information gathering and distribution, which manifests in a lack of monitoring and reporting, a theme the PCE has elaborated on previously.[39]

Planting trees without first identifying and managing threats can lead to failed plantings. Threat identification is hindered by a lack of readily available environmental information for landowners on what issues might exist within the surrounding landscape. There are some indicators to look for – a lack of natural regeneration can indicate that something is amiss, for example. However, this doesn't immediately identify the type of pressure that exists or how it could be managed. Better environmental monitoring and information sharing would help address this.

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[31] Halkett, 1983.

[32] Halkett, 1983.

[33] Bergin and Steward, 2004.

[34] Pardy et al., 1990.

[35] Te Uru Rākau – New Zealand Forest Service, 2024.

[36] This includes exotics, although about half of these have been the species we know most about – radiata pine.

[37] As of 2024, 227 ha that were intended for native afforestation had been withdrawn from the programme (Te Uru Rākau – New Zealand Forest Service, 2024).

[38] Whatever its social or economic success, One Billion Trees represents a missed opportunity to provide high-quality information on planting successes and failures, which would have helped in ensuring that any future public expenditure on similar projects could be better spent.

[39] PCE, 2024a; PCE, 2022a.

Box 5.4: Counting the trees that count[40]

A common issue with planting natives is a lack of monitoring after planting, despite the considerable benefits that could accrue from understanding successes and failures alike. Trees That Count (TTC) is a national campaign that began in 2016, aimed at mobilising people to plant native trees. TTC enabled the planting of over 2.5 million trees by the end of 2024 and currently supports about 200 planting projects a year. Beyond encouraging planting itself, TTC has recognised that monitoring success is key to helping practitioners learn as they go. It assists in refining best practice management (such as post-planting weed and pest animal control), as well as being a way to report outcomes to funders. Planters are required to include monitoring in their restoration plan to support timely maintenance and adaptive management.

TTC, in collaboration with Tāne's Tree Trust, has developed advice and tools on how best to monitor plantings to ensure post-planting maintenance is effective. This ranges from a simple self-reporting tool to detailed plot-based monitoring for large projects, which allows planters to report on, analyse and assess progress. TTC has also created a network of regional advisors to undertake verification and check on monitoring. By the end of 2023, TTC had monitoring data for about 300,000 sampled trees – with an average estimated survival rate of 89.9% after the first year of planting. TTC will shortly begin conducting an audit of early plantings to determine the success rate of native afforestation at least five years after planting.

A number of logistical, ecological, cultural and social issues make native tree planting fundamentally different to planting exotic species. Some of these are explored below.

Seeds and seedlings

There are logistical challenges with collecting, storing, germinating and growing native seeds. A brief summary is provided below and further detail can be found in Appendix 2.

Seed collection is often time-consuming and labour intensive, with seeds generally collected by hand. Access to habitats is often restricted too, with permission needed from private landowners or the Department of Conservation (DOC).

Matching conditions at seed source and planting sites is widely understood to improve the chance of successful establishment, but opinions differ on whether seeds should be collected from areas close to where they will be planted – an approach known as eco-sourcing. Eco-sourcing is often recommended for restoration plantings to maintain local adaptation and genetic patterns and to respect whakapapa.[41] However, recent research suggests current eco-sourcing approaches may be "unnecessarily restrictive".[42] Using wider seed collection zones could reduce the risk of inbreeding, improve resilience and adaption for climate change and increase conservation options for threatened species.[43] However, any steps to widen sources of seed collection need to consider

40 https://monitoring.tanestrees.org.nz/; https://treesthatcount.co.nz/

41 https://docs.tanestrees.org.nz/ecosourcing-of-native-species-for-planting/

42 Heenan et al., 2024.

43 Heenan et al., 2024.

the role of Māori as kaitiaki responsible for taonga species and their seeds. Guidance for native seed collection has been developed but it can still be difficult to verify if these practices have been followed when ordering plants from a nursery.

After collection, seeds need to remain viable and be stored appropriately.[44] From the little we know, native seed viability is highly variable, but the seeds of most woody native plants in New Zealand can be stored in conventional seedbanks following a drying and freezing process.[45,46]

When it comes to germinating native tree seeds, our level of understanding is rather limited. Seeds of some species are known to require treatment to stimulate germination.[47] Methods required can be expected to vary between species and although we know the appropriate techniques for some common species, knowledge is lacking for many others.[48]

The way a germinated seedling is cared for in a nursery will have a big impact on its chances of survival once planted out. Factors such as pot sizes or types, growing conditions, planting media and fertilisers are all important.[49] Hardening off seedlings (by either leaving them outside to face the elements, or by withdrawing nutrients and water for a period) is also considered good practice.

Some native plants may be grown from cuttings, an approach that is costlier and takes longer but can overcome issues with seed availability and allows for greater control of genetics.

Site

To ensure establishment, native tree species need to be more carefully matched to site conditions than radiata pine.[50] Some species only grow in fertile, sheltered areas, whereas others can tolerate less fertile soils or more extreme conditions. For example, rimu is slow-growing and can tolerate low nutrient levels, while tōtara is best suited to open, well-drained sites.[51]

As with natural regeneration, most planted native species will do best in warmer, wetter areas. Native establishment can be extremely difficult and slow in dryland areas.

Unsurprisingly, where native trees are being grown for timber, establishing them in sheltered sites with deep, fertile soils and adequate moisture generally provides the best opportunity for good growth rates and wood quality. But such sites won't necessarily be the most readily available to those wishing to plant.

Site selection for native planting is going to become more difficult with climate change. It may become increasingly challenging to re-establish diverse native forests in some areas where they would have grown previously.

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[44] https://docs.tanestrees.org.nz/collecting-and-handling-seed-of-native-trees-and-shrubs/

[45] Seedbanks allow large volumes of seed to be stored at relatively low cost, in minimal space and for long periods.

[46] Wyse et al., 2023. Seeds from some species have been found to be sensitive to conventional seed storing methods so may require different treatments.

[47] The seeds of some species just take time to germinate and it may be difficult to speed up that process.

[48] Van der Walt et al., 2021; Ford and Lloyd, 2023.

[49] Recent research (Ford et al., 2022) has found that the seedlings of some native species tōtara can be grown in smaller pots (which are more aligned with large-scale commercial planting practices) and still perform well in the field, particularly when planted by experienced crew on good sites with pre-planting preparation and weed control. However, on poorer-quality sites larger pots may still be needed to achieve good survival rates, and some species are not suited to smaller pots regardless of the site.

[50] Bergin and Gea, 2005.

[51] Wardle, 1985.

The vital role of fungi

Fungi play an important role in how forests develop and function. Most plants form symbiotic associations, or 'mycorrhiza', with fungi in the soil, which enhance the plant's nutrient and water uptake and feed the fungi. Different types of fungi are found in different forest types. If the appropriate mycorrhizal fungi aren't present, plants can struggle to achieve good growth rates and may even fail to establish.[52] A lack of suitable fungal symbionts at a given site can hinder forest development, but little is known about this topic.

It has been found that introducing early-successional native forest species to an unforested area can inoculate the soil with fungi that support the establishment of later-successional natives. Ectomycorrhiza, a subset of mycorrhizal fungi, are particularly important for beech trees and their absence may be a key factor in why beech trees struggle to establish in areas outside existing beech forests. However, beech can establish in areas where mānuka or kānuka are present, likely due to overlapping ectomycorrhiza associations between the three species.[53]

Some exotic plant species can also introduce fungi to the soil that then form mycorrhizal associations with native plants. Research suggests that beech trees may be able to 'hijack' some of the mycorrhizal fungi introduced by lodgepole pine trees.[54] The suitability of exotic mycorrhizal associations for other native forest species is unknown. Introducing exotic fungi to an area could also have unintended consequences, such as causing competition with native fungi or making the site more suited to invasion by exotic plants.

In the same vein, introducing the right mycorrhiza into native nurseries might improve seedling health, growth and establishment. Clearly, the role that mycorrhiza could play in native afforestation efforts requires further research.[55]

Nurse crops

Nurse crops can help alleviate some of the issues faced when trying to establish new native forests through planting. Nurse crops are typically fast-growing plants that rapidly establish a closed canopy, supporting the establishment, growth and survival of other plants. They do this by:

- regulating the microclimate by providing protection from wind, extreme temperatures, solar radiation, soil water evaporation and low humidity
- creating suitable soil conditions by introducing fungi and enhancing nutrients
- attracting pollinators
- reducing competition with weeds
- in the case of unpalatable nurse crops, protecting wanted plants from browsers.

The role of nurse crops is well-known and approaches to using them vary. In some cases, the nurse crop is naturally present; in other cases, it is sown or planted. The species can be exotic or native. Perhaps most famously at Hinewai Reserve on Banks Peninsula, kānuka and gorse, a nitrogen fixer,

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[52] Lakhanpal, 2000.

[53] Wilson, 1994; Smale et al., 2012; Dickie et al., 2012.

[54] Dickie et al., 2010.

[55] Some research is underway: in 2020, Lincoln Agritech and Ngāti Whare's Minginui Nursery received five years of funding to investigate how trichoderma fungi could improve native plant resilience and health (https://www.iranz.org.nz/news/2020/lincoln_ag_partnership_hunts_helpful_fungi).

have been used to aid native forest regeneration. But other species, such as mānuka, coprosma, tree lucerne and scotch broom, have been used with success elsewhere. A review of exotic woody plants with good nurse crop potential found the most promising species tended to be low-stature and short-lived so they wouldn't outcompete the target native species.[56] However, using exotic nurse crops can result in notably different vegetation and soil outcomes than those involving only native species.[57] This could have impacts on future forest composition. As it can take many hundreds of years to develop diverse, mature native forests, the long-term outcomes of using exotic nurse crops to facilitate native succession is currently unclear.

On sheltered sites nurse crops can be planted at the same time as the target species, but in exposed areas it can be beneficial to plant the nurse crop a few years in advance to develop a protective canopy. Using naturally present nurse crops can reduce upfront costs, but some canopy manipulation may be needed to make enough space and light for the planted target species. This can be expensive and time consuming when carried out on a large scale.

Box 5.5: Retiring farmland into native forest to restore the land and provide a sustainable native timber resource[58]

At Cassie's Farm in the Waikato, Ian Brennan has been retiring gullies and low-productivity grazing areas into native forest for over 16 years. This is being achieved through planting a diverse mix of tree species, including tōtara, kauri, rimu, kahikatea, tanekaha, pūriri, kohekohe, mataī and miro among others. In open areas, shade-tolerant species are planted with mostly mānuka as a nurse crop to improve survival and growth rates. Plantings are typically done at two-metre spacings to encourage early canopy closure and minimise weed control. Further species enrichment occurs thanks to an abundance of existing local seed sources and bird populations. A favourable climate adds to the site's natural advantages.

The forest is being established under a continuous cover forestry regime that supports biodiversity and ecosystem services while also providing a sustainable timber resource – albeit one which can only begin to be extracted from 2071. Waikato Regional Council provided significant funds for this reforestation from 2016 to 2023 and has in return secured a covenant over the planted land. While such covenants typically prohibit any form of harvest in perpetuity, the council recognised the value of supporting native continuous cover production forestry and adapted its standard terms to allow silviculture and eventual low-intensity harvest.

[56] Williams, 2011.

[57] Kānuka and gorse had differing outcomes at Hinewai – at higher elevations, kānuka has tended to result in the regeneration of native beech trees whereas gorse has led to podocarp-hardwood forest. At lower altitudes, both are succeeded by podocarp-hardwood trees (Wilson, 1994). The lack of beech regeneration under gorse may be because gorse doesn't introduce the mycorrhizal fungi needed by beech trees, while kānuka does. Other studies have found similar differences between gorse and kānuka (Sullivan et al., 2007).

[58] Tāne's Tree Trust, pers. comm., 20 November 2024.

Source: PCE

Figure 5.5: Various native tree species and stages of afforestation can be seen in this photo from Cassie's farm.

Planting strategies

Blanket planting

The choice of planting approach has a huge impact on cost.[59] High-density, large-scale planting of native trees can be prohibitively expensive.[60] The cost for typical densities (1.5 metre spacings) is estimated at roughly $25,000 per hectare, excluding pest control, fencing and transport.[61,62] Lower-density plantings can cost $7,800–$11,000 per hectare for 3 metre and 2 metre spacings respectively.[63] This is still far more than the cost of establishing radiata pine, which ranges from $1,330–$1,706 per hectare.[64] Native planting is more expensive through every part of the process:

- Native seedlings typically cost more than exotics, ranging from $0.60 to $10 per native plant compared with $0.50 to $1 per radiata pine.[65]
- Transport costs are greater as the use of larger pots means fewer plants are transported per vehicle.

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[59] Bergin and Gea, 2005.

[60] Dungey et al., 2023.

[61] Based on a survey of native forestry practitioners. It assumes typical planting densities of 4,444 stem/ha, seedling supply from a commercial nursery, use of a professional planting crew and one year of commercially implemented releasing and blanking. Taking average costs for seedling supply, planting, releasing and blanking, use of the most popular restoration grades results in an average forest restoration planting cost of $22,314/ha. The same scenario, but only for the second most popular seedling grade, results in an average forest restoration cost of $27,425/ha (Forbes Ecology, 2022).

[62] Fencing can greatly increase costs, particularly on steep land. A 2016 report found that the average cost of non-electric 8-wire fencing for sheep and cattle increased from $13.02/m on flat terrain to $16.64 on steep land and could cost up to $24.88. Deer-proof fencing costs are higher (average $18.90/m on flat terrain, $22.71 on steep, with a maximum of $32.55) (The Agribusiness Group, 2016).

[63] Based on planting costs for 3 m and 2 m spacings of $2,811 and $6,050/ha respectively, with post-planting costs of up to $5,000/ha. The Tīmata ('kick-start') method advocates low-density plantings of mānuka or kānuka as a nurse crop followed by long-lived tree species 3–5 years later. It has been applied in Hawke's Bay and the Bay of Plenty on retired pastoral land (Dewes et al., 2023).

[64] Based on research from 2019, for a structural/framing timber regime planted at 900 stems/ha. Establishment costs include land preparation, buying and planting the tree crop, and weed control for the first year only (for comparison with the native high-density planting cost estimate), and vary due to slope. See https://www.canopy.govt.nz/forestry-data-research/putting-a-value-on-the-benefits-of-planted-forests/

[65] Forbes Ecology, 2022; NZFFA, 2025.

- There is higher usage of protective materials such as tree guards to protect from browsing damage, smothering from grasses and wind.
- There is a need for longer weed and pest animal control.
- Survival rates can be low so more plant replacements may be needed, particularly on poor sites.

There are trade-offs between the different planting strategies. High-density plantings have high upfront costs and are expensive to replace if they fail. However, they achieve more rapid canopy closure, so they require less weed control and plants are less vulnerable to exposure. Lower-density plantings may cost less upfront but require more ongoing expenditure to achieve canopy closure.[66]

Where native forests are being established for timber, initial high-density plantings may be needed to achieve good tree form and a well-stocked stand of trees. For example, tōtara plantations are known for developing trees with poor form for timber production.[67] Lower-density plantings reduce the number of trees to select for harvesting and may require more pruning to achieve an acceptable amount of merchantable timber. The upfront savings of lower-density plantings may mean further costs down the track and less timber revenue.

Due to these high costs and often low success rates, native plantings have tended to be relatively small-scale, so long-term data to assess the relative costs and benefits of different approaches is lacking.[68] Research is underway to investigate how to reduce costs of native afforestation.[69] Determining the long-term success and economics of different native planting approaches will require dedicated research over multiple decades and it will always be context-dependent. A range of propagation, growing and planting recipes will be needed along with knowledge of when to plant. Planting during droughts or in late winter in drought-prone areas often results in poor survival after planting. The best time to plant can vary between sites and regional climates.[70]

Regardless of the approach taken, planting technique is crucial.[71] While volunteer planting groups might appear to be an economically attractive option due to lower upfront costs, professional planting crews may be necessary to achieve good survival and growth rates of native seedlings when planting at scale.

Māori developed an in-depth knowledge of their rohe and utilised a lunar calendar, the maramataka, to plan out their planting, harvesting and seed collection during the year. Where available, maramataka could be used for more localised timing for planting specific rākau. For example, the monthly moon phase of Ohua is recommended as the best time for seed planting (‘hua’ is one word for egg or source). The moon phase of Otane is considered a good time for giving back to Tāne Mahuta, either in the form of planting or seed collection. Ngāti Rehia has utilised the maramataka to advise the Northland Tōtara Working Group when to selectively harvest tōtara in Northland.[72]

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66 Dewes et al., 2023; Baillie, 2020.

67 Quinlan, 2022.

68 Dungey et al., 2023.

69 Auckland University of Technology’s Living Laboratories Programme is trialling different experimental approaches to restore native forest at three sites that were previously pastoral farmland. This includes investigating the impacts of different planting densities and configurations, species composition, nurse species and early plantings of late-successional species (Buckley et al., 2023).

70 Bergin and Gea, 2005.

71 Incorrect planting techniques include improper planting depth, not loosening rootballs, not doing a positive pull-up and not firming in the seedling once planted (see https://www.canopy.govt.nz/establish-forest/plant-seedlings/).

72 For more, see Tāne’s Trees Trust 2024 newsletter https://www.tanestrees.org.nz/site/assets/files/1984/ntwg_newsletter_2024_final.pdf

Box 5.6: Restoring native forest after exotic forest clearance

The Hunua Ranges are a crucial water catchment for Auckland, supplying about two-thirds of the city's drinking water. In 2017, Watercare purchased the forestry rights to around 2,000 hectares of exotic plantations in the ranges. It is working to restore the land to native forest through planting and aiding natural regeneration, with the aim of protecting the water supply from sediment and chemical runoff from forestry activities. To inform its restoration approach, Watercare has been trialling different site preparation methods on recently harvested areas, including manipulating slash, controlling weeds with herbicides in out-of-catchment areas or scrub cutters, and over-sowing the cutover with grass.[73]

Different native planting densities have also been trialled. Initial findings suggest that planting natives, such as mānuka and kānuka, at a high density directly into the slash, in combination with targeted herbicide use to control weeds, provides the most cost-effective results. Lower-density plantings initially cost less but led to problems with weeds due to longer canopy closure times. Additionally, native growth rates were greatly reduced in areas where soil had been compacted by heavy harvesting machinery. Pest control was found to be important for natural regeneration. These learnings are being used to inform future restoration efforts within the catchment.

Source: Rhys Millar

Figure 5.6: The effects of five years of native afforestation efforts at the Hunua Ranges are beginning to show.

[73] Watercare, pers. comm., 5 December 2024.

Seed islands

An alternative approach to widespread planting is to establish a network of small, intensely managed plantings in favourable areas with good access. These plantings should include tall, later-successional tree species that are native to the area but are now missing or scarce within the surrounding landscape. The intention is that, once mature, these 'seed islands' will act as hotspots of diversity that release seeds and stimulate regeneration within the wider area.[74] This approach is more affordable and manageable than attempting to revegetate a large area all at once.

Seed islands are a relatively new concept, although a similar approach was employed on the East Coast over 20 years ago and is informing current research.[75] The success of seed islands in stimulating natural regeneration within the wider area is yet to be determined but it will be affected by pressures within the surrounding area and the suitability of the site for natural regeneration. If there are invasive weeds or browsing mammals outside the managed seed island, native seedlings will struggle to establish. Similarly, without predator control there will be no birds to disperse seeds. Positioning seed islands within a matrix of regenerating shrubland or low-density plantings of mānuka or kānuka may increase the chance of success by providing shelter to seedlings and facilitating seed dispersal by birds. The time it will take for seed islands to start producing seeds and triggering regeneration in the wider area will vary depending on the species and growing conditions – tōtara can produce seed within 10 years on good sites; kauri can take 25–40 years.[76]

Sowing a native forest

Direct seeding – sowing or casting seeds over large areas – offers the appeal of reforesting retired pastoral land and other areas cost-effectively but has not yet proven effective at scale. While it shows potential, it remains in the research phase and success rates can be low. Research to date has included trialling drone-based dispersal of seed pods, hand sowing and mechanical methods, such as direct seeding machines. Other application techniques being promoted include the seed-bearing slash method for mānuka and kānuka, and spraying water-based mixtures of seeds, mulches and adhesives (hydroseeding) onto steep, unvegetated sites.[77]

Major challenges to the success of direct seeding at scale remain, including:

- the large volumes of viable seeds required due to germination and survival uncertainties. Some seeds will be eaten and there will be seedling competition with existing vegetation, particularly exotic grasses
- the costs of equipment required to collect, store, distribute and disperse seeds
- the difficulty of working on steep slopes and remote sites.

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[74] https://docs.tanestrees.org.nz/how-to-establish-seed-islands-of-natives/

[75] Single-species groves of trees were established at Waikereru Ecosanctuary on the East Coast in the early 2000s to support natural regeneration. This is informing a current research programme at the same site. See https://www.waikereru.org/assets/documents/SeedIslandsReportMarch2022.pdf

[76] Bergin, 2003; Bergin and Steward, 2004.

[77] The 'seed-bearing slash' method involves cutting seed-bearing branches from mature trees and laying them on the soil at the target location to form a dense mat that supports seedling germination and growth.

Likewise, key knowledge gaps need to be addressed, including:

- identifying which species are most amenable to direct seeding
- learning how to ensure germination and survival of sown seeds
- establishing species-specific sowing methods, rates and timings
- trialling which species can be mixed together
- understanding the impacts of soil fungal communities
- the impacts of previous land use, such as how soil compaction in previously grazed or harvested areas affects establishment and growth rates.

While offering some promise, cost-effective direct seeding of native forests at scale is still some way off.

Tending young trees to ensure establishment

Once plants are in the ground, some management will be required to ensure successful establishment. Native seedlings need to be monitored within the first few weeks and months of planting, and then several times a year for the first few years to assess survival and identify any pressures in the surrounding environment.

Most seedlings require some pest and weed control, but native seedlings tend to require control for longer, due to slower growth rates and the greater palatability of some species. For example, while radiata pine seedlings only need releasing once after planting, native tree seedlings require releasing once or twice a year for at least the first two or three years, or longer under poor growing conditions.[78] Spray releasing methods for radiata pine are well-established and straightforward – it is safe to spray over the top of radiata seedlings without harming them using the right herbicide. But less is known about alternative exotic and native species, and as the effects of herbicides tend to be species-dependent, it can be risky to use herbicides around young native trees unless there is good knowledge of the impacts. Manual weed control avoids this issue but isn't feasible at larger scales or on difficult sites.

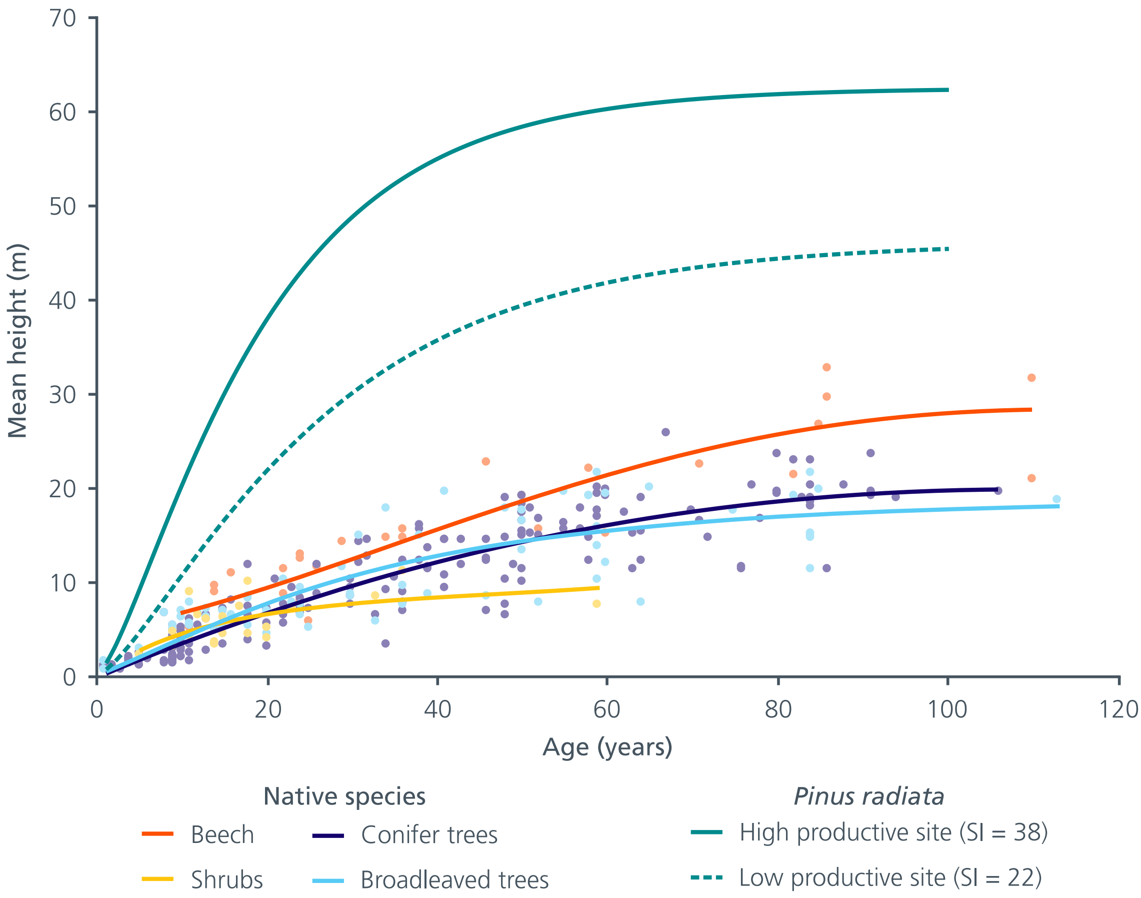
Similarly, native seedlings are vulnerable to browsers for many years, while possums can significantly damage older saplings and trees.

Additional interventions may be needed to ensure survival, such as plant guards and mulching to protect against the elements. Even then, some replacement planting may be required.

[78] Releasing involves clearing the area immediately around target plants of grass and weeds.

Growth rates

Despite the often-repeated claim that native tree species are slow-growing, the height and diameter growth rates of individual native tree species are highly variable. Some of the most comprehensive growth rate data for planted native trees and shrubs is held in a national database managed by Tāne's Tree Trust.[79] This data shows that, over the first 80 years or so, beech trees, especially red and black beech, have the fastest height growth rates of any native trees, reaching average heights of 29 metres. The second-fastest growing group are the most commonly planted conifer species: kauri, tōtara, rimu and kahikatea, which reach average heights of 21 metres over 80 years. Hardwood tree species, such as pōhutukawa, pūriri and rewarewa, have similar growth rates and can sometimes exceed native conifer growth rates on good sites. However, the longest-lived conifers can continue growing for hundreds of years, achieving heights of 40–60 metres and trunks that are several metres in diameter.



Source: Data from Tāne's Tree Trust, and van der Colff and Kimberley, 2013

Figure 5.7: Growth rates of native trees and radiata pine. Radiata pine growth rates are shown for a high-productivity and low-productivity site. (SI = Site index, the average height at age 20 for a given site.)

[79] The Tāne's Tree Trust Indigenous Plantation Database has measurements of 15,000 planted native trees and shrubs nationwide from 5 years to 110 years old. Measurements are taken from over 100 permanent sample plots (PSPs) and growth plots established in planted native stands across the country. See their website for more information https://www.tanestrees.org.nz/projects/indigenous-forestry-plantation-database/

Site and climate are (almost) everything.[80] On good sites with good management, planted native tree species can grow much faster than those in natural stands. But under poor conditions they can struggle – for example, well-managed stands of tōtara on fertile soils in favourable climates can achieve diameter growth rates that are nearly double those of poorly-managed stands in dry conditions.[81] A well-managed stand of tōtara planted at 1,200 stems per hectare on an average site is expected to achieve a total stand volume of 640 cubic metres per hectare at age 60 years.[82,83,84] Thinning can also greatly increase growth rates.[85]

There are still big unknowns about native tree species' growth rates and productivity, and how these vary between regions and management approaches. Understanding the impacts of these interacting factors on forest growth rates is crucial to developing realistic expectations of carbon sequestration in native forests.

The growth rates of native trees compared to radiata pine are sometimes referred to as the tortoise versus the hare. But this comparison paints native trees in an unfair light. Undeniably, radiata pine grows much faster than native species, with an average harvest age of around 28 years for timber logs, while the fastest growing native timber trees in New Zealand (beech, tōtara and kauri) have current rotations of 60–80 years.

Yet the speed at which radiata pine grows in New Zealand is exceptional and helped by many decades of targeted research. While a 60–80 year rotation might seem slow, it is comparable to the rotations commonly observed in European forests. For example, the typical felling ages for Scots pine and European beech in Europe are 80–100 years and 100–130 years respectively.[86] A rotation of 60 years is also comparable to the rotation length of Douglas fir in New Zealand before any investment in breeding and management was made.

New Zealand's native tree species have not been subject to the same selective breeding and research. Our native trees aren't slow tortoises – radiata pine is just very fast and has been given every attention.

Silviculture

Silviculture of native forests is more complex than that of radiata pine plantations, particularly where multiple species are present. Silvicultural interventions, such as pruning and thinning, are required to produce high-value timber, which is important given the low harvest volumes permitted in many native forests. The timing and intensity of those interventions varies between species and harvest regimes. Good silvicultural information has been developed for a small number of species, such as kauri, tōtara and various beech species, but is lacking for others.[87]

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80 Bergin and Kimberley, 2003.

81 Table 4, Bergin and Kimberley, 2003. See Pukekura Park, Taranaki, and Purau, Banks Peninsula.

82 Tāne's Tree Trust Toolkit Calculator (https://toolkit.tanestrees.org.nz/). Assumes 100% survival.

83 For comparison, radiata pine produces around 900 m^3/ha by age 30 in the North Island (Watt et al., 2021).

84 But wood harvested from tōtara at 60 years will be predominantly sapwood, not the heartwood tōtara is renowned for (although there are uses for sapwood).

85 Richardson et al., 2011; Bergin and Steward, 2004.

86 https://forest.eea.europa.eu/topics/forest-management/harvest

87 Quinlan, 2021b, a, 2022; Bergin and Steward, 2004; Satchell, 2018; Dungey et al., 2025.

Periodic clearing and re-establishment may be needed in stands of mānuka or kānuka that are managed for honey production. If left unmanaged, and conditions are conducive, mānuka and kānuka stands are likely to be outcompeted by taller tree species and transition to mixed native forest. This of course is not an issue if mature forest restoration is the aim.

Harvesting

The harvest and milling of native timbers is more strictly regulated than that of exotic forests.[88] Still, some native timber harvest does occur – around 10,000 cubic metres have been harvested per year since 2020.[89] Currently the most commonly milled native timbers are silver and red beech, and softwoods, such as rimu, tōtara, mataī and kauri.[90] Hardwoods, including kānuka, mānuka and black maire, and tree ferns are also harvested at low levels.

Native timber is typically harvested from forests under continuous cover regimes, which allows for low-volume harvest while maintaining other environmental values.[91] There are a handful of commercial, native continuous cover forestry operations in New Zealand. The largest are located in the South Island and involve the sustainable harvest of beech forests, either within large tracts of secondary forest or in smaller scattered areas managed cooperatively to achieve economies of scale.

How a native forest is harvested affects which species regenerate and by how much. For example, some species require large disturbances to trigger regeneration, making them suitable for coupe harvest, whereas others grow best under a closed canopy with smaller light gaps, making them suitable for selective tree harvest. Understanding how harvesting affects regeneration is therefore important for sustainable forest management and the future composition of the forest.

Different harvesting approaches were trialled in native forests last century. This included single tree harvest and small coupe harvest of podocarps in Whirinaki Forest, and strip-felling of rimu forest in Westland.[92] Such research yielded useful results: it demonstrated compositional changes in the regenerating understorey following harvest and the benefits of selective harvest. However, this research was largely abandoned after the 1980s as the widespread harvesting of native trees came to an end. As a result, our understanding of how to best sustainably harvest different types of native forests is limited. There is an interest in resurrecting some of the older trial sites. Recent experimental harvesting of regenerating tōtara on farmland in Northland has also sought to improve knowledge in this area.[93]

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88 The Forest Act 1949 covers the harvest and milling of native forests and timbers. For naturally regenerated forests, harvesting is restricted to very low intensities under Sustainable Management Plans or Permits, and the forest's natural values must be maintained. Planted native forests are not subject to harvesting restrictions and can be clear-felled (although milling restrictions still apply).

89 See data under 'Quarterly Production, Stock and Roundwood Removals' at https://www.mpi.govt.nz/forestry/forest-industry-and-workforce/forestry-wood-processing-data/wood-processing-data/

90 MPI, pers. comm., 18 November 2024.

91 A recent report reviewed existing and emerging examples of native continuous cover production forestry in New Zealand, including examples of black beech, red beech, silver beech and tōtara timber production (The Connective et al., 2023).

92 Dungey et al., 2025.

93 Dunningham et al., 2020.

Box 5.7: Weaving native production forestry into farmland[94]

A new native forestry opportunity is emerging on farmland in Northland. Less productive areas of farmland often naturally revert to forest dominated by tōtara, which is unpalatable to stock and grows so vigorously that some landowners view it as a weed. The Tōtara Industry Pilot project, initiated in 2018 by Tāne's Tree Trust, sought to make the most of this opportunity by testing a business case for a new native timber industry based on the sustainable harvest of regenerating tōtara on private and Māori land.

The project ran for two years and harvested 300 cubic metres of tōtara logs from three farms, in accordance with sustainable management requirements under the Forests Act 1949. The timber was successfully milled at an existing radiata pine sawmill, dried and sold, which provided valuable insights into the supply chain, costs of production and current market value.

Different management approaches were also trialled. Naturally regenerating tōtara seedlings were found to benefit from light grazing to help reduce competition during early establishment, after which stock exclusion and thinning were necessary to increase understorey diversity and growth rates. Single tree harvest was successfully implemented with minimal damage to the surrounding forest, but low regeneration rates suggest larger clearings, prohibited under the Forests Act, may be needed to ensure sufficient regeneration of light-demanding species like tōtara.

The project showed there is a market for high-value tōtara timber, and that a small, slow-growing timber industry in Northland is practically and financially viable. Yet challenges remain, such as the scattered nature and uncertain scale of the tōtara resource, gaps in technical knowledge, slow and costly permitting processes, and the need for greater market development and functional supply chains.

Knowledge gaps for large-scale native afforestation

If native afforestation is going to be pursued on a much larger scale than anything experienced to date, many knowledge gaps will need to be filled or we risk wasting large amounts of money and effort. Some critical knowledge gaps are:

Natural regeneration

We need:

- to monitor the long-term outcomes of regeneration efforts and the causes of successes and failures
- to understand how disturbances stimulate regeneration in podocarp forests, and how this could be applied to assist forest regeneration.

[94] Dunningham et al., 2020.

Planting and other establishment methods

We need:

- to monitor the long-term outcomes of different planting approaches and develop ‘recipes’ for different environments. This includes:
  - trialling different planting densities, species mixes and configurations of seed islands
  - determining how planting can encourage natural regeneration at scale across marginal landscapes
  - assessing the success and cost-effectiveness of direct seeding methods at scale
  - assessing the long-term effects of different nurse crops on native forest development
  - understanding the causes of successes and failures
- to identify the most appropriate seed storage and germination methods for different native species in nurseries
- to understand the role that mycorrhiza plays in native afforestation, including the impacts of seedling inoculation and exotic mycorrhiza on survival and growth.

Knowledge gaps relevant to all establishment methods

We need:

- to understand how long it is likely to take to develop mature native forests in different areas and using different approaches
- to assess the impacts of previous land use on native establishment success
- a greater understanding of the long-term economics of establishing and maintaining native forests at scale
- to determine what level of pest control is required to enable diverse native forest regeneration
- to develop suitable silvicultural regimes for different species and wood products
- to collect detailed growth rate data across different sites and regimes
- to explore the feasibility of transitioning exotic forests to native forest (see next chapter)
- a better understanding of the wider environmental, social and cultural benefits of native afforestation.

Long-term considerations for native forests

All forests need to be managed for the environmental pressures they face. The amount and type of ongoing management will depend on the forest's purpose. Ongoing management will require ongoing investment. How this will be provided needs to be determined at the outset, before planting starts.

Risks to native forests

Pests and weeds

Where long-term biodiversity and forest resilience are desired outcomes, native forests will require ongoing pest and weed control. Introduced predators, such as possums, stoats, rats and feral cats, prey on native fauna, such as snails, skinks, geckos, insects and birds, reducing biodiversity and disrupting the role these species play in forest functioning.

Mammalian pests directly damage native flora in several ways. Possums can severely damage mature trees by systematically stripping them of young shoots, fruits, flowers and leaves. This damage also opens up the canopy and increases the forest's vulnerability to rain, wind, disease and insect damage, and can cause canopy dieback. For example, within 15–20 years of possums arriving in the southern rata-kāmahi forests in Westland, many valleys had lost more than half of their canopy trees.[95] Additionally, possums and rodents limit regeneration by reducing the number of viable seeds on the forest floor.

Source: John Barkla, iNaturalist NZ

Figure 5.8: Feral goats, such as this one pictured in Whareorino Forest, western King Country, feed on young plants in the understorey, compromising native regeneration and ultimately changing the forest's composition and structure.

[95] Hutchings, 2015.

Browsing ungulates, such as goats and deer, also reduce regeneration in native forests by feeding on young plants in the understorey. This can greatly reduce understorey diversity, particularly of palatable species, resulting in changes in forest composition and structure.[96] Exclusion or intensive control of browsers may be needed to support regeneration of palatable species.[97]

The long-term impacts of browsers on forest carbon stocks in mature forests are uncertain. The limited data available suggests that, in general, browsing ungulates have little impact on carbon storage within mature forests in the short-term to medium-term as most carbon is held in larger trees, which are not affected by these species over decadal timeframes.[98] This is in contrast to possum damage, which has more immediate carbon impacts. In addition, carbon losses from palatable species may be counteracted by greater regeneration of less palatable species, such as podocarps. However, the benefits of controlling ungulates to improve plant diversity are clear, as are the carbon benefits of control in young and regenerating forests.[99] More diverse forests are also more resilient to disturbances, such as extreme weather events, pathogens and insect damage.[100]

The risk of weeds invading native forests is higher where they are close to modified land cover, such as pasture, exotic plantations and urban areas. These areas can provide a constant seed source for a huge range of weeds so ongoing vigilance is required, particularly during periods of increased vulnerability after disturbances.[101] Weeds, such as wandering willie, wild ginger and tree privet, can penetrate intact native forest. Others, including climbing asparagus, woolly nightshade and Chinese privet, can prevent regeneration and displace understorey species. Some plants, such as banana passionfruit and jasmine, can smother quite large native trees and cause canopy collapse.[102] Some wilding conifers can also remain an issue in mature native forests. The shade-tolerant Douglas fir is particularly problematic in beech forests with more open canopies and sparse understories.[103]

Of course, the case for management flows in both directions. Any sort of forest cover can facilitate the spread of pests and weeds to other areas if left unmanaged. In the course of writing this report, a number of land managers raised the issue of mammalian pests and weeds spreading into their land from neighbouring unmanaged native forest.

Diseases

There are already some diseases in New Zealand that can have severe adverse effects on native tree species. The most notable are kauri dieback and myrtle rust.

A number of pathogens found overseas, but not yet present in New Zealand, could threaten our native tree species. These include the South American strain of myrtle rust and the Hawaiian strain of Ceratocystis wilt, which has killed large numbers of Ōhi'a trees, a close relative of pōhutukawa and rātā.[104] Other potential pathogens exist but little is known about their impacts on New Zealand's native tree species. A 2021 review of plant biosecurity science in New Zealand found that there is very limited capability and capacity to predict the impact of exotic pathogens on our

96 Hawcroft et al., 2024.
97 Husheer and Tanentzap, 2024; Wright, 2017.
98 Peltzer and Nugent, 2023.
99 Peltzer and Nugent, 2023.
100 Oliver et al., 2015; Barrere et al., 2024; Liu et al., 2018; Jactel et al., 2017; Brockerhoff et al., 2017.
101 Jo et al., 2024.
102 PCE, 2021a.
103 Froude, 2011.
104 Dyck, 2021.

natural estate, and that plant biosecurity surveillance in this area is relatively weak.[105] Knowledge of native pathogens within New Zealand forests is also limited.

Establishing new native forests could affect the spread of diseases in multiple ways. Nurseries could inadvertently be vectors for pathogens as could movable infrastructure (such as beehives or machinery). There is little domestic research in this area.

Insect pests

The insect pests of native forests are less well-studied than those of commercial exotic forests. This may be in part because no introduced insects have yet caused serious issues for native tree species, and under normal circumstances native insects exist in a natural balance with native trees.[106] However, large disturbance events can increase insect-related tree mortality. For example, native pinhole borers typically cause little mortality in beech forests (although they can cause timber defects) but disturbance events can weaken trees and increase borer-caused mortality rates. Beech forests appear to be more prone to insect damage than mixed-species forests – the caterpillar stages of various native insects are particularly damaging. Insects are also vectors for many plant pathogens.

Wildfires

Much of the information about wildfires in Chapter 2 also applies to native forests. In general, well-established, healthy and diverse native forests are less flammable than exotic forests due to the complex understorey that supports a cool, moist microclimate and the presence of low-flammability species. However, the early stages of native forest development often involve highly flammable species, such as mānuka and kānuka. Many exotic species that co-occur with natives during early natural forest regeneration, such as gorse, are also highly flammable. Repeated fires can trigger a fire-begets-fire feedback loop and lower the chances of mature forest development.[107] If diverse native forest is the desired outcome within an area of high wildfire risk, it may be necessary to curtail the risk window by accelerating native forest succession towards less flammable species. Establishing low-flammability species, such as poroporo, hangehange, ngaio or karamū, can contribute towards a more diverse fuel environment that disturbs fire behaviour and slows the spread of any fires that do occur.[108] Grazing under the canopy can also reduce grass fuel loads.

[105] Dyck and Hickling, 2021.
[106] Ridley et al., 2005.
[107] Perry et al., 2014.
[108] Gross et al., 2024c.

Environmental effects of establishing new native forests

Biodiversity

Establishing new native forests could help address some of the main threats to New Zealand's native biodiversity, including habitat loss, fragmentation and degradation. However, it cannot be assumed that every new native forest will support large biodiversity values. Greater biodiversity benefits can be expected to be achieved by:[109]

- protecting existing remnants of now scarce native forest ecosystems and other important native ecosystems[110]
- restoring or improving connectivity of forest ecosystems that are now rare, such as in lowland, wetland complexes and coastal ecosystems
- improving connectivity between existing areas of natural habitat
- providing habitat for threatened forest fauna and flora or species that are nationally, regionally or locally significant
- having a high level of representation of threatened or scarce tree species
- maintaining a healthy forest through good management and effective pest and weed control.

While well-managed exotic forests can support native biodiversity, diverse native forests support a greater range of native plants and animals. Diverse continuous cover native forests provide a more stable environment and a greater range of habitats and food sources than exotic forests.[111] For example, fruit and nectar-feeding birds and lizards are rarely found in radiata pine plantations due to a lack of food, and hole-nesting species are uncommon in forests managed under a clear-fell regime, due to the removal of older trees.[112]

Restoring diverse native forests on pasture and shrubland greatly increases native biodiversity within an area.[113] Monocultural native forests, such as mānuka plantations and stands of regenerating tōtara, support less biodiversity than diverse forests but can act as important refuges for native biodiversity in agricultural landscapes. A study by Manaaki Whenua – Landcare Research found that native invertebrate communities can survive in fragmented mānuka plantations within highly modified landscapes and over time outcompete their exotic counterparts.[114] Research from Gisborne has shown that 60 year-old kānuka forests can support a similar level of invertebrate diversity as old-growth forests.[115]

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[109] McGlone and Walker, 2011; Aimers et al., 2021; Bergin, 2021.

[110] Looking after our existing native forests is covered in more detail in Chapter 8.

[111] Clout and Gaze, 1984; Brockerhoff et al., 2003; Scion, 2023c.

[112] Pawson et al., 2010.

[113] Carswell et al., 2012.

[114] For more see the BioHeritage website (https://bioheritage.nz/cape-to-city-looks-for-thriving-ecosystems-amid-manuka-plantations/).

[115] Dugdale and Hutcheson, 1997.

Source: Jon Sullivan, Flickr

Figure 5.9: Native forests dominated by a single species, like this stand of windblown tōtara can support native biodiversity, but less than diverse native forests.

Sediment and woody debris

Mature native forests typically provide the best protection against landslides during extreme weather events, although some erosion can still occur – particularly in steeper, less stable areas.[116] Native tree species tend to have shallow, strong roots, which make them effective at reducing shallow landslides on steep slopes with thin soils but are perhaps less effective for deeper-seated forms of erosion.[117] Some native species, such as kauri, mānuka and tī kōuka (cabbage trees), can develop deeper root systems unless prevented by geological barriers.[118] At an individual species level, exotic species generally outperform native tree species for most measurements of soil reinforcement other than root tensile strength.[119]

Of the limited data available on erosion control provided by secondary native forests, the best relates to mānuka and kānuka. These early-successional species can provide moderate soil protection from a relatively young age, with efficacy improving over time. For example, during Cyclone Bola, 10 year-old high-density stands of naturally regenerated mānuka reduced the incidence of landslides by 65% compared to pasture; 20 year-old kānuka-dominated stands

[116] McMillan et al., 2023; Rosser et al., 2023; Hicks, 1991. However, the density of landslides during Cyclone Bola was marginally lower in exotic forest >8 years old than in native forest (Marden and Rowan, 1993).

[117] Alfeld et al., 2018; Phillips et al., 2023.

[118] Geological barriers include shallow bedrock, high water tables or stony soil.

[119] Phillips et al., 2023.

reduced the incidence by 90%; and older stands were even more effective.[120] But high stem densities are critical; lower-density stands are far less effective.[121]

Although less is known about other native species, there are differences within and between species in root and canopy development and distribution, which will influence erosion control.[122] There are also likely to be differences between sites, such as slower canopy closure and root development on erodible, low-fertility sites.[123] Most young native trees tend to have less extensive root systems than equivalent-aged exotics such as poplars, alders, cypresses and redwoods.[124] The challenge in highly erodible landscapes will be getting the young native forest to establish a closed canopy and form protective roots before a storm damages the vegetation or triggers a landslide and resets the forest's development.

Clear-felling native forests would likely cause similar erosion and woody debris impacts to radiata pine forests. The main native species grown for timber do not coppice, so a window of vulnerability to soil erosion would occur following clear-felling. Periodic clearance of mānuka plantations to maintain honey production can create periods of increased erosion vulnerability, although their roots appear to decay more slowly than radiata pine.[125] Forests managed through continuous cover production forestry would have far lower rates of erosion and woody debris generation than those from clear-felled forests.[126] Unsurprisingly, unharvested forests provide the best long-term protection.

Water yield and quality

In general, establishing native forests on unforested land is likely to have similar impacts on water yields to exotic afforestation: reducing overall annual yields within catchments, and buffering high and low flows. Data on how the impacts would differ between exotic and native afforestation is lacking, but the changes might occur more slowly under certain types of native afforestation.[127] Native forests are most likely to successfully establish in areas with good rainfall, where reductions in water yields may be less noticeable.

While mature native forests have been shown to support higher water quality than pasture or production forests, the effects of young native forests are less well studied.[128] Prior land use can have legacy effects on water quality that last for decades.[129] There is a lack of research comparing the short-term and long-term effects of exotic and native afforestation on water quality, but a lot will depend on how the forest is managed. It is clear, however, that native forest provides significant benefits to water quality compared to pasture, particularly for sediment and nutrient loads.

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[120] Bergin et al., 1995.
[121] Marden and Phillips, 2015.
[122] Phillips et al., 2023.
[123] Alfeld et al., 2018.
[124] Phillips et al., 2023.
[125] Watson et al., 1997.
[126] Bloomberg et al., 2019.
[127] White et al., 2021.
[128] Quinn and Stroud, 2002.
[129] Julian et al., 2017.

Climate mitigation

Native forests often include long-lived tree species that sequester carbon more slowly than exotics but can continue doing so for hundreds of years. On average, tall native forests in New Zealand hold around 252 tonnes of carbon per hectare, but there is considerable variation between forest types, with regenerating forests and shrubland holding substantially less.[130]

Newly established diverse native forests could therefore act as long-term carbon sinks, while offering more resilience to extreme events and pathogen outbreaks than single-species stands. However, as with exotic forests, there is no guarantee that a native forest established today will persist into the future and continue to store carbon sequestered from the atmosphere. In fact, some types of old-growth native forests are losing carbon in response to stressors.[131] Long-term management is needed to keep native forests healthy and functioning as carbon sinks.

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[130] In 2002–2007, average carbon stocks in silver beech-red beech-kāmahi forest were 353 t/ha; silver fern-māhoe forest held 152 t/ha; and mānuka shrubland held 27 t/ha, Paul et al., 2019.

[131] Paul et al., 2019.

Tōtara *(Podocarpus totara)*

6 Another path to native forests? Managing a forest to transition from exotic to native

Key points in this chapter:

- Transitional forestry is gaining interest as a way to fund native afforestation through the carbon sequestration of an exotic tree nurse crop. It could also offer a more environmentally responsive way to move erosion-prone land out of existing exotic plantations.
- Various approaches have been proposed. Canopy interventions, such as creating gaps, strips or small coupes, may be necessary to stimulate native species growth.
- There are significant knowledge gaps regarding the long-term outcomes and best practices for transitional forestry, including optimal planting strategies, timeframes for transition, regional suitability and the carbon trajectories of different approaches. This results in high uncertainties that create financial risks for those interested in establishing transition forests, and environmental risks from potentially adverse outcomes.

There is growing interest in exotic-to-native transitional forestry (or so-called ‘transition forests’), a relatively recent term that refers to managing an exotic forest so that it gradually converts to a native forest while maintaining a continuous canopy cover (as opposed to clear-fell harvesting exotic plantations and then establishing native species). The intent is for the exotic tree species to act as a nurse crop for the slower-growing native species underneath. The transitional forestry approach aims to mimic, at an accelerated rate, natural successional processes in forests that lead to early or intermediate-successional species (the exotic tree crop) being replaced by late-successional species (the native tree species).[1] Exotic forests are already being established with the intention of transitioning them to native forest.[2]

[1] This section draws on existing work on transition forests, in particular a 2021 report by Forbes Ecology for MPI (Forbes Ecology, 2021), which covers the state of knowledge of transition forests in more detail than can be provided here. A practical guide for landowners looking to transition exotic plantations to native forest is also available (Forbes, 2021b).

[2] The actual area of exotic-to-native transition forests in New Zealand is unknown, since non-harvest intentions for forests are not captured in national surveys and intentions can change over time. However, Scion has estimated that there may be more than 60,000 ha of planted exotic forests that are either being actively managed to transition to native forest or are being left to transition naturally (Scion, pers. comm., 15 January 2025).

There are two main drivers behind transitional forestry:

1. The need to convert some existing exotic plantation forests into native ones. This includes forests on steep and highly erodible land where it is increasingly obvious that clear-fell harvesting is not appropriate and native forest is preferred at the site in the long term.[3]
2. The desire to create new native forests funded by the rapid carbon sequestration of newly planted exotic nurse crops. Fast-growing exotic species can earn carbon credits quickly, which can be used to fund interventions that support native tree establishment below the exotic canopy. This could offer an economically viable way to establish native forests and a route to long-term afforestation on marginal land.

Both pathways could potentially assist in establishing new native forests while also improving the mauri of the area and strengthening connections between the ngahere and the people.

Natural regeneration within existing exotic plantations

Because transitional forestry is relatively new, we don't know much about the long-term outcomes or how best to manage the transition process.

The best information we have to date is based on studies of native regeneration in pine production forests.[4] This has been reviewed in detail elsewhere.[5] These studies were undertaken in the absence of any specific management to stimulate growth of the native understorey and were mostly limited to typical clear-fell rotation timeframes (27–30 years), which limits their applicability to transitional forestry. However, they provide some useful insights into the opportunities and challenges posed by transitional forestry:

- It is clear that **pine plantations can support native regeneration** in the understorey, but this is highly variable. Native regeneration is highest in older pine stands, in areas with good rainfall and where abundant native seed sources are found nearby.
- **Dry sites and those far from native seed sources see little natural regeneration**. Pine forests in the Canterbury Plains have lower species richness and understorey cover than plantations on the West Coast, Bay of Plenty or central North Island.[6]
- **Light levels are important**. As the exotic canopy closes, weeds are shaded out, which makes room for shade-tolerant natives to establish. As the exotic forest ages and trees are thinned out, a forest microclimate develops, which can facilitate growth of a native understorey.
- **Tall, long-lived native tree species are uncommon** in the understorey of pine plantations when natural regeneration is relied on alone.[7] Exceptions exist in areas close to tall native forests and where seed-dispersing birds are also present.

[3] Transitional forestry is similar to the concept of 'conversion forestry' in Europe where, faced with increasing damage from adverse events (storms, drought and bark beetle outbreaks) and an increased focus on ecosystem services, there is interest in converting monoculture plantations of Norway spruce to mixed-species forests (Löf et al., 2023).

[4] For example, Allen et al., 1995; Brockerhoff et al., 2003; Ogden et al., 1997.

[5] Forbes Ecology, 2021.

[6] Brockerhoff et al., 2003.

[7] Allen et al., 1995; Forbes, pers. comm., 9 November 2024.

- **Browsing can greatly limit regeneration** and reduce the likelihood of a native canopy forming.[8]
- **The choice of exotic crop species may influence regeneration** through differences in light levels, ecological resources (e.g. flowers and fruit) and leaf litter, but more research is needed.[9]

Across these studies and others, there was little evidence of native trees infiltrating or replacing the exotic canopy. This indicates that some interventions, such as planting of tall long-lived species, canopy manipulation and browser control, are likely to be needed to support a transition to native forest. Longer timeframes may also provide more promising results.

Box 6.1: Could wilding pines transition to native forest?[10]

Wilding conifers pose a serious environmental and economic threat across much of New Zealand and millions of dollars of public funding are spent controlling them every year.[11] Some have suggested that leaving wilding stands uncontrolled could support the regeneration of a native understorey and eventually native forest. It is difficult to say how likely this is, as scientific evidence of wildings transitioning to native forest is limited and many variables will come into play.

Anecdotal observations at two locations in Kaeo, Northland, indicate just how variable native regeneration under a wilding canopy can be, even within the same locality.

The first location is an old stand of wilding maritime pine (*Pinus pinaster*) on farmland, which has a dense native understorey, including tōtara, kauri, tanekaha, taraire and tree ferns. The wildings are sparse, allowing in lots of light through the canopy, and are interspersed with some mature native trees. Regeneration is particularly abundant in areas where pines have fallen over. The high density of podocarps in the understorey may have resulted from the heavy winter grazing that occurred during early establishment, which would have reduced competition from more palatable species like ferns and māhoe. While the native seedlings and saplings currently provide little biomass in comparison to the wilding pines, it's reasonable to imagine this stand transitioning to native forest in the future.

In stark contrast, a nearby stand of old wilding radiata pine and acacia tower over a sea of weeds and kānuka, with few native tree seedlings. In this case, a transition to a native forest is far harder to envisage and would likely require intense, ongoing management.

8 Forbes, pers. comm., 9 November 2024.

9 Forbes, 2021a.

10 Tāne's Tree Trust, 2025.

11 The National Wilding Conifer Control Programme receives $10 million pa. Closer to $22 million pa is needed just to secure the gains made to date (Sapere, 2022; PCE, 2023c).

Source: Tāne's Tree Trust

Figure 6.1: A stand of old wilding pinaster pine with a healthy native understorey (left). A sea of weeds under wilding radiata and acacia (right).

Without controlled trials, it is hard to say how applicable either of these two scenarios would be to other sites around New Zealand. But it does suggest that regeneration under wilding stands will be highly variable across the country. Although some areas may show signs of transitioning to native forest, leaving mature wildings uncontrolled presents an ongoing risk of invasion to the surrounding environment.

Proposed approaches to transitional forestry

In what is a nascent field, a variety of establishment and management approaches are being proposed.

Starting state of the land

The starting state of the land will determine which silvicultural approaches may be needed. Older existing plantations that are being retired may not require much thinning if the gaps between trees are sufficiently large to support native tree growth. Where this isn't the case, canopy interventions may be needed to stimulate growth of native species in the understorey.[12] As native species' richness and cover is highest in older exotic stands, it might be easier to achieve good regeneration and growth rates of native species under an existing mature exotic canopy rather than under a young exotic stand, other things being equal.

Some exotic forests are being planted with the specific purpose of managing them to transition into native forests. There are questions about how such purpose-built transition forests should be established. Establishing the exotic forest at typical production forest density could leave room for native tree establishment early on. Alternatively, planting trees at a higher density might provide other advantages (e.g. rapidly shading out weeds and developing a suitable microclimate while

[12] Forbes et al., 2016a.

also maximising carbon sequestration). There are different schools of thought, but the evidence to support transitional forestry under a high-density approach is currently lacking, as most of the research on natural regeneration within exotic plantations has been undertaken in plantations with the lower stocking levels typical of timber production forests.[13] The optimal timing of any introduction of native species amongst the newly established exotic crop is also poorly understood.

Regenerating, planting or both

The different approaches to establishing native tree species discussed in Chapter 5 largely apply to transition forests too. Those wishing to transition from an exotic forest to a predominantly native one could consider assisted natural regeneration, intensive planting or an intermediate approach. The major difference with transitional forestry is that the nurse crop is a tall exotic tree species that will compete with the native trees growing in the understorey for longer than shorter nurse crop species like mānuka or gorse. This means more canopy interventions may be required. A taller and denser nurse crop could also harbour more pests, which will need to be controlled to enable the native species to grow.

The level and diversity of natural native regeneration within an area is a useful indicator for the likely level of management required to transition to a native forest. Native regeneration within an exotic forest will vary from one area to another, depending on the amount of light penetrating the canopy and other factors identified in Chapter 5, such as climate, local seed sources, pests and weeds. If large blocks of forest are being managed to transition, some parts of the forest may be substantially further from the nearest source of native tree seeds than others, leading to uneven bird-based and wind-based native seed distribution.[14] Similarly, some areas may be better suited to regeneration than others. On larger sites, management interventions will need to be tailored to a variety of local conditions.

In some cases, relying on natural regeneration may result in a small number of native species, such as tree ferns, dominating the understorey of exotic plantations and shading out other natives.[15] Tree fern removal and enrichment planting of underrepresented native canopy tree species, together with pest control, may be required to support the desired transition to a mature native forest.

Some level of native planting is likely to be required in most forests.[16] The rapid canopy closure provided by the exotic trees removes the need to plant hardy native nurse crops, which are typically needed when planting native seedlings into grassland environments. The optimal planting density and configuration is unknown – but in large forests, widespread native planting is unlikely to be feasible. Seed islands within or adjacent to transitioning forests could be a viable option and is an area of active research.[17] The required size and distribution of seed islands within the forest is unclear. Regardless of how planting is done, other pressures, such as browsing, will need to be addressed to ensure success.

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13 Forbes Ecology, 2021.

14 Most bird-based dispersal occurs within 100 m of a seed-bearing tree (Wotton and McAlpine, 2015), so assessing the availability of seed sources across a 1 ha grid could indicate how much enrichment planting will be needed. Wind-based dispersal probability also reduces with increasing distance from seed source.

15 Forbes et al., 2016b.

16 However, research by Tāne's Tree Trust has found examples where no native planting is required as the pine forest is transitioning naturally to a diverse native forest (this coincides with minimal browser pressure and good native seed supply) (Graeme, M., pers. comm., 26 November 2024).

17 For example, see Tāne's Tree Trust website https://www.tanestrees.org.nz/projects/adaptive-management-of-coastal-forestry-buffers/

Canopy interventions – gaps, strips and coupes

Creating small gaps in the exotic canopy by felling individual trees or small clusters of trees scattered throughout the forest can mimic the natural processes of forest disturbance and increase native seedling regeneration and growth.[18,19] Felled trees can either be removed, where there is sufficient access to avoid damage to the understorey, or left in situ to decay on the forest floor and increase the structural diversity of the forest.

An alternative approach to canopy gap creation is the use of herbicide injection ('drill and fill'), which involves poisoning trees and leaving them standing, allowing them to slowly decay. This method results in a more gradual change in light levels and microclimate than occurs through felling, which could be beneficial where seedlings are sensitive to sudden changes in conditions or weeds are an issue. Studies of vegetation succession after wilding conifer control have found that herbicide injection provided good conditions for the natural regeneration of native species.[20] Herbicide injection also reduces the damage caused by felling to surrounding vegetation.

Gaps in the exotic canopy could be created in areas where seedlings of target species have naturally regenerated or to stimulate the growth of planted seedlings. Ideally, the size of gaps should be tailored to the light preferences and regeneration requirements of the target species.[21] Even within tree families, shade tolerances can differ markedly. Amongst podocarps, kahikatea and tōtara need high light levels, whereas miro and mataī are shade-tolerant. Little is known about the optimal size, distribution and timing of canopy gaps.

Other canopy interventions have been proposed, such as managing the transition process through strip or small coupe harvesting. This involves clear-felling small areas of exotic plantations at a time and replanting them in natives or a combination of exotics and natives, with the aim of eventually transitioning the entire forest to native. A benefit of this approach is that it allows easier harvesting of merchantable timber than canopy gap creation, providing an additional revenue stream that could support management of the transition. Evidence from overseas suggests it can also increase the growth rates of target species.[22] The applicability of this approach is largely unproven in New Zealand, but learnings could be taken from historic studies into the selective management of native forests.[23] If successful in New Zealand, strip or coupe harvesting could support a faster transition to native forest than the more gradual process of canopy gap creation, with some suggesting that a predominantly native forest could be achieved within 60 years if felling and replanting interventions started at year 15.[24]

A proposed variation on this approach is to manage a relatively large portion of a given area under transitional forestry with strip or coupe harvesting and plant the remaining portion of the area directly in natives. The direct native planting could be funded through the carbon and timber

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[18] Forbes et al. (2016a) found that planting tōtara and tawa seedlings beneath canopy gaps that were formed by felling in a mid-rotation pine plantation led to increased growth rates.

[19] Trials at the Hunua Ranges by Watercare suggest that, in areas with an existing abundant native understorey, thinning pines to 150–250 stems/ha, allowing the understorey to recover, and then undertaking additional thinning operations, can be a cost-effective way to facilitate a transition from pine to native forest (Watercare Services, pers. comm., 5 December 2024).

[20] Paul and Ledgard, 2009.

[21] Marshall et al., 2023.

[22] Trials in *Pinus radiata* stands in Chile suggest strip-felling could be an effective way of accelerating growth rates of planted target species compared to those planted in undisturbed pine forest, particularly for shade-intolerant and semi-tolerant species (Kremer et al., 2021).

[23] For example, James, 1987.

[24] Weaver, 2023.

revenue from the transitioning forest. The viability of this approach and the amount of land that could be planted directly with native species depends on the carbon price per tonne.[25]

Creating canopy openings that are too frequent or too large could destabilise the forest by increasing the risk of windthrow or by creating 'weed-shaped holes' that are rapidly dominated by fast-growing exotic species. Large canopy gaps could also remove the sheltered microclimate created by a closed canopy, reducing native seedling survival and growth rates. This may be particularly relevant for strip-felling or coupe harvesting as larger openings are created. The prevailing wind direction and site exposure would need to be considered.[26]

The need for canopy intervention will be site-specific. In some mature pine stands there will be enough light reaching the forest floor to support native regeneration without any canopy manipulation.[27] Taking a longer-term view of transitional forestry and relying more on natural self-thinning of the exotic canopy could free up resources for pest control and the establishment of seed islands.

Other key considerations for transitional forestry

Objectives of the forest

The objective of a given transitional forestry operation will affect how it should be managed. For example, if maximising carbon storage is the focus, a gradual shift from fast-growing exotic species to high-volume natives might be the best approach. If protection of a sensitive catchment is the aim, a more rapid transition to some form of native cover (regardless of the carbon storage benefits) may be more desirable.[28]

Kaitiakitanga and rangatiratanga in practice

As discussed in Chapter 2, most Māori would like to see Papatūānuku covered and protected in native forest. But how to get there raises questions about financing this land use change and how the forest can be maintained. An analysis report by Te Taumata to support a submission made to the Minister of Forestry and the Minister of Climate Change in 2023 describes the difficulties that Māori face and the opportunity that transitional forestry can provide.[29]

Due to the steep and marginal nature of much Māori land, afforestation is often a practical option. Land that is inaccessible or far from ports is uneconomic for timber production, so carbon forestry is often the only option. Planting in exotics first and registering the land in the NZ ETS provides upfront funding and probably the only option to finance a transition to native ngahere. Importantly, it removes reliance on government funding and allows Māori to practise kaitiakitanga and rangatiratanga of their land over the long term.

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[25] An analysis by Weaver, 2023 showed that a 70:30 ratio of transition forest to direct native planting was the maximum proportion of direct native afforestation that could be achieved while being financially viable, under a modelled carbon price of $90 per tonne.

[26] Marshall et al., 2023.

[27] Many pine stands in the Coromandel and Tairāwhiti have naturally self-thinned. Tairāwhiti measurements have included an unthinned stand initially stocked at 1,000 stems/ha that had ~400 stems/ha at age 31 and other stands now at ~150 stems/ha by age 42 (Graeme, M., pers. comm., 26 November 2024).

[28] Forbes Ecology, 2021.

[29] Te Taumata, 2023.

Climate

Pine plantations in warmer areas with high rainfall tend to have more abundant and diverse understories than those in drier and cooler areas. Ultimately, in areas where natural regeneration of native tree species is low due to the climate, the required level of planting to achieve a dominant native canopy, combined with low seedling survival and growth rates, may make transitional forestry impractical.

Choice of exotic nurse crop

Transitional forestry is often thought of as facilitating a shift from radiata pine to native forest, but other exotic species or polycultures could be suitable or even advantageous. Mixed-species plantings could increase structural diversity, for example. Flowering species could attract more birds, aiding native seed dispersal.

While the long-term evidence of transitional forestry resulting in a mature-phase, native-dominant forest is lacking for all exotic species, some general assumptions can be made about what would make an exotic species or mix of species more ecologically suitable as a nurse crop for natives, based on natural successional processes. These include:

- being relatively short-lived in comparison to mature-phase native forest species to enable the native species to become dominant over time. In the absence of manual or chemical control of the exotic crop, the average natural senescence for the exotic species will affect how long it takes to achieve a native-dominant forest – which in some cases could be centuries
- being light-demanding and unable to regenerate under a canopy, to prevent regrowth and competition with target natives
- being suited to regional and site conditions, so that the species rapidly achieves canopy closure and provides a favourable microclimate for the natives growing underneath
- creating the right soil, leaf litter, microclimate and light conditions to support germination and growth of the target native species
- being attractive to birds that can introduce seeds from nearby native sources to support natural regeneration.

Potential alternative exotic tree species that could be suitable for transition forests, if site-appropriate, include tree lucerne, poplars, eucalypts and other low wilding-risk pine species (noting that coppicing nurse species may require chemical control when it comes to removal).[30] There has been little research comparing native regeneration under different exotic canopy species, although a recent study from eastern Otago provides some insights.[31] The study showed that where native seed sources are present nearby, a number of exotic canopy species (i.e. radiata pine, Douglas fir, eucalypt, cypress and poplar) can support native-dominated understories that include potential native canopy species – although the diversity of native species in the understorey is lower than under native canopies. Older plantings of podocarps under exotic canopies could be revisited to advance knowledge in this area.[32]

[30] Species such as redwoods may be unsuitable, as they are shade-tolerant, coppicing, long-lived climax species that could outcompete native tree species for hundreds or thousands of years.

[31] Pritchard et al., 2024.

[32] For example, plantings of podocarps under eucalypt and pine canopies in the central North Island are described in Beveridge and Bergin, 1999.

Animals and weeds

Protecting native seedlings from browsing animals may be more challenging under a canopy that hides animals and weeds from plain view compared to open sites. Heavy browsing pressure has been reported in studies of native regeneration under exotic canopies, but the intensity can vary.[33] A transition will not occur if an understorey of native tree species cannot develop.

The level and feasibility of required management interventions

The type and intensity of management interventions that are required to assist a transition to native forest will vary. Site characteristics will need to be assessed, and the likely long-term management interventions identified before considering whether transitional forestry seems feasible at a particular location. However, this may be challenging, as the gaps in our knowledge and uncertainties regarding transitional forestry are substantial.

Depending on the approach taken, the people completing the transition may be several generations away from those who start it.

Source: Hamish Kendal

Figure 6.3: Exotic forests with a good native seed source nearby and a favourable climate – like this example in Whangapoua Forest on the Coromandel Peninsula – can develop dense native understories. Activities such as enrichment planting, canopy interventions and long-term pest control may still be needed to support a transition to mature native forest.

[33] Varying levels of browsing pressure were noted in Tairāwhiti forestry stands depending on hunter pressure. In Whangapoua Forest, heavy possum browsing of highly palatable species such as kohekohe was recorded in trial plots where goats and deer were absent (Graeme, M., pers. comm., 26 November 2024).

Knowledge gaps in the ecological feasibility of transitional forestry

There is a lot we do not know about transitioning exotic forests to native forests. Key knowledge gaps include:

- the germination, survival and growth rates of different native tree species in exotic plantations under different canopy interventions and environmental conditions
- the potential success of large-scale native plantings within exotic plantations, including optimal timeframes, densities or species mixes for native planting under a pine canopy and how these vary with region and site
- how best to design and employ seed islands and how long it will take for them to start seeding the surrounding area
- how likely it is that natural regeneration or planting of native tree species under an exotic canopy would eventually result in a dominant late-successional native canopy
- most research that informs our understanding of transitional forestry was undertaken in mature radiata pine stands that were thinned and pruned to low densities. There is little evidence regarding:
  - the implications of a higher stocking rate
  - initiating transitions in younger pine plantations
  - different silvicultural practices
  - other exotic plantation species that could act as nurse crops
- the impact of different exotic nurse crops' mycorrhizal fungi associations on native forest regeneration and growth
- understanding how timeframes for transitions vary depending on the key factors noted above. Taking a more active approach through canopy manipulation and enrichment planting could support the succession to tall native forest, but this is unproven. Estimated timeframes for a transition to a native-dominated forest canopy range from 60–150 or more years[34]
- which areas of the country are best suited to transition forests beyond high-level climate and native seed source requirements, and where the required level of intervention would be prohibitively high
- what might happen to a forest from an environmental perspective if a transition is abandoned due to lack of funds or other issues.

The scale of uncertainty surrounding transition forests calls for considerable research if this technique is going to be relied upon. A cautious approach needs to be adopted while the results of that research mature.

Some research is being carried. A five-year project led by Tāne's Tree Trust and funded through the Sustainable Food and Fibre Futures fund is assessing the impacts of forest characteristics on understorey development in existing radiata pine forests. This involves assessing existing permanent

[34] Weaver, 2023; Te Taumata, 2023; Forbes Ecology, 2021.

sample plots within plantation forests, surveying additional sample plots and establishing trial sites to monitor the effects of different management interventions – with and without canopy interventions, fencing and planting – on carbon and biodiversity. Results will inform carbon and biodiversity modelling. Early results show the critical importance of pest control and native seed sources.[35] The project is also investigating how understorey regeneration varies along environmental gradients to identify which parts of the country may require more or less intense management approaches to transition. Once complete, this could be combined with existing mapping of natural regeneration potential in unforested areas to provide a coarse assessment of the geographic suitability of various approaches to transitional forestry.[36]

Such research will provide useful guidance in the short term. Longer-term research will be needed to inject more fine-scale insights as experience and research results accrue. This will require good monitoring and evaluation to support a 'learning by doing' approach.

Risks and environmental effects of transition forests

The risks and environmental effects of transition forests are likely to reflect some combination of those encountered in both exotic and native afforestation efforts. As the exact pathway is unclear and likely to vary, there isn't much that can be said with certainty at this stage. The most apparent risk specific to transitional forestry is that a forest may not progress along the expected trajectory. For example, a forest may not fully transition to a native forest, instead resulting in some mixture of exotic and native species. Alternatively, the forest may become predominantly native but lack tall, long-lived tree species, such as podocarps, which could have long-term consequences for carbon sequestration. Whether either of these scenarios represents a failure would likely be in the eye of the beholder – both outcomes could still provide biodiversity, soil erosion control and improved mauri compared to unforested land or exotic monocultures.

The economics of transitional forestry

Deliberately managing a forest to transition from exotic to native costs money. So, what do we know about the economics of transition forests?

Published economic analyses of transitional forestry are scarce. Weaver (2023) compared the costs of native forest establishment through natural regeneration, native planting, transitional forestry, and a combination of transitional forestry and native planting. He found that the only financially viable options were those involving transitional forestry.[37] This was due to the relatively high investment costs and low-carbon returns of the native-only scenarios.[38] Weaver noted that, even if the focus is on biodiversity rather than profits, a forest carbon project with negative or highly marginal returns leaves little or no funds available for ongoing pest and weed control. Naturally regenerated forest carbon projects without an exotic tree crop can work at small scales or where the landowner can afford to cover the costs without generating revenue in the short term. However, Weaver argues that the carbon sequestration outcomes, in terms of meeting medium-term national targets and the economic realities of direct native afforestation, are problematic.

35 Graeme, M., pers. comm., 26 November 2024.

36 Mason et al., 2013.

37 Weaver, 2023.

38 The natural regeneration scenario assumed land rental payments would be needed for the first 12 years because the landowner won't be receiving carbon credits. Some landowners may be willing to forego a land rental payment when no carbon revenue is being received.

Carbon stock trends during a transition

The economic argument for transitional forestry often relies on the assumption that the sale of carbon credits earned through the exotic nurse crop's rapid, upfront growth can be used to fund the managed transition. The carbon stock trends of transition forests and the carbon price over time are therefore key to this argument holding up. Sequestration rates and trends in carbon stocks in a given forest will be affected by:

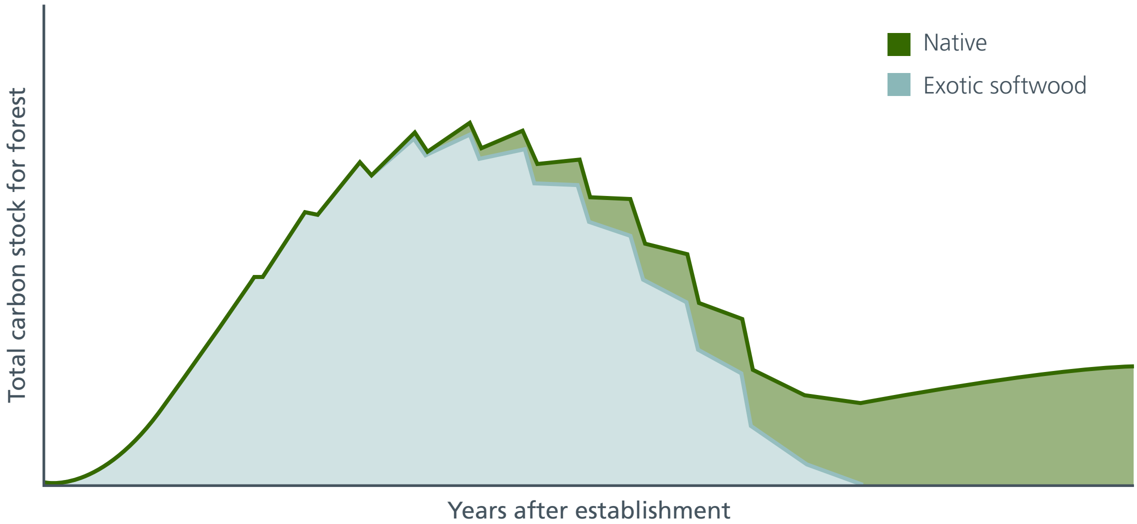
- climate and site characteristics, such as soil and topography
- choice of exotic crop species and planting density
- type, intensity and timing of silviculture interventions, if any
- choice of native planted species and density, if any
- timing of native planting or replacement exotic planting, if any
- intensity of natural regeneration and species composition
- presence of browsers, weeds and other pests – as these could slow the establishment of natives, leading to a greater drop in carbon during transition
- any large-scale natural disturbance events like storms, wildfires or disease.

Publicly available trajectories of estimated carbon stocks within transition forests are rare, despite the considerable interest in this concept and the variation in proposed approaches. Those that exist have tended to be simple, conceptual and opaque about what assumptions were being made (e.g. Figure 6.4). However, they do highlight a fundamental challenge of transitional forestry: the total carbon stocks of the forest are unlikely to increase to a maximum and then stay there. During the transition from an exotic canopy to a native canopy, reductions in total carbon stocks within the forest are highly likely.[39] This is because the large exotic trees that are storing the vast majority of the carbon are gradually removed or allowed to naturally senesce/thin in order to make way for a native canopy.

If a 'carbon dip' does occur, it could result in substantial carbon liabilities for a forest owner, even if the dip is due to natural processes rather than harvesting.[40]

[39] This is driven by changes in the carbon stored in the trees, as the carbon stored in the soil is assumed to remain constant over time.

[40] For post-1989 forests under stock change accounting, calculations of negative changes in carbon stocks between the start and end of an emissions-return period represent emissions and would result in a surrender obligation, regardless of whether those reductions were due to harvesting or natural senescence/self-thinning. A change in forest types can also result in a surrender. Reductions in carbon stocks could be detected in different ways, such as through changes in forest type, forest age or field measurements. The exact mechanism would depend on how the carbon stocks of the forest were calculated over time, which is an area of ongoing research (MPI, pers. comm., 3 February 2025).



Source: Adapted from MPI (2023)

Figure 6.4: This conceptual figure illustrates a concern raised by many – that the total carbon stored in a transitioning forest will drop considerably as the forest shifts from an exotic canopy to a native one.

Modelling carbon stocks under different transitional forestry scenarios

To support a more informed debate about the possible consequences of transitional forestry on carbon stocks, the PCE contracted Manaaki Whenua – Landcare Research to model the carbon stocks in hypothetical forests that are managed to transition from exotic to native.[41] The aim was to explore how carbon stocks might be expected to vary over time under different transitional forestry management approaches. The variables included in the modelling scenarios are shown in Table 6.1.

[41] The full method, scenarios and results are documented in Mason et al., 2025. A copy of this report is available on the PCE website www.pce.parliament.nz.

Table 6.1: The variables investigated during modelling of carbon stocks in transition forests by Manaaki Whenua – Landcare Research.[42]

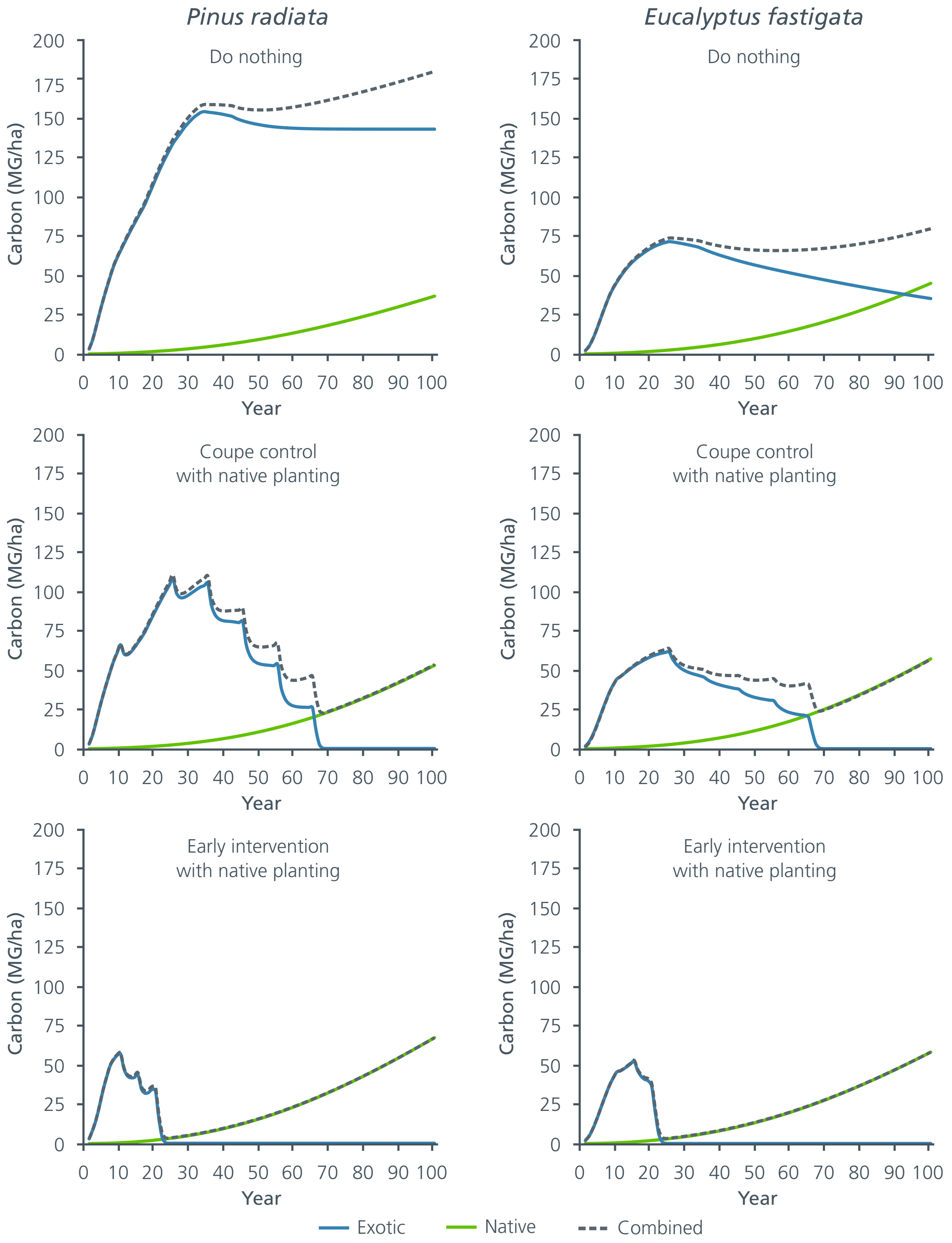
Variable	Modelled categories	Rationale/description
Starting condition	Existing forest (e.g. pre-1990)	Some exotic forests originally established for timber production are now being managed to transition to native forest. When modelling this scenario: • exotic stands were thinned from an initial density of 1,250 stems/ha to 370 stems/ha 10 years after stand establishment (as expected under typical pre-1990 management for timber) • there were five treatments whereby 20% of the exotic stand area was killed (ring-barked or poisoned and left standing) in coupes beginning at age 40 years and separated by 10-year intervals • only radiata pine was modelled • three scenarios were modelled: as above; with and without native planting (starting at time of first coupe control); and no thinning, canopy interventions or planting.
	New forest	Some exotic forests are being established for the purposes of transitional forestry. 14 scenarios were modelled, using most combinations of the below variables.
Exotic canopy species	*Pinus radiata*	Selected for its existing dominance in forestry.
	Eucalyptus fastigata	Selected for its well-studied growth rates and interest as an alternative exotic species.
Exotic canopy intervention	'Do nothing'	• Initial exotic planting densities of 833 stems/ha and 1,000 stems/ha were modelled. • No exotic canopy manipulation is undertaken. • No native planting occurs. • Natural mortality is the only driver of reductions in the exotic canopy.
	Gradual coupe control	• Initial exotic planting density of 833 stems/ha modelled. • Stands are thinned to 500 stems/ha 9 years after stand establishment. • Five treatments whereby 20% of the exotic stand area is killed (ring-barked or poisoned and left standing) in coupes beginning 25 years after stand establishment and separated by 10-year intervals. All exotic trees are killed by year 65.

[42] For full model specifications and a list of scenarios, see Mason et al. (2025).

Variable	Modelled categories	Rationale/description
Exotic canopy intervention	Early intervention	• Initial exotic planting density of 1,000 stems/ha modelled. • Tree felling of one-third of stems beginning nine years after planting and separated by 5-year intervals. All exotic trees are killed by year 19.
	Whole stand control	• Initial exotic planting density of 833 stems/ha modelled. • All exotic plantation trees are killed (ring-barked or poisoned) and left standing 25 years after planting. • Following canopy disturbance, mānuka and kānuka are planted at 1,100 stems/ha with 550 stems of each species (this differs from the planting scenarios below, which were applied to other canopy interventions).
Native establishment method	No planting	• Natural regeneration only, based on native seed sources in the surrounding area.
	Planting	• Natural regeneration and planting. • The native species selected for planting at each site was the canopy dominant species (either conifers, beech species or tawa) with the highest predicted occurrence probability based on permanent sample plot data. • One native tree was planted for every two exotic stems removed at the year of removal.

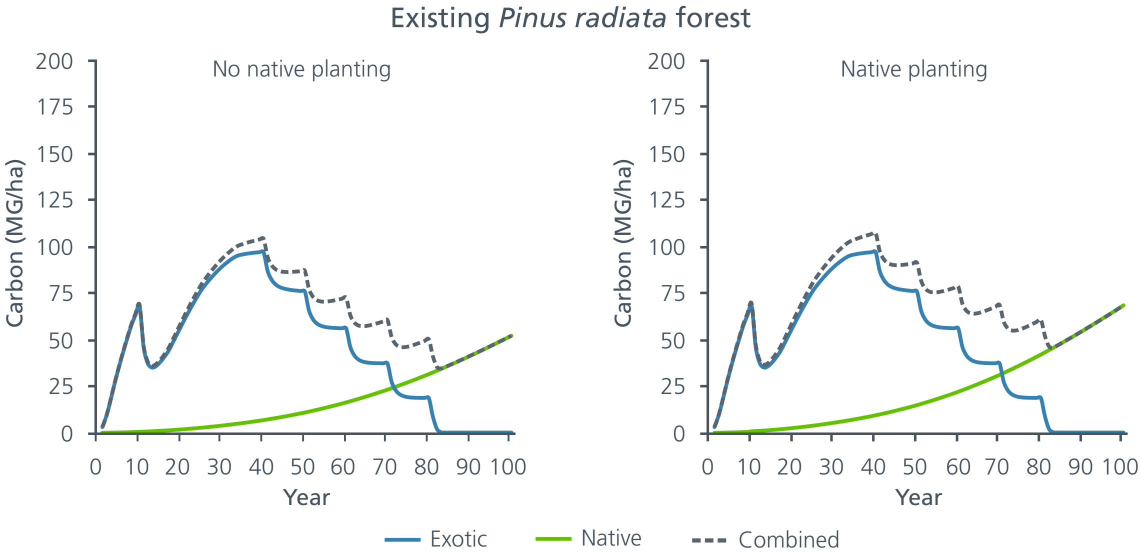
The carbon stocks of the exotic and native components of forests were modelled over a 100-year period under different transitional forestry management approaches. The growth of the native forest component over time was affected by the exotic canopy area to reflect changes in understorey light levels. Each scenario was modelled at 100 sites across the country and included the effects of temperature, rainfall, topography and local native seed sources, the latter being based on permanent sample plot data. For each management scenario, different sites were modelled individually and then combined to calculate mean carbon stocks across the country over time per component of the forest (exotic, native, dead, alive and total forest carbon).

A selection of modelling results is shown in Figures 6.5 and 6.6. Scenarios with and without native planting had broadly similar carbon trends (e.g. Figure 6.6) but in some cases there were small but significant differences in actual carbon stocks. Where native planting had a significant effect on carbon stocks, the effect was positive for all but one scenario.



Source: Adapted from Mason et al., 2025

Figure 6.5: Modelling of different transitional forestry scenarios indicates high variability in forest carbon stocks over the first 100 years since forest establishment. Each graph shows the mean values for the total (live and dead) carbon stock for the exotic and native components, as well as the combined (exotic and native) total. See Table 6.1 for scenario details.



Source: Adapted from Mason et al., 2025

Figure 6.6: Modelling of an 'existing' *Pinus radiata* forest transitioning to native forest without (left) and with (right) native planting. Each graph shows the mean values for the total (live and dead) carbon stock for exotic and native, as well as the combined (exotic and native) total. See Table 6.1 for scenario details.

Some important limitations with the approach used include:

- the assumption that weeds and browsers are adequately controlled so as not to limit native survival and growth
- the assumption that natural dispersal mechanisms (e.g. seed-dispersing birds) are present
- the assumption of no large-scale mortality from windthrow or disease
- the limited native species growth rate data and a lack of data to calibrate later stages of the transition forest process
- only modelling one planted native species per site for the scenarios with planting
- a lack of detailed soil data
- no modelling of leaf litter impacts
- the limited number of sites, simulations and management scenarios
- a lack of real-world data to validate the models.

These limitations as well as others identified in the detailed report mean the results are hypothetical and should be interpreted with caution.

Notwithstanding these limitations, the management approaches modelled in the full report indicate:

- **The only way to avoid a large dip in carbon is to avoid making any exotic canopy intervention at all**. But this means that the exotic component of the forest dominates for most – if not all – of its first century. As eucalyptus has a higher natural mortality than radiata pine, it gives way to native forest carbon dominance faster, whereas radiata pine remains firmly dominant over the 100 years. The so-called 'do-nothing' approach with radiata pine captures the most carbon of any scenario.
- **The timing and type of exotic canopy interventions are important**. All the scenarios with canopy interventions initially led to large drops in total carbon, even with native planting, but there was variation between approaches. Removing the exotic crop quickly, as in the early intervention scenario, resulted in a drop in total forest carbon stocks to practically zero as the native component hadn't had time to grow. The more gradual coupe control initially leads to large exotic carbon stocks, followed by a substantial drop during the transition, but because the native crop has had time to grow the total forest carbon remains higher than in the early intervention scenario.
- **The choice of exotic species affects total carbon in the forest, which affects the size of the carbon dip**. Across all scenarios, the drop in carbon is smaller for eucalyptus than for radiata pine because radiata pine sequesters more carbon. The choice of exotic canopy species had little effect on native growth rates (but note limitations).
- **The native forest component can achieve carbon stocks similar to those of the exotic component under scenarios with canopy intervention, but this takes time**. Substantial carbon liabilities could exist in the meantime. After 100 years, the native carbon stocks were higher in scenarios with exotic canopy interventions than those without.
- **In general, the effect of native planting on mean carbon stocks was minor**. This is likely to reflect the assumptions of the model, such as that natural regeneration is not limited by pests, weeds or seed-dispersing birds. Applying different settings, such as a higher native planting rate or running the model for longer than 100 years, may have eventually resulted in a larger native carbon stock.
- **Existing mature exotic forests that are subjected to canopy interventions may have more 'safe' carbon than newly established exotic forests with earlier interventions**. This is because the native forest component will have had more time to develop by the time the exotic canopy is removed. However, this is heavily dependent on the level of natural regeneration occurring within the exotic forest.
- **Protecting the native understorey during canopy interventions is important**. If damage to the understorey is minimised, the native component of the forest can continue growing while the exotic crop is removed.
- **There is wide variation in predicted carbon stocks across the country**, demonstrated by the wide confidence intervals. Native carbon was highest where rainfall and temperatures were high.

Additional research in this area is being carried out by Tāne's Tree Trust, with a particular focus on modelling the impacts of transitional forestry on biodiversity and carbon in existing exotic plantations.[43]

[43] Tāne's Tree Trust, 2024.

Economic uncertainties of transitional forestry

There are a number of uncertainties regarding transitional forestry that place a big question mark over its economic viability. These uncertainties include:

- What type and intensity of management and administration activities will be needed, and how might these change over time? Animal pest and weed control, enrichment planting, silviculture, monitoring and reporting are likely to be needed to varying degrees throughout the transition process and beyond in some cases. Carrying these activities out over 50 or 100 years, even at a low level, will have a cost. Required interventions will likely vary depending on the site, and may change over time as knowledge improves. For instance, more enrichment planting may be needed than was initially envisaged, or pest control may need to increase if populations in the surrounding landscape grow.
- What will the heavy reliance on revenue from carbon, primarily from the NZ ETS, mean for owners of new transition forests?[44] Risks could include:
    - hefty carbon liabilities if forest owners have to surrender units during the transition to native species. This will depend on how the carbon stocks of transition forests change over time, how many credits can be safely sold ('low-risk units'), and how many will need to be retained or replaced for surrender in later years
    - unforeseen issues, such as storm damage, disease or poor seedling survival, that could set the clock back and increase costs. Severe damage to the exotic nurse crop could see carbon credit accumulation paused while the forest recovers to its pre-event carbon levels, pausing the revenue relied on to fund the transition process. Activities such as pest control would need to continue in the interim
    - changes to NZ ETS settings around permanent forests are likely, as this is an issue of constant debate. To date, little thinking has been done on how it will work for transition forests. On top of that, there is a more existential question about whether the compliance carbon market and the NZ ETS will still exist beyond 2050.
- What role could alternative revenues play in making a transition economically viable? These could include timber, honey, oil, rongoā, pharmaceuticals, natural remedies, hunting, environmental services (water regulation, biodiversity, erosion control) and tourism. Should a drop in carbon stocks occur during the transition, alternative sources of revenue could help bridge the funding gap.

[44] Issues around the NZ ETS, including those related to transition forests, are discussed in Chapter 9.

7

White peppermint *(Eucalyptus pulchella)*

Alternative exotic forests

Key points in this chapter:

- Alternative exotic species can complement radiata pine forests by offering diverse traits with different environmental benefits as well as novel commercial and land use opportunities. Some could also be a contingency species for timber production, should a biological disaster affect radiata pine.
- While many possible options for alternatives exist, those closest to large-scale commercialisation should be given priority. These include coast redwoods, eucalypts, cypresses, poplars and the radiata-attenuata pine hybrid, among others.
- The benefits and risks of exotics vary across species – with some more suitable for continuous cover forestry, which can better support biodiversity and erosion control, and others more susceptible to pest and diseases. All require more careful site selection than radiata pine. No species is without risk.
- Promising alternative exotic species and management regimes could enable a wider range of economic and environmental outcomes.

For many New Zealanders, the case for establishing native forests does not have to be made. But alternative exotic species also have valuable qualities to offer. Depending on the species, these can range from their suitability for more environmentally friendly harvesting systems than clear-felling to their commercial value in particular overseas markets. They also mirror native species in being variably useful depending on site and growth characteristics.

Radiata pine's strengths mean, in the absence of any large-scale biological disasters, it is likely to remain the mainstay of New Zealand's timber production industry for the foreseeable future. Alternative exotic species could complement radiata pine by providing different qualities that enable a better targeting of other values, such as biodiversity, long-term carbon storage and erosion control, as well as novel commercial and land use opportunities. Certain alternatives could also act, to some extent, as contingency species for timber production.[1]

[1] This is not a new argument. During a keynote address in 1989, Geoffrey B. Sweet, the former head of the Forest Pathology and Entomology branch at the FRI, argued it was 'time for forest managers to at least question their "radiata on all sites" approach' and that research into alternative species was vital to ongoing plantation forestry in New Zealand (Sweet, 1989, p.149).

This chapter covers what is known about utilising some of the more promising alternative exotic forestry species that could complement commercial, environmental and carbon storage objectives.

Which alternative exotics?

A number of alternative exotic species are generating interest in New Zealand. Understanding their potential environmental impacts (both positive and negative) will be important for the future shape of afforestation.

With many exotic tree species to consider, some sort of rationalisation is required. A recent report by Scion provided a comprehensive stocktake of commercially viable alternative exotic species to radiata pine for timber production in New Zealand.[2] From an initial list of 45 species or genera identified through a literature review, a 'shortlist' of 12 candidates were recognised as having the greatest potential for commercial production in New Zealand (Table 7.1). Notably, there were key gaps in research and understanding of implementation across value chains for each of the shortlisted species. Climate change also poses uncertainties for all species, particularly regarding impacts on site suitability and the spread of pests and diseases.

Table 7.1: Advantages and disadvantages of the main commercially viable alternative exotic species for timber production in New Zealand, according to Jones et al., 2023. Other advantages, disadvantages and research needs may exist (such as the provision of various ecosystem services or increased wildfire risk). * = applies to some species.

Species	Advantages	Disadvantages	Key research needs
Coast redwood (*Sequoia sempervirens*)	• Fast-growing • Low disease/pest risk • Long-lived • High-value timber • Existing international timber market	• Drought-intolerant • Requires careful siting and silviculture • Limited clonal stock with high variation in growth and form	• Growth and form studies of clones
Durable eucalypts (e.g. *Eucalyptus saligna, E. maidenii, E. botryoides, E. globoidea*)	• Fast-growing • A range of species suited to different climates* • Drought tolerance • Naturally durable, high-value timber	• Prone to pests/disease* • Require careful siting and silviculture • Low clonal propagation success • Limited seedstocks • Limited commercial timber data and market • Management regimes undeveloped	• Breeding for improved resilience and commercial values • Improved clonal propagation • Seedstock development • Siting studies • Improved timber data for marketing and building standards • Management regimes

[2] Jones et al., 2023.

Species	Advantages	Disadvantages	Key research needs
Non-durable eucalypts (e.g. *E. fastigata, E. nitens, E. regnans*)	• Fast-growing • Good timber/fibre opportunities • Silviculture understood	• Pests/disease* • Careful siting and silviculture needed • Limited seedstocks • Commercial timber data lacking • Processing issues and uncertainties	• Seedstock development • Breeding for improved resilience • Develop optimal processing regimes
Cypresses (*Cupressus macrocarpa, C. lusitanica*)	• Fast-growing • Tolerates warmer climates (lusitanica) • Naturally durable, high-value timber • Existing domestic timber market (macrocarpa)	• Cypress canker (in *C. macrocarpa*)	• Disease resistance • Breeding, propagation and processing techniques
Other pine species or hybrids (*Pinus* spp.)	• Potential contingency species for radiata pine • Potential for fast growth rates • Potential improvements to climate and disease resilience	• Potential wilding and disease risk • Low-value timber • Lack of New Zealand data • Limited seedstocks	• Import and develop seedstock
Douglas fir (*Pseudotsuga menziesii*)	• Silviculture/growth well-known • Existing domestic timber market • Grows in cooler climates than radiata pine	• High wilding risk • Disease-prone • Highly variable growth rate • Suspected low climate resilience	• Wilding mitigation (sterile plants, improved chemical control) • Disease resistance
Japanese cedar (*Cryptomeria japonica*)	• High-value timber • Existing international timber market	• Limited genetic stocks in New Zealand	• Seedstock development • Breeding trials
Poplars (*Populus spp.*)	• Existing international timber market • Planted widely for erosion control	• Some species vulnerable to possum damage • Low-durability timber • Limited breeding and silvicultural knowledge	• Breeding for possum resilience and improved timber qualities
Acacias, e.g. Blackwood (*A. melanoxylon*)	• High-value timber • Existing international timber market	• Wilding risk • Slow growth rates* • Limited site suitability	• Improve wilding risk knowledge

Species	Advantages	Disadvantages	Key research needs
Grand fir and other firs (*Abies grandis, A. vejarii, A. religiosa*)	• Shade-tolerant, suited to continuous cover forestry • Wind-hardy	• Lack of seedstocks • Limited breeding knowledge • Limited timber applications*	• Develop seedstocks • Breeding trials
Larches (*Larix* spp.)	• Good growth rate • Existing domestic timber market	• Wilding risk • Limited range and siting knowledge • Limited breeding knowledge • Limited timber use	• Breeding trials
Oaks (*Quercus* spp.)	• Wide climatic range (across species) • High-value timber	• Not drought-tolerant* • Slow growth rates • Limited New Zealand data and breeding knowledge	• Breeding trials

The Scion report concluded that priority should be given to the species with the greatest level of existing development as these were the closest to commercial success. It could be argued that other metrics, such as potential benefits that alternatives could provide, should also be considered during any prioritisation exercise. The stocktake was subsequently combined with expert input to produce an information booklet on growing alternative exotic forest species, focusing on those with the most immediate potential to be grown at scale for timber.[3] The featured species include cypresses, durable eucalypts, non-durable eucalypts, redwood, Japanese cedar and poplars.

While the stocktake and booklet were specifically focussed on alternative exotic species that are suitable for commercial wood-based production systems, many of the species also have traits that make them suitable for more environmentally friendly forestry regimes and offer benefits over radiata pine for other purposes.

Appendix 1 focuses on what we know about growing redwoods, eucalypts, cypresses, poplars and alternative pine species in New Zealand. This is not an exhaustive review of all the options – as noted above, there are other exotic species that could be further developed. Rather, the well-developed species described in the appendix are used to indicate the variety of options that exist.

Location, location, location

One of the valued properties of radiata pine is its ability to grow in a wide range of regions and environments. This is due to its natural plasticity combined with decades of targeted breeding research. Currently, no alternative exotic species are known to grow as well across such a wide range of latitudes, altitudes and soil types in New Zealand.[4] This means a more tailored region-

[3] The 2023 MPI booklet, '*A New Zealand guide to growing alternative exotic forest species*', is available at https://www.canopy.govt.nz/forestry-resources/growing-exotic-forest-species/

[4] Our understanding of where these species could grow would be improved by more research into site suitability and likely impacts of climate change.

specific or site-specific approach to planting alternatives will be needed. Figure 7.1 indicates where five alternative (native and exotic) species that have had their productivity modelled might succeed. Where wood or fibre production is an aim, sufficient volumes of alternative timbers would be needed within regions to achieve economies of scale. For example, in southern and eastern regions of the North Island, an assessment of the most suitable species to plant on marginal hill country based on health, siting and productivity found that after radiata pine, coast redwood and *Eucalyptus fastigata* showed the most promise.[5]

Some alternative exotic species will be more appropriate than radiata pine in certain areas, such as on erosion-prone land. Eucalypts, redwoods and poplars are examples of exotic species that coppice, which means a portion of the existing root network stays alive following harvest and trees can regrow from stumps. This means the erosion risk following harvest or other damage is likely to be lower than that of non-coppicing species.[6] It is still important to position species appropriately within erosion-prone landscapes. For example, while redwoods can be good for erosion control, they require reasonable soil depth and soil moisture, so are more suited to lower slopes than steeply eroding areas. Small-statured and hardy species with shallow but strong root systems may be more appropriate in steeper exposed areas.[7]

5 Watt et al., 2012.

6 Good evidence of the erosion control efficacy of coppicing species is limited (Vergani et al., 2017). Felling can reduce the volume of living roots even if the stump remains alive, and it can take several years for roots to redevelop enough to prevent erosion. Removal of the canopy at harvest would reduce rainfall interception and evapotranspiration, which would mean some increased erosion risk, regardless of whether a species coppices or not. Combining coppicing species with continuous cover forestry would offer the greatest erosion protection where timber harvest is intended.

7 Such as some poplar varieties and eucalypt species, and natives like mānuka or kānuka (Hawke's Bay Regional Council, 2002; Bulloch, 1991; MPI, 2023a; Bergin et al., 1995).

Box 7.1: Bioenergy from wood fibre

There is growing interest in scaling up the use of wood fibre to produce bioenergy, a renewable energy source. Bioenergy is created when biomass derived from plants or animals, such as wood, crops or manure, is used as fuel. Bioenergy already makes up around 7% of the total energy use in New Zealand, most of which comes from burning leftover woody biomass.[8] It is used for wood processing and pulp/paper manufacture. But with the urgent need to reduce fossil fuel use, demand for bioenergy is expected to grow. This has sparked interest in purpose-grown, short-rotation forests made up of fast-growing species, such as radiata pine, eucalypts or poplars. These forests would be planted at a high density and harvested after 12–18 years. Coppicing species, such as poplars and eucalypts, could be advantageous as they would not require replanting as often, but coppice systems are restricted to more expansive areas of flatter land where industrial-scale coppice cutting machinery can operate.

The carbon stored in short-rotation forests before harvest would be comparable to that of production forests as, although grown for less time, they would be stocked at a higher density. But when the benefit of displaced carbon emissions from fossil fuels is taken into account, the climate mitigation benefits to the nation could be substantial.[9]

Scion has identified several wood supply regions where high future bioenergy demand coincides with an availability of lower-value land and good transport access to processing locations.[10] These include Northland, the central North Island, the East Coast, Hawke's Bay, Canterbury and Otago/Southland. However, the suitability of short-rotation forestry in regions with highly erodible soils, such as the East Coast, is highly questionable given that more frequent harvests mean more frequent periods of erosion vulnerability.

From a purely commercial perspective, there can be reasons to consider alternative species in some locations. When sited appropriately, some alternative species can be more productive than radiata pine in terms of timber volume.[11] Redwoods are on average more productive by age 30 than radiata pine in the North Island and northern areas of the South Island that receive sufficient rainfall, but the pattern flips in more easterly and southerly areas of the South Island where redwoods struggle with the cold, dry conditions. Similarly, an analysis of the carbon sequestration potential of five species (radiata pine, Douglas fir, coast redwood, *E. fastigata* and tōtara) at three sites across New Zealand found that no single species universally achieved the best sequestration rates across all sites and that the results were affected by rotation length.[12]

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[8] EECA, 2025.

[9] Scion, pers. comm., 14 November 2024.

[10] Scion, 2024c.

[11] Although without a developed market, greater timber production does not necessarily mean greater profit.

[12] Salekin et al., 2024.

Source: Adapted from Scion, pers. comm., 15 November 2024

Figure 7.1: This indicative map shows where some alternative tree species might succeed using productivity estimates for five alternative tree species (exotic and native).[13]

[13] Other suitable species and locations exist but robust productivity data is lacking. Site-specific growing requirements are important when siting tree species. The underlying data for cypresses are dominated by *Cupressus lusitanica* on the North Island and by *C. macrocarpa* on the South Island. Some areas may be unsuitable for *E. nitens* due to health issues, Lin et al., 2023.

Due to the timeframes associated with forestry, it would be prudent to consider future climates when selecting which species should be planted where. For example, some eucalypt species are particularly drought-tolerant and may perform better than other species in dry areas or areas predicted to become drier under climate change. Similarly, weediness characteristics will change with climate change.[14] However, assessing the likely impacts of climate change on site suitability for alternative exotic species is challenging, as there is incomplete information on the ideal growing conditions for many species. Species that are currently suited to the North Island or lowland areas may become increasingly suitable for the South Island or high-altitude areas, but good evidence to support this is currently lacking.[15]

Appendix 1 details some of the alternative exotic species that have received the most development and are attracting the most interest in New Zealand.

Environmental effects of alternative exotic forests

Many of the environmental effects of alternative exotic forests will be similar to those of radiata pine forests, depending on how the forests are managed and where they are located. For example:

- Establishing any exotic or native forest in an area that was previously grassland will lead to reductions in water yields within the catchment. This can help buffer the impacts of heavy rainfall but also lower annual flow rates in dry areas and during drought.
- The spread of pests and weeds can be facilitated by any sort of forest cover in the absence of effective control.
- Similarly, any forest can support native biodiversity to some extent if managed appropriately: the main difference with native forests is that the crop trees themselves are part of that native biodiversity.
- Clear-fell harvesting any type of forest can lead to sedimentation and woody debris.

There are some differences in the traits of tree species that drive differences in how they might impact on the environment. But in many cases, the forest management approach is just as important for risk management and ecosystem service provision as the species of tree (Table 7.2).

[14] PCE, 2021a.

[15] Jones et al., 2023.

Table 7.2: Examples of how environmental values can be improved through species' traits and management methods.

Environmental value sought	Tree species' traits that may improve the value	Forest management activities that may improve the value
Erosion control and water quality	• Strong root systems that hold the soil • Coppicing ability that allows some roots to survive harvest. Note: the extent to which erosion control is temporarily reduced is unclear • Wind hardiness, making trees less prone to snapping or being blown over • Evergreen species intercept rain on their canopies throughout the year	• Low-intensity harvest, e.g. selective tree harvest (requires shade tolerance) or no harvest • Unharvested steep gullies and riparian buffers
Biodiversity	• Flowering or fruit bearing – attracts birds and insects. Note: these may also attract pests • A mature canopy that allows some light through, enabling an understorey to develop. Note: excess light can cause weed problems • Associating with mycorrhizal fungi that also support native plant species • Light-demanding, short-lived species can make good nurse crops for native tree species	• Low-intensity harvest, e.g. selective tree harvest (requires shade tolerance) or no harvest • Mixed-species forests are more structurally diverse, providing a wider range of habitats for other species to occupy • Protection of higher-value conservation areas within harvested environments • Retention of old and dead trees to provide nesting habitat • Adequate pest, disease and weed control
Long-term carbon storage	• Long-lived • Strong root systems • Wind-hardy • Not severely affected by any pests and diseases already in New Zealand or likely to arrive • Tolerant of a wide range of weather and climate conditions, including an ability to cope with climate change	• Low-intensity harvest, e.g. selective tree harvest (requires shade tolerance) or no harvest • Silviculture for forest health and resilience (e.g. thinning if overstocked) • Fire surveillance and mitigation activities • Surveillance and management of pests and diseases • Planting genetically diverse forests to improve resilience if a disease does occur

Environmental value sought	Tree species' traits that may improve the value	Forest management activities that may improve the value
Low wildfire risk	• Low flammability • Not severely affected by any pests and diseases already in New Zealand or likely to arrive – as stressed trees may have a lower moisture content and generate more dead material	• Planting in low fire risk environments • Fire surveillance and mitigation activities • Retention of a moist microclimate (e.g. continuous cover forestry) • Silvicultural interventions such as pruning to reduce ladder fuels, with waste material removed
Low risk of spreading or encouraging weeds	Low wilding risk: • limited seed production or viability • limited seed dispersal distance • high palatability – as a species may then be controlled by grazing if any spread occurs Note: shade tolerance can enable some exotic species to invade native forests Low risk of weeds: • rapid canopy closure shades out weeds	• For species with windborne seeds, planting in sheltered areas with a low spread risk and avoiding exposed 'take-off sites', such as ridge tops • Planting single sex trees that cannot reproduce asexually • Maintenance of a tree canopy cover at all times (e.g. continuous cover forestry) • Weed surveillance and control • Grazing to suppress palatable weeds where appropriate
Fewer harmful chemicals in the environment	• Naturally durable timbers could reduce the release of hazardous chemicals in the environment if used to replace treated timber • Tolerance for low-fertility environments means less fertiliser required • Rapid canopy closure can outcompete weeds and may require less herbicide use	• Matching species to site conditions so that less chemical intervention is needed (e.g. fertiliser, herbicides)

Kauri *(Agathis australis)*

8

What could be gained from better management of our existing native forest estate?

Key points in this chapter:

- New Zealand still has a sizable remnant native forest estate but it is neither distributed evenly nor representative of the various forest types that once existed.
- Many existing native forests are in poor or even declining health due to pests, despite decades of pest management (of varying degrees of effectiveness). As a result, some species once found in these forests have become locally or even nationally extinct.
- Despite this, existing native forests are still highly valuable. They provide considerable native biodiversity, substantial carbon storage, water-regulating services and erosion control, as well as amenity values, such as landscape and recreational benefits.
- Future challenges, and in particular climate change, mean that even retaining the benefits these remnants provide will be challenging. Increased management will be needed to improve forest resilience and stem further losses.
- To improve native biodiversity (including improved connectivity and representation of rare forests ecosystems), soil erosion control and climate mitigation, we need to better manage our existing native forests and establish new well-managed forests.
- Improving mauri in existing ngahere will improve a wide range of environmental conditions, such as biodiversity, which will benefit everyone. For tangata whenua, better management of our remnant ngahere and an ability to reconnect with them are critical if they are to enjoy the cultural benefits of improved forest mauri.

Why consider existing native forests in a report about alternative afforestation?

This report focuses on what we know about afforestation using alternatives to radiata pine. But could some of the values we are seeking from new forests be achieved by better management of our existing native forest estate? After all, it requires both land and considerable resources to establish and maintain a new forest.

What native forests do we currently have, and where are they?

The eight million hectares of native forest in New Zealand today cover about 30% of the country's land area, 80% of which was forested prior to human arrival. The area of native forest has remained relatively static since 1996.[1,2]

These existing native forests are not distributed evenly in terms of size or location throughout the country. The largest forests tend to be found on steeper upland areas of the North Island and South Island and are mostly contained within the public conservation estate or under Te Urewera Act 2014. Combined, these forests account for 80% of all native forests in New Zealand. This highly uneven distribution of the larger remnant forests can be seen when mapped across the country (Figure 8.1).

By contrast, many of the native forests that remain on private land are smaller, more isolated fragments. These are often found in steeper, less accessible places, such as gullies. Yet some of these forest fragments still contain many rare and threatened species. Of particular importance are the private forest remnants of threatened coastal and lowland ecosystems (e.g. floodplain forests), which are underrepresented on public lands.[3]

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1 Nationally the total amount of land covered in native vegetation continues to trend downward. Between 2012 and 2018 a further 12,689 ha of land was lost from this broader vegetation category (Stats NZ, 2021).

2 Regionally, the picture is more complex, but losses in some regions, such as the West Coast, have been largely counterbalanced by gains in others, such as Hawke's Bay and Manawatū-Whanganui (MfE and Stats NZ, 2024).

3 MfE and DOC, 2007.

Source: Adapted from Manaaki Whenua – Landcare Research, 2020

Figure 8.1: Map showing the recent (2018) distribution of native forests in New Zealand.

Native forests in New Zealand are commonly grouped into two main types (broadleaf-conifer and beech), but the Department of Conservation (DOC) has detailed 59 types of native forest ecosystem spread over five zones.[4] While certain types of beech forest are relatively common, others are much less so. Few lowland coastal forests remain, for example, as most of the land they occupied has been cleared for agricultural and urban development.

[4] Singers and Rogers, 2014.

Since the initial wave of forest clearances, some areas that were once forested have been allowed to regenerate. There is currently estimated to be about one million hectares of regenerating or secondary native forest in New Zealand.[5]

What ecosystem services do our existing native forests provide?

Native biodiversity

The most obvious benefit that native forests can provide is a sanctuary for biodiversity. Despite the ongoing ravages of introduced pests, a wide range of native flora and fauna species can be found in remaining forest fragments. In some cases, populations are barely clinging on (or worse), whereas in other areas with active pest management, species can be abundant. A relatively large proportion of native species are endemic (unique to New Zealand). Over 80% of the 2,500 species of native conifers, flowering plants and ferns are found nowhere else.[6,7] Many native species are culturally significant taonga of great importance to New Zealanders.

Carbon sequestration and storage

The historic clearing of vast areas of native forest represents – by far – the largest contribution to global warming from human activities in New Zealand.[8] It is estimated that in clearing native forests, about 3,400 million tonnes of carbon were transferred to the atmosphere.[9] Total fossil fuel emissions since 1850 represent just 532 million tonnes by comparison.[10] Nevertheless, the forests that remain represent a significant stock of carbon. Temperate old-growth forests, such as those found in New Zealand, contain large amounts of carbon – more per hectare than many tropical and boreal forests around the world.[11,12] These native forests are estimated to contain 1,759 million tonnes of carbon in their live and dead biomass pools (excluding soil carbon).[13,14] For comparison, New Zealand's latest greenhouse gas inventory reported that the country emitted 31.6 million tonnes of CO_2 in 2022, which equates to 16.6 million tonnes of carbon, less than 1% of the amount thought to be stored in native forests today.[15]

Erosion and water regulation

Native forests slow or even halt erosion and help prevent hillsides from slipping into valley floors. While some parts of New Zealand are naturally subject to high rates of erosion, the large-scale clearance of native forests has precipitated some of the most intense erosion problems experienced today. In holding hillsides, native forests help regulate water, cleaning and buffering flows. The presence of native forests in the upper headwaters of many catchments helps ensure a reliable supply of clean, cool water to ecosystems and communities downstream. Since most extensive native forests are on public conservation land and can't be felled, these services are uninterrupted by disturbance from any harvesting regime.

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5 Based on data provided by Scion used in Paul et al., 2021.

6 Costello, 2024.

7 Brockie, 2007.

8 See Figure 3.9 in PCE, 2019.

9 See PCE, 2019, p.66.

10 Friedlingstein et al., 2023; Global Carbon Budget 2023v.1.1.

11 Keith et al., 2009.

12 Paul et al., 2021.

13 Paul et al., 2021.

14 The soil in native forests contains a considerable amount of carbon as well, but this carbon pool is considered comparatively stable overall.

15 MfE, 2024.

Improving mauri

According to te ao Māori, our remaining native forests provide protection to Papatūānuku by cloaking the whenua and protecting the land from erosion, desiccation and damage. Many native forest plant species are a rongoā first and foremost to Papatūānuku – they nurture and heal the land.[16] Indigenous forests also provide shelter for the tamariki of Tāne Mahuta – the birds and animals that reside in the forest. They protect the atua that are guardians of those domains. Kaitiaki are a part of the forests they care for, and resource use, pest management or spiritual connection are ways they can assist in strengthening the mauri of the forests.

What state are our remaining native forests in?

Much of our remaining native forest estate is in declining or poor health. Most forests are infested with exotic species, whether they are invasive plants, like wild ginger, climbing asparagus and banana passionfruit, or mammalian pests, such as deer, pigs, goats, rats, stoats and possums.[17] Many of these pests have invaded even our remotest valleys and most isolated ecosystems. Furthermore, many smaller forest patches suffer from fragmentation and separation from the larger forest areas needed to sustain some species.

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[16] McGowan, 2022.

[17] Despite considerable effort, and in part reflecting the scale and complexity of the task at hand, key biodiversity metrics are still trending in the wrong direction and a large proportion of our native species (flora and fauna) remain threatened with extinction (Stats NZ, 2023).

Box 8.1: Saving a forest from collapse

The Raukūmara Conservation Park covers over 110,000 hectares of remote and steep forest and tussock ranges on the East Coast of the North Island. It has long stood as a stronghold of indigenous biodiversity. Despite some sporadic pest control efforts over the decades, the forest is regarded as being in a very poor state, if not actually collapsing.[18]

As Jade King-Hazel, Director Eastern North Island, Regional Operations, DOC, explains:

"Decades of unchecked predation by introduced species, specifically deer, goats, pigs, rats, stoats and possums, has decimated this once thriving ecosystem. Native undergrowth has been stripped bare, the regeneration of crucial plant species has stalled and towering canopy giants are dying."

In 2020, $34 million of Government funding from the Jobs for Nature Programme was allocated to the iwi-led Te Raukūmara Pae Maunga project, a partnership between Te Whānau-ā-Apanui, Ngāti Porou and DOC to control pests and manage restoration in the area.[19] The kaupapa has involved intensive monitoring, culling, trapping and aerial pest control, with the first large-scale aerial 1080 drop occurring in 2023. None of this work would have been possible without several years of community engagement.

Preliminary signs are promising, with reports that the forest is already beginning to recover.[20] Jade King-Hazel says that the survival of Te Raukūmara goes beyond pest control:

> "It is about restoring balance, protecting taonga species, and climate resilience. Long-term investment, bold innovation and the continued leadership of iwi will be critical if the gains made are to be maintained to ensure that future generations inherit a thriving ngahere."

Source: Raukūmara Pae Maunga Restoration Project

Figure 8.2: Community engagement has been integral to restoration work in the Raukūmara Conservation Park. In the photo, rangatahi from Te Kura o Te Whānau ā Apanui are on a hikoi in Te Raukūmara, accompanied by project kaimahi.

[18] Gisborne Herald, 2019.

[19] Officer of the Minister of Conservation, 2020.

[20] minsley31, 2024.

It's not just plants and mammals that are wreaking havoc in our forests. Exotic insects such as wasps are known to have a severe impact on native ecosystems such as the beech forests in the Nelson region.[21] These introduced wasps compete with natives for food, such as sugars from plants and protein from insects.

Some unique forest-dwelling species have been lost forever, others have been severely reduced in range and number. In many cases, forest composition and successional processes have been radically altered in the fragments that remain.

This gigantic and complex upheaval is still playing out, so the consequences are not yet fully understood. A major concern from a long-term, forest health perspective is whether the composition and state of the native undergrowth will allow a forest canopy to be maintained and regenerate following disturbance. As many native seeds and seedlings are highly palatable, the forest understorey in a browsed forest can often be greatly modified. This may lead to major compositional shifts in the long run.[22]

The vast carbon store in our remaining native forests has been estimated to be currently in equilibrium at a national level – neither acting as a source nor a sink of carbon.[23]

While carbon stocks are seemingly in balance at a national level, there is greater variability between different types of forests. One common remnant tall forest type, kāmahi-podocarp forests, has been found to be losing carbon in a statistically significant way.[24] It has been suggested that browsing by mammalian pests may be the main cause of carbon loss in these forests but there is currently insufficient data to say so definitively.[25] On the other hand, recent research has indicated that some native forests, such as those in south-west Fiordland, are currently accumulating carbon.[26] The state of flux of carbon in existing native forests remains difficult to predict, particularly over the longer timeframes relevant to the lifetimes of long-lived native trees.[27]

The ability of our existing native forests to continue to store carbon, and potentially gain more, is of great benefit for climate mitigation. It is in our best interest to ensure that these forests hold as much as they can for as long as possible.[28] Failing to do so could result in them becoming a carbon source rather than a sink, further exacerbating climate change.

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21 Manaaki Whenua – Landcare Research, 2025.

22 Hawcroft et al., 2024.

23 Paul et al. (2021) split our native forests into two main types: tall (old-growth) forests and regenerating or secondary growth ones. Between 2002 and 2014, the former type was found to be a stable carbon store (not increasing or decreasing) containing 252 tonnes of carbon/ha on average, whereas the latter type held much less (just 54 tonnes of carbon/ha) but was steadily increasing at 0.6 tonnes of carbon/ha per year. This is somewhat of a global anomaly as most existing forests are currently thought to be acting as carbon sinks, although the picture is far from clear (Paul et al., 2021).

24 Paul et al., 2021.

25 Hackwell and Robinson, 2021, highlighted this issue for Forest and Bird. They considered that the most likely cause of this loss was heavy browsing by introduced mammals. While it is possible, they had no data to support this assertion. The authors also pointed out that previous work by Holdaway et al., 2012, found that detecting small changes in carbon storage using the methods employed for Paul et al. (2021), is difficult, but that greater sampling effort may have allowed an overall difference from zero to be detected.

26 Steinkamp et al., 2017; Harvie, 2021.

27 This is the amount of time it might take to feel the impacts of failed recruitment into the canopy.

28 The huge value in protecting existing old-growth forests for climate mitigation is widely recognised internationally (Goldstein et al., 2020). See also https://pursuit.unimelb.edu.au/articles/planting-trees-is-no-substitute-for-natural-forests

Can existing native forests be better managed to improve the benefits they provide?

Given that pest animals and weeds are impacting the mauri, biodiversity, resilience and carbon stocks of existing native forests, it is worth considering how improved management of these pressures could provide gains in these areas.

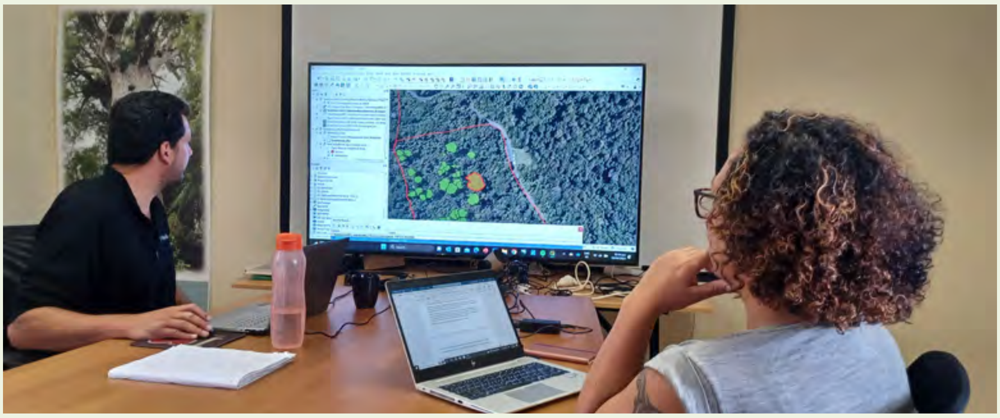
Box 8.2: Kauri Ora – breathing life into the protection of ancient kauri forests through an iwi-led initiative

The soil-borne pathogen *Phytophthora agathidicida* (PA) has been killing kauri (*Agathis australis*), our ancient forest giants, for decades. The disease is sometimes known as kauri dieback, but a recent initiative, Kauri Ora, flips the narrative and places a life-giving focus on the efforts to protect these towering taonga.

Significant funding was allocated to the cause in 2018 when the Government announced the allocation of $29.5 million for research into the disease from the BioHeritage National Science Challenge.[29] This funding boosted the strength of the Kauri Ora initiative, a collaboration that already existed between four iwi: Ngāti Kuri, Te Rarawa, Te Roroa and Ngāti Wai.

The initiative seeks to identify Māori-led solutions to address kauri dieback, with a focus on conservation and restoration. The iwi has implemented a management approach that focuses on 'putting the forest first'. They are deploying detailed GIS mapping in tracking the health of individual trees. Various treatment options are being trialled, including some informed by pūrākau, such as the application of rongoā to the base of trees. The programme has a strong focus on measuring outcomes, ensuring sustainability, and education and communication, including supporting neighbouring iwi.

Funding for Kauri Ora ran out in March 2024, but the iwi-led work to protect these trees continues.



Source: PCE

Figure 8.3: Te Roroa leader, Taoho Patuawa (left), demonstrates the GIS tools they are using to help manage *Phytophthora agathidicida* (PA) from their office deep in the heart of the Waipoua forest.

[29] For more information, see the Biological Heritage website https://bioheritage.nz/about-us/nga-rakau-taketake/

Native biodiversity gains

Decades of pest control (of both plants and animals) have demonstrated that forest management has a critical part to play in improving biodiversity outcomes in our ngahere and their surrounding areas.[30] The extent to which a forest can be restored to its former condition is another question that requires consideration of the other biotic factors influencing the forest in question.

Although New Zealand has become a world leader in killing exotic pests of all shapes and sizes, no mammalian pest has ever been eradicated from the mainland following establishment. That is not to discount some spectacular local successes, such as the eradication of all exotic mammals from some forested offshore islands, including Whenua Hou (Codfish Island – 14,000 hectares), and elimination from mainland fenced sanctuaries such as Maungatautari – 3,500 hectares). But the scale of these successes in the scheme of things is comparatively small.

Complete eradication of introduced pest mammals remains a long-term goal, but in the meantime, sustained funding and resources are usually required to reduce pest populations and then hold the line on any gains made. Acceptance that ongoing maintenance is a cross that will have to be carried in perpetuity (unless some new technology provides a breakthrough) has not yet dawned on many New Zealanders who were borne along by aspirational goals like 'Predator Free 2050'.

Insufficient funding means that prioritisation is needed and, if priorities shift, gains can be lost. There is a risk that focusing attention on a certain set of introduced species, or areas, might let other pest species 'get away'. For example, while there has been a strong recent focus on introduced predators, such as rats, possums and stoats, other pests, such as feral goats, pigs and deer – all insatiable browsers of many native seedlings, have spread and numbers continue to increase.[31]

Our existing native forests face threats from diseases too. Kauri dieback has been found in Northland, Great Barrier Island and the Coromandel Peninsula. It is caused by a fungal pathogen (*Phytophthora agathidicida*) that damages the roots of kauri trees, reducing a tree's ability to take in water and nutrients from the soil. Over time this causes the tree's canopy to reduce and most trees that become infected eventually die. There is no known cure, so management has focussed on reducing the spread of infected soil (see Box 8.2).

A more recent arrival is myrtle rust, a fungal disease caused by *Austropuccinia psidii,* that disperses on the wind and affects plants in the myrtle family, including mānuka, kānuka, pōhutukawa, rātā and the rare swamp maire. It was first detected in New Zealand in 2017 and is thought to have blown over from Australia. Myrtle rust is now present across most of the North Island and top of the South Island, although there is no systematic surveillance for the disease. It infects young actively growing leaves, shoots and stems, causing bright yellow and orange pustules and lesions that result in deformation, dieback and plant death in severe cases. It remains unclear how harmful this disease will be for native forest health or how to best manage a wind-borne disease. Research shows that myrtle rust spores can also be spread by bees, so restricting the movement of beehives into currently affected regions may help limit the spread.[32]

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[30] The eradication of all mammalian pests from islands and reserves typically leads to a large increase in abundance and diversity of native species, including providing refuge for critically endangered species from elsewhere. For example, the removal of possums and wallabies from Rangitoto Island in 1992 helped restore the world's largest pōhutukawa forest. All remaining exotic mammals were eradicated in 2011 and the island now contains populations of various native flora and fauna species including birds such as kākāriki, kākā, kiwi, pōpokotea (whitehead) and tīeke (saddleback) (https://www.doc.govt.nz/parks-and-recreation/places-to-go/auckland/places/rangitoto-island/nature-and-conservation/).

[31] DOC's 2023 assessment of the conservation status of vascular plants in Aotearoa New Zealand notes that browsing pressure is one of the key factors of decline for the majority of plants listed in their report (De Lange et al., 2024). The report also points to increased pressure from increasing populations of ungulates over the last two decades.

[32] Pattemore et al., 2018.

Conservation efforts on both public and private land are notoriously hamstrung by limited funds. Sustained funding is hard to come by. Many ecosystems and the species in them are not adequately managed. DOC is, in its own words, 'spread thinly'– both functionally and physically – across New Zealand.[33] For example, just 440 of the over 4,000 native species assessed as 'at risk' or 'threatened' are being actively protected today.[34]

Clearly, it is possible to improve the biodiversity in our existing native forests, but it is not easy or cheap and will take sustained and coordinated effort.[35] This will also be the case in any new native forests established for biodiversity purposes.

Carbon sequestration gains

If carbon sequestration is the goal, better management of at least some existing native forests may make better sense than trying to establish new ones from scratch. Regenerating native forests that are not currently storing the maximum amount of carbon could have their growth (and carbon sequestration) sped up by better browser control, for example. Mature forests that are losing significant amounts of carbon could also be targeted, where there is good evidence to show that this is due to browsing pressure. However, if the motivation for improving sequestration by existing native forests is driven by carbon accounting, this could prove disappointing as attributing gains to management interventions can be very hard to do.

Between 2007 and 2013, DOC set out to better understand the impact exotic animals have on carbon storage in our native ecosystems under a research programme called Wild Animal Control for Emissions Management (WACEM).[36] DOC commissioned Manaaki Whenua – Landcare Research to investigate whether pest control could assist carbon sequestration in indigenous ecosystems. The WACEM synthesis report concluded that it might be possible to control wild animals to make small gains (of carbon storage) in existing forests but that "it will be very challenging to quantify sequestration […] that a) can be attributed to wild animal control and b) is additional to the sink that already exists."[37]

The corollary is that it is difficult to conclusively establish a baseline (i.e. the state and trend of carbon storage in our remaining native forests) and whether or not various human interventions have altered this trajectory. These issues matter from a carbon reporting perspective because the carbon stored in our forests is included in our net zero approach to climate targets domestically and for our NDC targets under the Paris Agreement. The latest New Zealand greenhouse gas inventory combines the research of Paul et al., 2021 with other relevant forest data and estimates that between 1990 and 2022, natural forests (those that existed prior to 1990) stored an extra 12 million tonnes of carbon.[38] However, this estimate carries a large measure of uncertainty. The actual amount of sequestration over that period could be quite different.

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33 DOC, 2023.

34 DOC, 2023.

35 Outcome monitoring remains comparatively rare in New Zealand, so the scale of the response is often hard to state. Positive responses to large-scale predator control programmes have been recorded. At a more subjective level, for those lucky enough to have seen before and after, the recovery of native ecosystems on islands returned to a predator-free state is spectacular.

36 For more information, see the DOC website https://www.doc.govt.nz/wild-animal-control-for-emissions-management

37 Carswell et al., 2015.

38 MfE, 2024, Table 6.4.3.

The simple fact is, we currently don't know enough to understand with much certainty what is happening to the vast carbon pool that resides in our remaining native forests.[39] Better understanding of the drivers of carbon change in these forests would allow us to better predict what might happen next. Baseline monitoring is going to be vital if we want to detect changes as a result of management approaches.

DOC is running a Maximising Carbon in Native Systems research programme.[40] This work includes looking at how Tier 1 monitoring data can help identify links between vegetation change and herbivore numbers in mature native forests, as well as improving how carbon is measured and trialling remote sensing techniques.[41] The work is part of a wider cross-government Maximising Carbon Storage initiative that includes MPI's Maximising Forest Carbon programme.[42]

The removal of browsers and predators is likely to improve the survival and growth of palatable seeds and seedlings, improve understorey composition and increase the chances of mature canopy trees surviving. But removing browsers such as deer might not always lead to increased carbon storage if it simply shifts the composition of the understorey from unpalatable to palatable species.[43] Removing exotic plants could also help, but the impact of this invasion dynamic on overall forest carbon storage is also unclear. In some cases, these actions might increase carbon storage, such as where canopy and understorey browsing pressure is high, but they will almost certainly increase the long-term resilience of this important carbon pool.

Irrespective of whether the existing native forest estate has been losing or gaining carbon overall, it would be foolhardy to expect them to necessarily remain in the same carbon state in the future. The ability of any forest to store carbon over the long term needs to be considered against all the challenges these forests face, climate change itself being a major one. Recent experiences from overseas certainly cast doubt on banking on forest carbon stores.[44]

A key message that bears repeating is that a healthy forest is a more resilient forest, one which can withstand more challenges and better hold onto the carbon it contains.[45]

Strengthening mauri

Mauri is influenced by the connection and interaction between things. As such, it not only relies on what is growing in the forest, native or not, but also on the ability for kaitiaki to restore, protect and care for the ngahere. The gravity of human pressures on te taiao (the environment) means that most native forests will need some form of management rather than just leaving them to their own devices. Having connected kaitiaki who hold multi-generational knowledge of the ngahere and assist in strengthening the mauri of the ngahere must be good for the overall management of our existing native forests.

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39 This point was made in the Climate Change Commission's EB4 draft advice (Climate Change Commission, 2024).

40 For a full description see the DOC website https://www.doc.govt.nz/our-work/climate-change-and-conservation/carbon-storage-in-native-ecosystems/

41 Promising as it would appear, it remains unclear when changes in forest carbon might be able to be reliably accounted for using remote sensing.

42 https://www.mpi.govt.nz/forestry/forestry-science-and-research/

43 In a report commissioned by the New Zealand Game Animal council, MWLR scientists concluded that "Game animals can have negative, neutral or positive effects on forest carbon (C) pools depending on animal population density, forest type and disturbance history." Peltzer and Nugent, 2023.

44 Hall et al., 2024.

45 For example, forests best-equipped to withstand climate impacts are those with high structural diversity, such as old-growth stands (Kellou et al., 2024).

How will climate change affect the existing forest estate?

An international review indicated that terrestrial ecosystems are highly sensitive to temperature change and suggested that "without major reductions in greenhouse gas emissions to the atmosphere, ... most terrestrial ecosystems worldwide are at risk of major transformation, with accompanying disruption of ecosystem services and impacts on biodiversity".[46]

The review went on to suggest that "impacts on planetary-scale biodiversity, ecological functioning and ecosystem services increase substantially with increasing GHG emissions, particularly if warming exceeds that projected by the Representative Concentration Pathways (RCP) 2.6 emission scenario (i.e. 1.5 °C)."[47]

New Zealand ecologists have considered the impact of climate change on native terrestrial biodiversity, including forests.[48] Despite a high level of uncertainty about outcomes, the scientists were 'sure that climate change will be pervasive throughout New Zealand and affect all biological systems at all levels'.

The ecologists considered that New Zealand ecosystems would be relatively well-buffered from large changes in the near future under current emissions trajectories, mostly due to our geographic location and variable climate. They suggested that the more major impacts of climate change itself could be half a century or more away and it was not necessary to be actively planning for climate-driven range changes or fluctuations in abundance. That prognosis was expressed over a decade ago and if revisited might not be so comforting.

As a general rule, mature native forests are considered to be more resilient than monocultures, thanks to the diversity of species and age classes they contain.[49] Hence, protecting biodiversity from the ongoing pressures of pests, weeds and land use change should strengthen these forests in the face of climate change.[50]

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[46] Nolan et al., 2018, p.4.

[47] It is important to note that based on current global climate mitigation efforts exceeding 1.5°C is almost a given.

[48] McGlone and Walker, 2011.

[49] "Moreover, we argue that focusing on planting diverse forests in reforestation efforts can help to reduce climate change effects on ecosystems: first, by increasing resistance and resilience to extreme climatic events" (Beugnon et al., 2022, p.5).

[50] McGlone and Walker, 2011.

Redwood *(Sequoioideae)*

9

Afforestation incentives: The New Zealand Emissions Trading Scheme

Key points in this chapter:

- The New Zealand Emissions Trading Scheme (NZ ETS) has influenced forestry behaviour since its inception in 2008. However, participation has fluctuated considerably as frequent policy changes have altered signals and incentives.
- The current NZ ETS settings and carbon price (~$63 per tonne in March 2025) provide a strong incentive to register existing post-1989 forests as well as establish new forests and include them in the scheme.
- Current settings favour fast-growing tree species that rapidly accumulate carbon. The NZ ETS provides less of an incentive for native afforestation due to the slower growing nature of these forests.
- The recent introduction of a Temporary Adverse Event Suspension (TAES) mechanism can be expected to further increase participation by removing the cost of having to cover liabilities from forest damage caused by natural events, which are expected to increase due to climate change.
- The marginal and isolated nature of much whenua Māori means that there are few other options for making economic use of this land. It is important that any further changes to the NZ ETS explicitly take account of their impacts on whenua Māori.
- The extent to which the NZ ETS is incentivising transition forests remains unclear, but uncertainties around how carbon stocks in forests will change over the transition presents large risks to forest owners. Modelling suggests there could be large dips in forest carbon stocks during the transition, which makes the financial viability of a carbon-funded transition challenging.
- Access to unlimited forestry offsets means the NZ ETS is not currently working as an effective tool in reducing gross emissions.

Introduction

The NZ ETS is the most consequential policy in New Zealand's climate mitigation toolbox, and one of the biggest current drivers of land use change. Recent government modelling shows the NZ ETS has, to date, been much more of a tree planting scheme than a gross emissions reducing one. The NZ ETS covers fewer than half of gross emissions: in 2022 it covered just 43%.[1] Crucially, the scheme does not cover biogenic methane or nitrous oxide emissions despite their significant contribution to New Zealand's emissions profile.

This chapter discusses the design of the NZ ETS and considers how it treats forestry, what types of forest it incentivises, what types it doesn't, and what this all might mean for afforestation in New Zealand.

Evolution of the NZ ETS

An ETS is an entirely artificial construct, created by legislation, that seeks to engage market mechanisms to reduce a pollutant being emitted.[2] Whether it makes sense to use an ETS for a pollutant that the regulator is trying to eliminate is a matter for debate.[3] But the NZ ETS has features that are unique and diverge from how cap-and-trade schemes normally operate. For that reason, it is useful to briefly sketch the 'standard' model.

In its simplest and purest form, an ETS works by creating a strictly limited number of 'permits to emit' (known as a 'hard cap'). The actual number of emissions permits available within the scheme is related to a particular emissions reduction goal. Over time a regulator can then reduce the number of available permits to emit by progressively lowering the hard cap. Such a scheme is well-suited to reducing gross emissions. It can also be used to manage net emissions provided there is a hard limit on the number of offsets that can be used (see below).

While the legislator, as a matter of policy, may decide to allocate some permits administratively, others may be auctioned. Once in circulation, permits are then tradeable in the open market, with participants setting the price by their willingness to pay and emit rather than reduce emissions.

In the case of greenhouse gas emissions, a more complex ETS design would allow a limited number of permits from carbon offsets to circulate in the market alongside emission permits. Offset permits are usually justified on the basis that a tonne of carbon sequestered (say in a tree) offsets the climate impact of a tonne of carbon emitted into the atmosphere.[4] This more complex design allows the setting of net emissions reduction goals as well. Provided that permits to emit provided by the regulator and offset permits created by market participants do not exceed the cap, the trading scheme can still achieve the desired level of emission reductions. But now, in theory at least, the regulator could control the levels of either, or both, gross and net emissions down to any given level – even zero.

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1 Expressed as CO_2e (CCC, 2024d).

2 The legislative basis for the NZ ETS is set out in the Climate Change Response Act 2002 (CCRA). The CCRA is 587 pages and has a whole part (Part 4) dedicated to running the NZ ETS (170 pages) and another whole part (Part 5) covering sector-specific forestry regulations (121 pages). Together they represent half the length of the CCRA. There is also secondary legislation, such as the Climate Change (Forestry) Regulations 2022, which runs to 117 pages.

3 Issuing permits to emit may not be the most appropriate legislative instrument for a pollutant that needs to be eliminated entirely. Taxes and prohibitions should work better for this kind of stock pollutant, whereas an ETS should be better at managing a flow pollutant within an acceptable bound (Anderson, 2004).

4 The actual warming impact of the two may not align. For example, the albedo effect of some forests may negate the cooling impact of their carbon sequestration (Hasler et al., 2024).

The original design of the NZ ETS took a completely different approach. It focused primarily on net emissions. Not only did it include forestry, but the creation of forestry units is uncapped. This can be traced to the circumstances of its design in anticipation of a global carbon market operating under the Kyoto Protocol. The NZ ETS, as created in 2008, had no limit on the quantity of offsets that could be used. Permits that could be surrendered to cover emissions included NZUs (New Zealand's name for a permit to emit), forestry offsets (also given NZU status) and international 'Kyoto units' bought offshore.

With no domestic cap, the Government had no effective control over the supply of units in the NZ ETS and, as a consequence, had no control over meeting any particular domestic climate target. The Government did have some control over the maximum price of a unit through the offer of a 'fixed-price cap' set at $25 per tonne. With this, companies could buy permits directly from the Government rather than buy credits on the open market. This essentially capped the maximum any emitter needed to pay.

Unsurprisingly, an uncapped supply of units (coupled with some other design features of the NZ ETS[5]) led to perverse consequences. The carbon price dived below $5 per tonne and a large stockpile of NZUs accumulated in private accounts that could be used in future years. There was little or no incentive for any participants to reduce their gross emissions and only limited signals to reduce their net emissions.

In an attempt to gain some control over the supply side of the NZ ETS, in the mid to late-2010s the Government made some major design changes. It banned the use of international units, removed the fixed price option and introduced auctioning of government-issued NZUs. In doing so, the Government essentially introduced a 'soft cap' to the NZ ETS. It is 'soft' because, while the Government can mostly control the number of NZUs it allocates, it has little control over the number of units that might enter the market from the existing stockpile or from forestry offsets in any given year.[6] This is where the design stands in 2025.

Beyond this basic overview, the NZ ETS has been the subject of a steady stream of changes (the Climate Change Response Act alone has had 40 amendments over its 22-year lifespan), all of which have made it a very complex, but still immature, hybrid regulatory-economic instrument. There remains considerable confusion and contention as to how the NZ ETS should function, including whether it should prioritise gross or net emissions reductions. Many experts agree that further substantive changes are needed – even if they don't agree on what they are.[7] Public submissions on a recent review of just some aspects of the NZ ETS settings, started by the previous Government in 2023, detail a litany of issues – some fundamental to the stability of the NZ ETS itself. The review

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[5] These included: the 'two-for-one' surrender obligation (where participants only had to surrender one NZU for every two tonnes of emissions); excluding agriculture from the NZ ETS; and keeping free allocations for so-called emissions-intensive and trade-exposed (EITE) industries at 90% rather than phasing them down as originally planned (the phase down was restarted in 2021). For more see the EPA website https://www.epa.govt.nz/industry-areas/emissions-trading-scheme/changes-to-the-ets/

[6] The Government can adjust auction volumes as an indirect control to take into account the anticipated supply of units from forestry and the stockpile. The Government has recently reduced further auction volumes (Watts. S., 2024) and is proposing to limit ETS afforestation on certain classes of land (McClay and Watts, 2024). It is yet to be seen how constraining those decisions will be.

[7] Articles with experts expressing differing opinions include: *Five things wrong with the NZ ETS* (Hood, 2023); *CCC warns of critical ETS oversupply* (Farmers Weekly, 2024); *Forestry groups welcome Emissions Trading Scheme reset* (Steele, 2024).

was abandoned but the issues did not go away. Two key unresolved issues remain: the scope of the NZ ETS and how much access to forestry offsetting should be allowed.[8]

Source: Beef + Lamb New Zealand Ltd

Figure 9.1: The NZ ETS is one of only two such schemes in the world that allows polluters to offset their entire emissions liability with forestry credits. This is having a large impact on land use change and the functioning of the NZ ETS itself.

Forestry and the NZ ETS

The NZ ETS essentially provides a system that allows a tonne of fossil carbon released into the atmosphere to be traded for a tonne of carbon sequestered in a tree.[9] The scheme issues carbon units (credits) that reflects this one-to-one equivalence in mass. Hence, assuming a forest is registered in the NZ ETS (more on this below) the forest owner is issued with a carbon unit for any additional carbon they sequester in their forest. The owner may choose to trade (sell) these carbon units but the forest (and the carbon registered as being stored in it) must remain as long as the carbon units issued in respect of it remain extant. If a forest is removed, the carbon units linked to the trees must be surrendered.

The net effect is that some carbon dioxide emitting businesses today are effectively paying foresters to store their emissions in forests **permanently**.

Several fundamental forestry-related issues remain the subject of ongoing debate and concern.

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8 Note there were two consultations: A Review of the New Zealand Emissions Trading Scheme consultation and the Redesign of the New Zealand Emissions Trading Scheme permanent forest category consultation (Henare and Shaw, 2023). The PCE lodged a joint submission covering both consultations, highlighting the need to consider the issues raised in each together (PCE, 2023b).

9 The carbon in the entire tree, including branches, trunk and roots is included, as is the carbon in coarse woody debris. The carbon stored in the soil is not.

These include:

- how a forest is defined in the NZ ETS, which in turn affects what forests are allowed to enter or exit the scheme
- how carbon is measured and accounted for in the NZ ETS, including the costs involved in monitoring and reporting, and who pays
- the biophysical risks forests face and what happens to the carbon liability when a forest is damaged or lost
- the extent to which forestry offsetting is delaying a transition to a low-carbon future.

Each of these issues is discussed in more detail below.

Definitions and eligibility

The NZ ETS defines forested land as being land that is one hectare in size and at least 30 metres wide (on average).[10] The land must have trees on it that are capable of reaching five metres in height and creating a canopy over more than 30% of this area. Only forested land that meets this definition, or land that is being managed to meet these criteria, can enter the NZ ETS. The reason for this is a combination of administrative efficiency and to create units where changes in carbon stock are meaningful and measurable. There are many wooded areas in New Zealand that do not meet this definition and therefore cannot enter the NZ ETS, despite having trees that are sequestering and storing carbon.[11]

As such, current NZ ETS settings primarily incentivise the afforestation of larger blocks of land and the comparatively dense planting of trees that grow tall. There is no incentive to plant small areas or low-stature bushes or shrubs (unless they are being used to facilitate the establishment of taller forest species). Including them in the NZ ETS would introduce significant complexity, cost and potential for error.[12]

Another NZ ETS design element that impacts on incentives is the different treatment of forests established prior to 1990 compared with those established post-1989. This reflects the provisions of the Kyoto Protocol, which created a distinction between forests established before and after 1 January 1990.[13]

Pre-1990 forested land

Land considered to have been forested (i.e. covered in forest as defined above or on track to become a forest, even if it wasn't at the time) on 1 January 1990 was automatically registered in the NZ ETS at its inception. There are about 1.4 million hectares of pre-1990 planted forests in New Zealand.[14] They were issued with some carbon units initially (to compensate for the loss of option value for the land) as there is an obligation to surrender units if the land they are on is

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[10] Shelterbelts, riparian strip plantings, some space planting (to reduce erosion and improve slope stability) and some low-stature forests are not eligible. Changes to the canopy height, size and shape of area, and required canopy cover would all alter what is considered an eligible carbon offset for the NZ ETS. For more information, see the MPI website https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/about-forestry-in-the-emissions-trading-scheme-ets/how-forest-land-is-defined-in-the-ets/

[11] Orchards are not eligible either.

[12] ICCC, 2019.

[13] United Nations, 1998.

[14] https://environment.govt.nz/facts-and-science/climate-change/measuring-greenhouse-gas-emissions/measuring-forest-carbon/

permanently deforested.[15] Pre-1990 forests are unable to earn more carbon credits via the NZ ETS for any additional carbon sequestration that has occurred since 1990.[16] This pre-1990 forest carbon liability has served as a disincentive to deforest that varies in strength with fluctuating carbon prices. It has also removed an incentive to maintain some of these existing forests, as any effort to retain or even increase the carbon stored in them is not rewarded.

Post-1989 forested land

By contrast, post-1989 forests are those established on land that was classed as unforested in 1989. But entry to the NZ ETS is entirely voluntary for owners of these forests, and not all post-1989 forests that are eligible have been entered.[17] For a forester considering entry, much depends on anticipated prices of both carbon and wood over the long term. When carbon prices rise, owners of existing post-1989 forests and those looking to afforest are incentivised to join the NZ ETS, since they can earn high returns in the short term from selling carbon units. Forests may still be grown principally to produce merchantable timber but if the carbon price is high enough, foresters may contemplate delaying harvest of existing crops (to increase the overall carbon stock of the forest or to defer their carbon liability temporarily). Alternatively, they may even consider establishing entirely new forests solely for carbon rather than wood fibre. These so-called ‘permanent’ forests are discussed below.

Post-1989 foresters can also leave the NZ ETS provided they pay back carbon credits earned. For example, if carbon prices drop low enough, some forest owners who have registered in the NZ ETS and wish to leave may choose to buy back any carbon units they had previously earned and sold, and surrender them back to the scheme, thereby allowing them to deforest the land at a relatively low cost.

Post-1989 entry into the NZ ETS on whenua Māori also brings its own challenges. On the one hand, registering may be advantageous as it will bring capital to develop or improve the whenua or transition back to native forest (as discussed in Chapter 6). On the other hand, whenua Māori decision-makers are under pressure to protect land for future generations without restricting their options.[18] Once registered in the NZ ETS, the liability to repay credits following deforestation limits the options for future decision-makers. That limitation, of course, already applies to whenua Māori that is classified as pre-1990 forest.

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[15] Harvesting does not count as deforestation, provided replanting and regrowth thresholds are met within stipulated timeframes. There is also some flexibility for that replanting to occur on other unforested land as a form of offsetting. For more, see the MPI website https://www.mpi.govt.nz/forestry/forestry-in-the-emissions-trading-scheme/deforesting-and-the-ets/deforesting-forest-land/

[16] The NZ ETS’s method of accounting for carbon differs from that used for reporting our emissions internationally. At the international level, credit for additional sequestration within exiting forests (such as the pre-1990 forests defined in the NZ ETS) can be counted if the sequestration goes above and beyond that accrued by ‘business as usual’ management of the forest – the aim being to promote new or ‘additional’ climate mitigation (Wakelin et al., 2021). In addition, the NZ ETS assumes instant oxidisation of the carbon removed from the site when trees are harvested, whereas the New Zealand greenhouse gas inventory accounts for slower release of carbon from the various harvested wood products (HWPs) the trees are turned into (Te Uru Rākau – New Zealand Forest Service, 2018; MfE, 2024). This NZ ETS-New Zealand greenhouse gas inventory mismatch has been the subject of consultation, but no changes have been made.

[17] Some afforestation will occur due to changes in demand for wood products and also from voluntary carbon market activities.

[18] Leining, 2022.

Carbon measurement and accounting

Measurement

Another aspect of the NZ ETS that has the potential to skew afforestation incentives is the way carbon is estimated and accounted for in a forest. This measurement is required to keep track of changes over time and allocate carbon units. It requires an understanding of how much carbon each tree in a forest contains. Despite rapid advances in remote sensing technology, we are far from being able to measure the volume of every tree in every forest. Instead, the NZ ETS uses tables that approximate the amount of carbon stored in a forest using reference data for small NZ ETS forests (less than 100 hectares) and by regular sampling of plots in larger NZ ETS forests. This is known as the Field Measurement Approach (FMA).

Only two species are currently detailed in the look-up tables used for small forests – *Pinus radiata* and Douglas Fir. The rest are grouped. The quality of the information is also highly variable. It is most developed for radiata pine (where regional tables exist) and least developed for native forests, which are treated as a single class of forest with the same physical attributes across the entire country.[19] It is easy to understand why this is the case. Not only is it a much simpler task to understand the dynamics of a plantation forest with regimented rows of a single species all planted at the same time, but there is also an economic incentive to understand tree growth in order to predict harvest yields. Native forest look-up tables are known to be very basic and may either under-estimate or over-estimate actual carbon stored, depending on the forest composition, its site and regional conditions.

Since larger forests must use the FMA, mismatches between the actual carbon stored in the trees and the amount estimated is likely to be less pronounced in the long run. But for small forests, the incentive to register native forests in the NZ ETS is heavily influenced by the single undifferentiated look-up table for the whole country. It is easy to see how galling it would be to carefully nurture and manage a fast-growing native forest only to be allocated a proportion of the actual carbon being sequestered. Conversely, over-allocation would represent an inappropriate gift to the forester as they would be storing less carbon than they are being paid for.

Accounting

In terms of carbon accounting, the NZ ETS has been subject to continual modification. The most recent changes date to 1 January 2023. There are now two ways that carbon in forests entering the NZ ETS can be accounted for: standard forestry or permanent forestry.[20]

Standard forestry refers to forests that are managed as regular rotation clear-fell crops; for example pine forests are typically harvested at around 28 years old (Figure 9.2). Instead of the forester needing to account for the large swings of carbon stored in the forests as they cycle through each rotation (as was the case previously under what is known as stock change accounting), standard forestry now uses averaging accounting to smooth out how much carbon is assumed to be stored in the forest in the long run. This has the effect of limiting the earning potential of carbon credits to about year 16 in the first rotation. While, in reality, the actual forest will continue to sequester carbon until it is cut down (when it loses a lot of the above-ground

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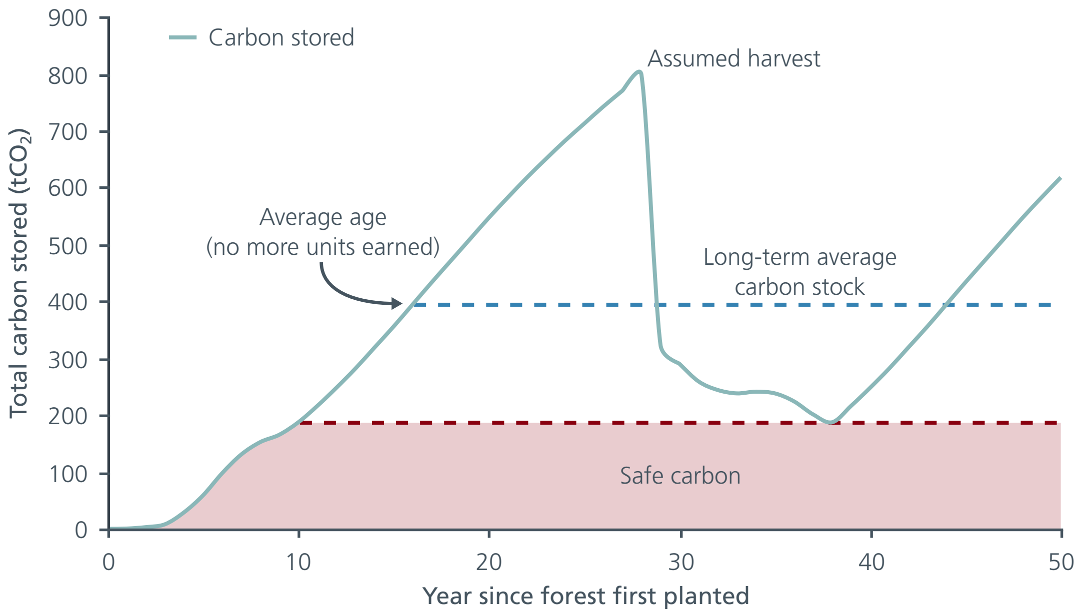
[19] *Climate Change (Forestry) Regulations* (2022). Note that MPI is currently working on updating and improving these look-up tables, including adding tables for additional species, such as redwoods.

[20] Previously plantation forests entering the NZ ETS were required to register under a stock change approach whereby owners were issued carbon credits as the trees grew but were also required to surrender them as they lost carbon, such as when harvesting occurred. Some plantation forests are still registered under this approach today.

carbon to harvesting), this accounting approach makes it simpler for foresters to manage their carbon stocks through rotations by dispensing with the need for alternating issue and surrender of units. As with any post-1989 forest, forests registered under this approach can be withdrawn from the scheme at any time, but the carbon units allocated must be concurrently surrendered.



Source: Adapted from MPI, 2019b, using look-up table data from the Climate Change (Forestry) Regulations 2022

Figure 9.2. The total amount of carbon stored in a given area of standard rotation forest changes over time as it establishes, grows, is clear-fell harvested and then replanted again (solid line). The dashed blue line shows the long-term average through multiple rotations which is the amount of carbon foresters are rewarded for storing. The red dashed line shows the amount of so-called 'safe' carbon – the level that the forest never dips below (once established).

The **permanent forestry** accounting approach refers to forests that are registered in the scheme but are only intended to have limited harvesting. These forests cannot be clear-felled and at least 30% of the canopy must remain at all times. Native or exotic trees are included but the carbon is accounted for under a stock change approach whereby units are issued as the forest grows and not averaged out. In this case, carbon units must be surrendered if the forest loses carbon at any stage. Another key difference between standard and permanent forests is that permanent forests cannot be removed for 50 years.

This is a curious definition of permanence. Fifty years bears no relationship to the length of time carbon must remain stored in the tree to offset carbon dioxide (some of which remains in the atmosphere over millennia). Some foresters have pointed out that multiple rotations of clear-fell forests are already much older than 50 years.

These two accounting methods have very different effects on afforestation incentives. For foresters looking to grow more trees for extractive resource production, entering a forest in the NZ ETS as a standard forest will allow additional revenue to be earned over the first 16 years or so of growth at a time when no harvest is likely to be occurring. The sale of new forest units can help finance their forestry operations in the short term when revenue from harvesting is not yet available. In this case, a prudent forester would still need to be considering supply and demand forecasts for whatever resources they intend to grow over the long term (multiple rotations) as well as how they manage their carbon liability.

For a landowner wishing to establish a forest, who has little or no desire to extract physical resources (wood or fibre) from the trees, the permanent forestry category provides the potential to accrue carbon units (and hence income) over a much longer period. This is a very different proposition. Entry to the NZ ETS could represent the bulk (or even all) of the income from the land for the long term. The returns will vary greatly depending on the type of forest that is established (see below), the location of the forest and the carbon price.[21]

Risks and liabilities for NZ ETS forests

As with most private concerns, the onus for protecting and insuring an asset typically falls on the owner. Given the long timeframes involved, any prudent forest owner will seek to protect their trees and insure them against loss or damage. There is a strong incentive to do so when harvesting is contemplated, as any return on the investment is typically decades after planting and forests face many hazards in the interim. Climate change itself is making forest insurance more expensive and difficult. In some cases, it is no longer possible to get insurance for some risks, such as wildfire. The value of carbon stored in a forest registered in the NZ ETS adds to the liability a forest owner faces in the event of damage and loss of carbon.[22]

The NZ ETS attempts to address some types of damage to forests and the carbon stored in them. A Temporary Adverse Event Suspension (TAES) mechanism was introduced to the NZ ETS in 2023. In a nutshell, the TAES relieves the owner of a post-1989 NZ ETS forest of the requirement to surrender any NZUs to compensate for the loss of carbon due to an adverse event that temporarily damages their forest, provided that certain steps are taken to ensure recovery. Carbon liabilities and entitlements within affected areas are paused until the carbon stocks return to the level stored prior to the adverse event.[23] Only then can the forest owner recommence earning forest units. If a forest is affected by repeated adverse events, the accounting pause may be reset after each event.

This change was introduced to help incentivise afforestation by removing any need for participants to privately insure against adverse events, thereby transferring moral hazard to the Crown. The extent to which the TAES mechanism will impact on the functioning of the NZ ETS itself or the wider ability of the Crown to meet international commitments and reporting requirements remains to be seen.[24] No full assessment of the Crown's financial exposure was made during the

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[21] Administrative charges, including entry fees and annual charges for participating in the NZ ETS also erode carbon farming revenue. These fees have been subject to considerable change and are currently up for review again (McClay, 2024a; MPI, 2024d; McClay, 2024b).

[22] This liability increases as the forest continues to grow and is exposed to any fluctuations in carbon price. The insurance premiums on some slow-growing indigenous forests reportedly can exceed the annual carbon returns.

[23] Land that is so badly damaged that forest re-establishment is no longer possible is permanently retired from the NZ ETS.

[24] A 2019 regulatory impact statement about NZ ETS forestry changes stated that introducing the TAES would "create a small increase to potential crown risk. That is because a temporary adverse event would be internationally recorded as a minor temporary decrease in forestry's contribution to international climate change targets, but there would be no associated reduction in NZU allocations" (MPI, 2019b, p.87). All else being equal, the Crown may need to find reductions equal to the forgone removals elsewhere. Initially MPI recommended that standard stock change forests should not be eligible for the TAES as they create a higher fiscal risk to the crown than forests under averaging. However, following pushback from the forestry industry, it was decided that all post-1989 forests registered in the NZ ETS would be eligible for the TAES. A 2020 addendum to the 2019 document noted a range of significant data constraints (including uncertainty about participant decisions and behaviour, and the number and scale of adverse events in any given year) that limited the ability to fully assess the impact of extending the TAES to all post-1989 forests (https://www.mpi.govt.nz/dmsdocument/40487-Addendum-to-Regulatory-Impact-Statement.pdf).

development of the TAES.[25] Only six claims (~875 hectares in total) have been made to date under this new mechanism.[26] The impacts of recent storms, such as those in 2023 (Cyclones Hale and Gabrielle), may not be recorded through the TAES mechanism yet, as applications only need to be made and approved before the next emissions return for the affected land – which is 2026 for the majority of participants.[27] However, over 650,000 hectares of post-1989 ETS forests are currently eligible to use the TAES and many more adverse events can be expected as climate change intensifies.[28]

How much and what kind of forestry is the NZ ETS incentivising?

Pricing the carbon stored in forests both discourages deforestation of existing forests and encourages afforestation of new ones.[29] Any assessment of how much afforestation the NZ ETS is incentivising needs to consider what land use change might have occurred in the absence of the NZ ETS. Making such an assessment is challenging because many other drivers are influencing land use changes over time. Without the NZ ETS, the total forest estate may have shrunk – for example, if the huge number of planted forests established in the 1990s were harvested and the land used for other uses instead of replanting pines. Conversely, it might have expanded if increased demand for wood and fibre drove afforestation in areas previously considered economically unviable for forestry.[30]

In 2022, forested land covered 10.1 million hectares (37.5% of New Zealand's total land area) compared with a total forested area of 9.4 million hectares in 1990, representing a 7.8% increase (732,000 hectares) over 32 years.[31] The NZ ETS can take credit for some of this increase, certainly in recent years. There has been a strong positive correlation between the price of carbon and the rate of afforestation since the NZ ETS began in 2008.[32] Afforestation was reported to be at 'historically high' rates in 2022, when over 86,000 hectares of new forests were established, the most since 1994.[33]

The establishment of new planted forests has dominated this afforestation effort in recent years, with native forests forming a small proportion of the overall increase (Figure 9.3).

[25] Nor was there any apparent assessment of how the frequency or intensity of adverse events might change in the future.

[26] MPI, pers. comm., 29 November 2024.

[27] MPI, pers. comm., 29 November 2024.

[28] MPI, pers. comm., 29 November 2024.

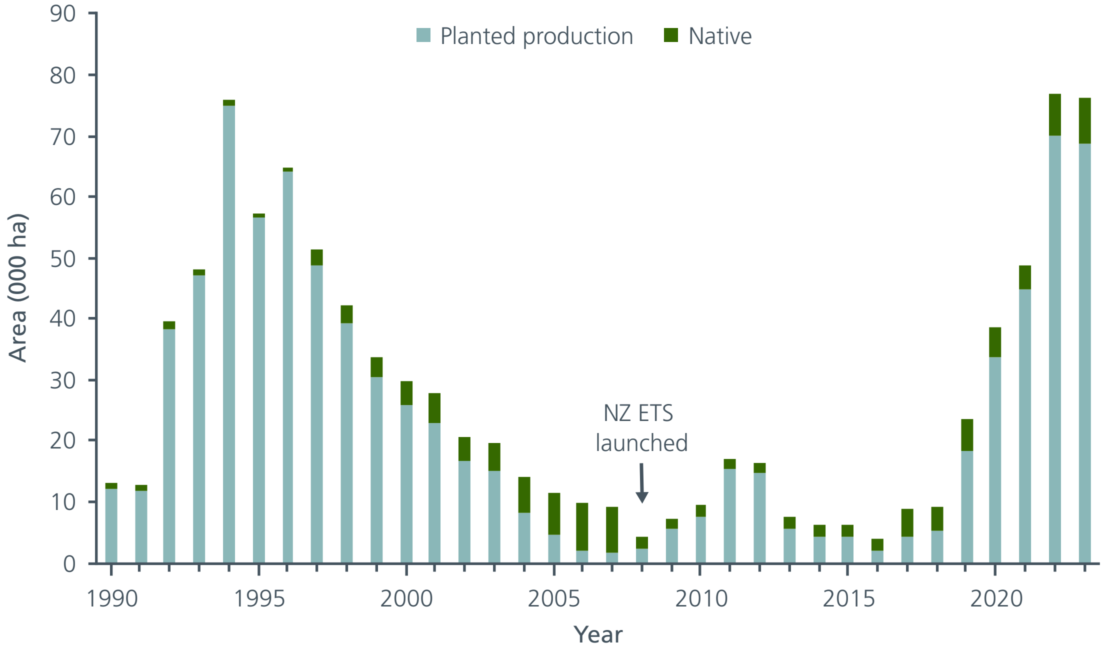
[29] The NZ ETS also encourages landowners to store more carbon in existing forests, but only in those that can receive further credit for these gains (post-1989 forests). Pre-1990 forest owners are not incentivised to increase (or even maintain) existing carbon stores in their forests.

[30] The area of older, pre-1990 natural forests might have shrunk further without the carbon liability of deforestation. Natural forests are mostly areas of existing native forests but can include areas where exotic species have self-sown and are managed as a forest.

[31] MfE, 2024c, p.258.

[32] Similarly, there has been a downturn in the amount of deforestation occurring: there was a large pulse of deforestation just prior to the start of the NZ ETS as forest owners deforested to avoid potential future carbon liabilities (MfE, 2024c).

[33] A small amount of deforestation occurred in 2022 too, just 4,200 hectares (MfE, 2024d).



Source: Data from the NZ GHG Inventory (MfE, 2024c)

Figure 9.3: Afforestation rates over the last 30 years have fluctuated greatly. Rates since the NZ ETS began have also varied, largely due to tinkering with NZ ETS settings affecting the carbon price signal. The planting boom over the last five years or so correlates with a high NZ ETS carbon price driving the planting of pines.

How much post-1989 planted forest is registered in the ETS?

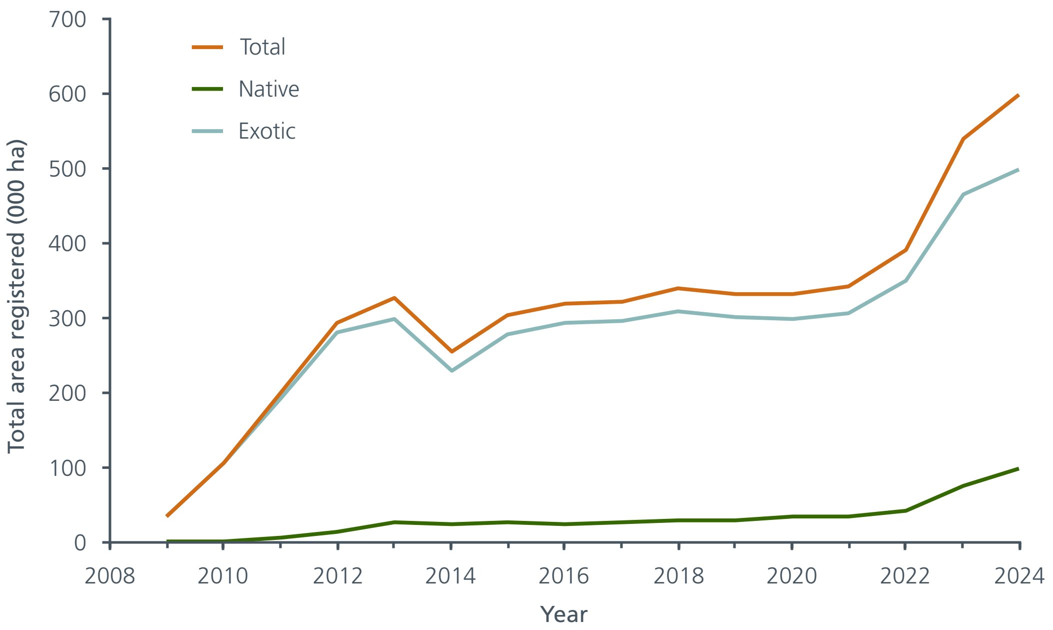
Not all post-1989 forests are registered in the NZ ETS. The voluntary nature of participation for post-1989 forests means that the amount of forestry in the scheme will largely be a commercial decision. The actual amount registered has varied considerably. According to an *Emissions Trading Scheme for Forestry* infographic produced by Te Uru Rākau, a third of the total planted forest estate is classed as post-1989 forest and about three quarters of that (77%, 540,000 hectares) was registered in the NZ ETS in December 2022.[34] The proportion of the post-1989 planted forest estate registered in the NZ ETS has risen over recent years from 46% in December 2020 to 60% in September 2022 (Figure 9.4).

The NZ ETS and planted native forests

As of December 2022, ~76,000 hectares of native post-1989 forests were reported to be in the NZ ETS, accounting for 14% of the total area in this category.[35] Two years earlier, that total stood at ~33,000 hectares. In just two years, ~42,000 hectares of post-1989 native forest was added to the scheme. Some of these native forests will have been mature post-1989 forests joining the scheme. Others will have been newly established forests. This rapid increase in indigenous forests coincides with a period during which two large government-incentivised planting schemes were operating – One Billion Trees and Jobs for Nature (Figure 9.4).

[34] The total planted forest estate was 2.1 million ha, of which pre-1990 planted forest was 1.4 million ha and post-1989 planted forest was 0.7 million ha (Te Uru Rākau – New Zealand Forest Service, 2022).

[35] Te Uru Rākau – New Zealand Forest Service, 2022.



Source: Data from Te Uru Rākau – New Zealand Forest Service

Figure 9.4: The amount of exotic and native post-1989 forest registered in the NZ ETS each year since the scheme's inception. The amount varies since entry and departure are voluntary. Not all forests established since 1989 have chosen to enter the scheme.

Recent settings changes – including the establishment of the permanent forestry category and the TAES mechanism – may result in a faster rate of native afforestation entering the NZ ETS[36], but numerous barriers identified in this report (and elsewhere) remain. These include:

- the slow-growing nature of many native trees in some regions, making revenue from carbon slow to come on stream
- the comparatively greater difficulty and cost of establishing native forests compared to radiata pine
- the complexity of the ETS acting as a deterrent for small-scale foresters focused on natives
- the undifferentiated look-up table for native forests that treats the rate of sequestration as being the same everywhere, regardless of site or management.

Māori land, forestry and the NZ ETS

It is hard to overstate the importance of the ngahere and forestry to Māori and, as such, the way the NZ ETS functions has a large impact on their operations.

In terms of potential areas suitable for afforestation, it has been estimated that about half-a-million hectares of land appropriate for forestry are owned by Māori.[37] A lot of this land is marginal, and forestry is one of the only land uses that can generate an income.[38] Therefore, changes to the way the NZ ETS functions will have disproportionate impacts on Māori.[39]

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[36] As of October 2024, a total of 45,080 ha was registered in the permanent category and more than half (63%, ~28,000 ha) was indigenous forest (MPI, pers. comm., 17 October 2024).

[37] Māori own ~400,000 ha of land in pasture (CCC, 2023a).

[38] Other factors such as complex ownership and financing issues and the remote and isolated nature of whenua Māori are also important considerations.

[39] Cardwell, 2023; Dewes, 2023.

The next chapter (Chapter 10) explores the challenges with whenua Māori in greater detail, but it is worth noting here that many Māori understand the issues raised in this report, such as the need to reduce erosion and that forests made up of exotic monocultures will be less resilient. In addition, many Māori aspire to restore their whakapapa and relationships with the ngahere. However, the cost of restoring native forest combined with the NZ ETS incentives mean that landowners are left with little choice other than planting permanent pine forest. The experience of whenua Māori clearly demonstrates the problems with creating an incentive that has a single-minded focus on rewarding carbon storage. In order to get landowners to plant a greater diversity of tree species that go with the grain of the landscape and a deeper connection to the whenua, they must be rewarded for the greater variety of services those trees provide.

Transition forests and the NZ ETS

Chapter 6 discussed the opportunities and challenges of transition forests. It is a costly exercise either to write off the harvest potential of existing plantation forestry or to re-establish a native forest from scratch. Demand for forestry units under the NZ ETS has raised the possibility of generating carbon from fast-growing exotic species that can generate revenue to facilitate longer-term carbon sequestration by a native forest.

For the owners of marginal land that is unsuitable or uneconomic for clear-fell forestry, carbon sequestration through permanent afforestation may be the only current way of achieving an economic return from the land. But unlike a conventionally harvested pine forest where the present value of the forest can be estimated from known silviculture interventions and the projected value of the wood (based on well-established yield tables), the income generated from carbon sequestration over time in a transition forest is much less clear. Both the amount of carbon stored over time and the carbon price could vary considerably.

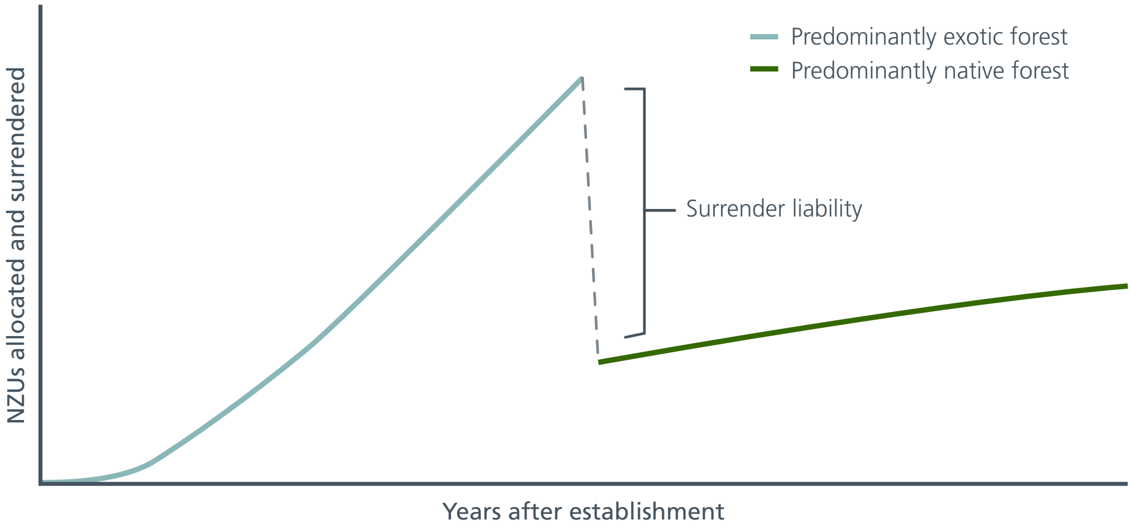
Carbon accounting in transition forests

Currently, transition forests qualify for inclusion in the permanent forestry category of the NZ ETS. As such, stock change accounting applies. Under current regulations, a forest owner could accrue carbon credits for as long as the forest continued increasing its carbon stock but would also have to surrender credits if the carbon stock reduced, whether due to management interventions or natural processes. If all the credits had been sold, the forest owner would have to acquire carbon credits from elsewhere to cover any surrender requirements. This has important consequences for transition forests because, as outlined in Chapter 6, current understanding suggests that the carbon stocks of a transition forest initially increase rapidly as the fast-growing exotic trees grow but then reduce as the large exotic trees are gradually replaced by smaller, slower-growing natives underneath.

The impact on the forest owner of a reduction in carbon stocks during transition is amplified by accounting rules that base the number of carbon credits a forest earns on the predominant forest type and standardised accumulation rates provided in the NZ ETS carbon look-up tables. The predominant forest type is defined by the particular forest species with the greatest total basal area in relation to an area of forest land. If a forest shifts from predominantly exotic species to predominantly native species, there is a change in the carbon yield table used to calculate the carbon stock of the forest. This means the smooth reductions (through canopy gap creation) or multiple small, sharp reductions (through strip or coupe harvest) in actual carbon stocks within a forest during a transition are simplified on the accounting side into a single, sudden drop when the forest shifts from >50% exotic to >50% native.

This is visualised in the figure below from MPI's 2023 proposal to redesign the permanent forestry category of the ETS.[40] The MPI document explains:

> "……under the status quo, transition forests will earn units based on the predominant forest type. When the predominant forest type has switched from exotic to indigenous – the forest will switch from earning units on the higher exotic forest yield table to a much lower indigenous forest yield table. This will create a large surrender obligation and could impact the long-term financial sustainability of the forest model due to units needing to be surrendered as carbon stocks reduce."



Source: Adapted from MPI, 2023b

Figure 9.5: Any drop in the overall carbon stored as a forest transitions would incur a surrender liability under current legislation.

As shown in the carbon stock graphs in Chapter 6, the amount of 'safe' carbon within a transition forest is likely to vary greatly, depending on how it is managed. In some cases, the carbon stocks within the native component of the forest could be essentially zero when the exotic crop is removed and the forest becomes predominantly native (Table 9.1).

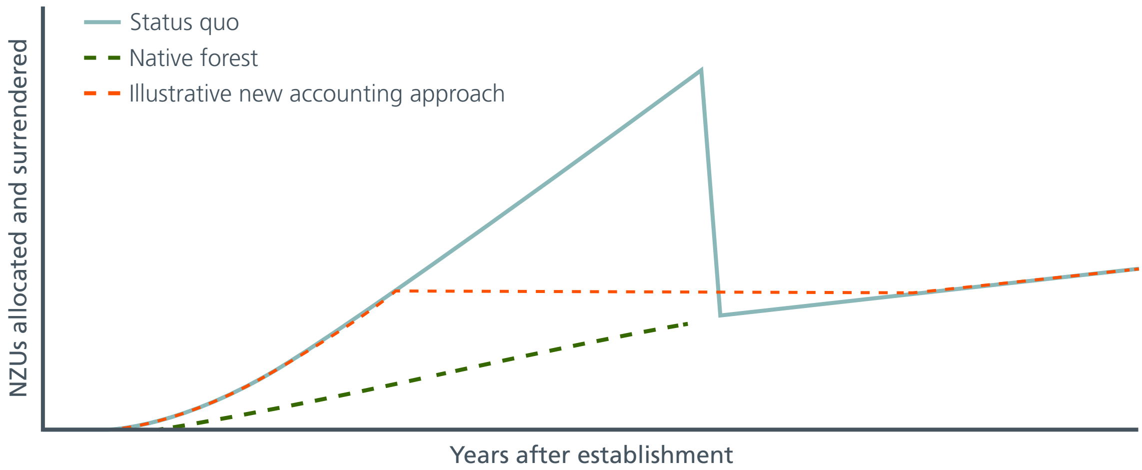
[40] https://www.mpi.govt.nz/dmsdocument/57448-Proposals-to-redesign-the-permanent-forest-category-in-the-New-Zealand-Emissions-Trading-Scheme-NZ-ETS

Table 9.1: The amount of safe carbon was found to vary considerably in the scenarios modelled for this report. In some cases, there was almost none. By far the greatest amount occurred when a pine forest was planted and simply left alone (with little in the way of a 'transition' occurring).

Exotic nurse crop	Planting density	Thinning regime	Native planting	Carbon peak		Post-peak low point (safe carbon)			Carbon at 100 years		When native carbon overtakes exotic carbon
Species	(SPH)			Year	Tonnes	Year	Tonnes	% of peak	Tonnes	% of peak	Year
E. fastigata	833	None	No planting	32	68	52	62	92%	78	115%	91
E. fastigata	1,000	None	No planting	25	74	53	66	89%	80	108%	79
P. radiata	833	None	No planting	34	153	48	151	99%	175	115%	-
P. radiata	1,000	None	No planting	39	159	48	156	98%	180	113%	-
P. radiata	833	Coupe	No planting	25	111	68	23	21%	51	46%	66
P. radiata	833	Coupe	Planting	25	111	68	23	20%	54	48%	66
E. fastigata	833	Coupe	No planting	25	65	68	27	42%	64	99%	65
E. fastigata	833	Coupe	Planting	25	64	68	25	38%	58	89%	66
P. radiata	1,000	Early intervention	No planting	10	58	24	3	4%	51	88%	23
P. radiata	1,000	Early intervention	Planting	10	58	23	3	6%	68	117%	23
E. fastigata	1,000	Early intervention	No planting	15	53	24	3	5%	49	91%	23
E. fastigata	1,000	Early intervention	Planting	15	54	24	3	6%	59	110%	23
E. fastigata	?	Whole stand	Planting	25	65	30	5	8%	71	109%	29
P. radiata	?	Whole stand	Planting	25	112	30	5	5%	72	64%	29

MPI's proposal included an illustrative example of how an alternative accounting approach for transition forests could avoid the large liability faced by forest owners, by averaging out the number of units earned during the transition and enabling the indigenous forest to earn units once its carbon stocks increased. This alternative way of accounting is shown below (Figure 9.6).

Clearly, far more research and consideration are needed regarding how an average accounting approach for transitional forestry could work.



Source: Adapted from MPI, 2023b

Figure 9.6: Novel accounting approaches could be employed to overcome any loss in carbon that occurs as a forest transitions. Such an approach removes any surrender liability but also lowers any revenue from carbon sales.

It is unclear when, or if, a redesign of the permanent forestry category might occur as MPI is not currently prioritising this work.[41] While the carbon liability still exists under the stock change accounting method, it does enable forest owners to make use of the greater volume of carbon credits provided by pine trees. Some forest owners have expressed an interest in 'loaning' a portion of these credits to other landowners who can then sell them and use the proceeds to fund their own afforestation intentions, paying back the credits over time as their own forests accumulate carbon.

Will foresters want carbon-incentivised forests to endure?

Some forest owners are trying to create enduring native forests that will hopefully remain for centuries. Receiving a carbon credit for the carbon that accrues in such forests may be appealing to these landowners because it can help raise capital to fund the forest's creation and ongoing management. These landowners are not likely to hold onto credits as they want their forests to endure and steadily accrue carbon and therefore do not envisage the need to ever repay credits.

A landowner opting to afforest their land for the economic returns it provides today, including both the future earnings from wood fibre and the carbon offsets, may be quite open to changing to another land use down the track, if it becomes more profitable. Rapid, large-scale land use changes have occurred in the past, such as during the dairying boom of the 2000s. In this case, the carbon credits issued as the forest grows represent an economic opportunity that requires consideration of the carbon prices over time (as well other factors, such as anticipated wood prices).

[41] The consultation website (now closed) referred to the Government wanting to make changes to the NZ ETS in 2025. It is unclear if this included any changes to the permanent forestry category, and the website does not mention if changes to the permanent category were made (https://consult.environment.govt.nz/climate/nz-ets-permanent-forestry-category-redesign).

To illustrate this with an extreme example, if carbon credits were to drop from their value of around $63 per tonne in March 2025 to a much lower figure in, say, 30 years, there could be significant economic advantage in selling as many carbon credits as possible, as soon as possible, on the basis that rebuying them at a future point if the land is deforested would be a relatively minor cost[42]. In this scenario, the forest is only being maintained on the land while it has high net present value. The forest may not endure – nor the carbon stored in it. Importantly, the converse is also true: if carbon prices steadily climb over time (as was signalled out to 2030 in the Climate Change Commission's demonstration pathway), changing land use down the track (deforesting) could become prohibitively expensive if the forest owner has chosen to sell the carbon credits as they were earned.

It is impossible to know what the policies and regulations governing carbon liabilities will be decades or even centuries from now, or how much carbon credits will be worth. But these are the timeframes implied by transition forests. Assuming some form of credit surrender is still required when a forest loses carbon, transition forest owners will either need to bank credits to allow for this or have a plan to acquire them from elsewhere when needed. Conversely, if the NZ ETS ends at some point, there would be no further income from the compliance carbon market to fund forest management and provide revenue beyond that point. These are some of the problems associated with developing policy instruments designed to manage situations that lie beyond any reasonable experience of the market or the political durability of such policies.

The role of the NZ ETS and future afforestation

On current policy settings, significant continued afforestation is foreseen if New Zealand is to meet its various climate targets. In its second emissions reduction plan, the Government restated its commitment to a 'net-based approach' to carbon that includes both gross emissions reductions and removals. The plan is, however, heavily reliant on forest offsetting. Despite the emphasis on native afforestation in the sentiment of the second emissions reduction plan, with talk of partnering with the private sector to enable native afforestation on Crown land, projections in the plan show a different story. Of the 930,000 hectares of afforestation projected to occur by 2050, just 30,000 hectares is native.[43] Regardless of the actual amount or type of afforestation that occurs, the NZ ETS is being expected to incentivise the delivery of most future afforestation.[44] Yet there are big questions about the ability of the NZ ETS to deliver the necessary levels of afforestation to meet emissions reduction targets and whether the risks of doing so are either manageable or acceptable.

Forestry in the NZ ETS creates potentially unpalatable risks

Foresters say they need certainty about NZ ETS settings to achieve the sorts of long-term afforestation being projected. Many are resistant to changes in the NZ ETS settings and have pushed back strongly when the Government has consulted on changing them. Foresters, other

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[42] Carbon News, 2025.

[43] MfE, 2024f.

[44] A 2023 cabinet paper projected the NZ ETS incentivising between 410,000–760,000 ha of new forests by 2035 (Shaw, 2023). The Government may opt to use other mechanisms outside the NZ ETS to encourage afforestation to meet its net climate targets. The extent of further afforestation required will depend on how much these mechanisms are used, as well as the extent of gross emissions reductions made in sectors not currently covered by the NZ ETS, such as agriculture.

market participants and NZ ETS commentators attribute considerable volatility in the carbon price to Government proposals to tinker with NZ ETS settings.[45]

However, the inclusion of forestry in the NZ ETS, and the current NZ ETS settings, create risks. Successive governments have yielded to participants' pressure rather than address those risks. But that hasn't made the risks go away. At some point, the risks will become so evident that the government will need to manage them. Changes to the forestry settings, including whether forestry offsetting continues to be allowed, are almost inevitable.

NZ ETS unit supply uncertainty and price suppression

As currently designed, the government provides three main sources of new NZUs in the NZ ETS: auctioned units, units freely allocated to emissions-intensive and trade-exposed (EITE) industries, and forestry units.[46] Taking into account advice from the CCC, the Government aims to control supply by varying the number of NZUs it auctions. That number is set in part by predicting how many forestry units might become available, how much of the stockpile might be used and the number of EITE units the Government will hand out. It is a complicated and highly inexact process but has significant consequences for the carbon price and forestry.

The most recent settings decision by the Government sees the number of NZUs to be auctioned declining from 13.1 million NZUs in 2025 to 7.1 million in 2029.[47] The number can be expected to continue to drop beyond 2029. Extrapolating the current trajectory would see the Government auctioning no units by 2033. An alternative estimate presented in the supporting information to the CCC advice on NZ ETS unit limits and price control settings for 2025–2029 indicates the auction volume dropping to 1.1 million in 2035.[48] In other words, from sometime in the mid-2030s onwards the Government will have little or no control over unit supply (and therefore price) in the NZ ETS – assuming the settings are not changed. It will obviously also not benefit from any revenue from auctions beyond that point.

From 2033, forestry will become the primary source of units in the NZ ETS. The supply of those units will only be 'controlled', if it can be called that, by foresters and the actions they take or choose not to take, regarding their forests in the NZ ETS. Those decisions include: how much they want to plant, their harvesting intentions, deciding which carbon accounting method to use and choosing when to register or deregister forests from the scheme. It is very difficult to predict with any certainty how those mixes of decisions will flow through into NZ ETS supply and price.

It is probable that at some point the supply of units through afforestation will meet, and then exceed, the level of demand from emitters in the NZ ETS. As the CCC points out, the resulting 'absence of a long-term price signal for afforestation could contribute to a possible decline in planting rates as it becomes understood by market participants'.[49]

[45] A 2023 report for Beef + Lamb New Zealand highlighted various factors they felt had influenced the carbon market in recent years, including regulatory uncertainty and apparent political interference and rhetoric (Orme, 2023). The CCC's 2024 advice on the unit limit and price control settings also highlights the impact of policy events on the secondary market spot price (CCC, 2024b).

[46] There is also the large unit stockpile that currently exists (estimated to be 68 m units as of September 2023) (CCC, 2024a).

[47] https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/ets/nz-ets-market/annual-updates-to-emission-unit-limts-and-price-control-settings/

[48] CCC, 2024a, (in technical annex 1: supporting spreadsheet).

[49] CCC, 2023b, p.60.

Climate targets may not be met

The principal risk from uncapped forestry in the NZ ETS is that New Zealand may not meet its domestic climate budgets and targets.50

If the NZ ETS is no longer incentivising afforestation, the Government will be forced to use other mechanisms outside the NZ ETS to meet its net zero targets, such as direct payments to encourage afforestation. That is because only half of New Zealand's emissions currently have surrender obligations within the NZ ETS.[51] Emissions outside the NZ ETS still need to be offset in order to meet a net zero target. Based on current policies, the Crown will start incurring those costs beyond 2037.

Forestry's moderating effect on the NZ ETS price is also an issue. Modelling suggests that maintaining access to unlimited forestry offsetting will keep the NZ ETS carbon price at around $50 per tonne or below in the long run (barring short-term fluctuations).[52] These modest prices are widely regarded as too low to effectively drive reductions from many domestic sources of gross emissions. According to the Government's ETS market model, the NZ ETS will only reduce gross emissions by around 10% by 2050.[53] Additional forests need to be planted for every year that gross emissions continue. The expanding area of land needed for this has flow-on effects (see below).

A similar problem occurs regarding New Zealand's Nationally Determined Contribution (NDC). By 2030 a gap of 101 million tonnes of carbon dioxide equivalent is predicted to exist between domestic emission reduction budgets and the NDC.[54] This gap cannot be addressed by the NZ ETS because the system was designed to align with the Government's 2050 target, not five-year emissions budgets or international obligations. Additional government spending is likely to be required if New Zealand's international commitments are to be met.

Land locked away forever

Using forestry to offset ongoing carbon dioxide emissions locks up increasing amounts of land in forestry in perpetuity. Once emitted, carbon dioxide stays in the atmosphere for thousands of years – in human timeframes that is effectively forever. Every additional molecule emitted must be offset to achieve and maintain net zero. Consequently, if gross emissions reductions are not prioritised within the NZ ETS, there will be an ongoing requirement to offset them by establishing and maintaining more and more forests.

The decision to plant forests as an offset severely restricts any option value the planted land may have for future generations. This is not a sustainable solution as it will lock up increasing areas of land from alternative uses. It also imposes a burden on future generations who must continue to pay for afforestation (or emissions reductions) and the ongoing maintenance of the expanding forest estate. As this report makes clear, forests once established cannot be forgotten about. They require management if their resilience is to be maintained. Given the timeframes implied by the logic of offsetting, the NZ ETS will be forced to remain in perpetuity, with no clear economic

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[50] New Zealand has legislated for a 'split gas' domestic target that has two main components; a net zero target (from 2050 onward) for all gases other than biogenic methane, and a gross reduction requirement for biogenic methane that has two targets – a 10% reduction by 2030 and a 24–47% reduction by 2050. A series of five-yearly budgets are set to reach these targets (CCC, 2024e).

[51] Based on using the carbon dioxide equivalent (CO_2e), almost half our emissions are from agriculture and these do not have surrender obligations (just reporting). See MfE website for more information (https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/ets/coverage-of-the-nz-ets/

[52] MfE, 2023.

[53] According to MfE's NZ ETS model, under the base case (zero price), emissions will be 14.5 Mt per year by 2050. With an NZ ETS price of around $50, this will reduce to 13.2 Mt per year – a drop of around 1.3 Mt per year.

[54] MfE, 2024e.

incentives for afforestation other than the necessity for future generations to balance their ongoing legacy of positive emissions.

The implications of this have been extensively canvassed in two reports from the PCE – *Farms, forests and fossil fuels: the next great landscape transformation* (2018) and *Going with the grain: Changing land uses to fit a changing landscape* (2023) and its associated case studies. Much of the planting of forests to offset emissions is likely to occur on agricultural land. At carbon prices of $35 per tonne, permanent exotic forests have been calculated to generate three times greater economic return per hectare than sheep and beef farms.[55] When carbon prices rise to $70, the economic return for permanent exotic forests becomes seven times greater than for sheep and beef farming.[56] Government projections anticipate that 700,000 hectares of land will be converted into forestry by 2050, based on the carbon price pathway outlined in the Government's baseline scenario.[57] This equates to about 15% of sheep and beef land in New Zealand today.[58] This land use change has both social and economic repercussions for rural communities. Whether that social and economic change is palatable is ultimately a political choice.

Alongside differences in employment (discussed in Chapter 3), export value is the other sticking point in the ongoing land use change debate. Other than through the voluntary market and unlike sheep and beef farms or forests grown for timber, carbon forests cannot generate export revenue or retain the option for alternative future land uses.[59] The argument then goes that as productive land is lost to permanent carbon forestry, New Zealand's economic prosperity will reduce. However, New Zealand has committed to meeting its international agreements and NDCs to climate mitigation. The Treasury has estimated that the potential fiscal costs of purchasing overseas mitigation to meet New Zealand's first NDC could be between $3.7 billion and $23.7 billion by 2030.[60] While not legally binding, New Zealand is involved in several trade deals that rely on these commitments. In this respect, domestic afforestation could contribute significantly to future economic prosperity.

Part of the problem lies with the way the NZ ETS incentivises forestry – it is both uncontrolled and indiscriminate in the land use change it drives.[61] Unless that changes, forestry risks losing its social licence with rural communities.

Long-term liability of the Crown

High use of forestry offsets could leave the Crown carrying a large implicit liability due to the risk of forest impermanence. Threats to forestry permanence come from fire, disease and insect outbreaks, climate change, extreme weather events and human mismanagement or changing management incentives. As carbon dioxide stays in the atmosphere for thousands of years, there is a requirement that any areas of forest being used as offsets are retained in perpetuity.[62] This liability represents an ongoing burden on future generations.

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[55] Measured according to net present value.

[56] MPI, 2022a.

[57] MfE, 2024e,f.

[58] PCE, 2024b, p.11.

[59] The global voluntary carbon market is expected to grow from $2 billion in 2022 to $100 billion in 2030 (Morgan Stanley Research, 2023).

[60] MfE and Treasury, 2022.

[61] The Government has announced changes to the NZ ETS, planned to take effect in 2025, that will limit the eligibility of exotic forests planted on certain classes of land (McClay and Watts, 2024). It is yet to be seen how constraining those changes will be.

[62] Issues with permanence and equivalence are being raised. See Cullenward, 2023 and Allen et al., 2024)

In other jurisdictions, insurance systems have been created which require ETS participants to contribute a specific percentage of carbon credits earned through afforestation to a so-called 'buffer pool'. In California, a portion of this buffer was intended to insure against losses due to wildfires. Despite the intention that this insurance system would cover wildfire risk for a period of 100 years, the fire protection buffer was exhausted in less than a decade.[63] Worse still, an apparent failure to acknowledge the increasing risk of wildfire suggests that "California's forest buffer pool is likely to experience mounting losses that far exceed its design criteria in the years and decades to come".[64]

The Californian example paints a bleak picture, one that is occurring elsewhere too, with Canada recording massive wildfires last year. While New Zealand is climatically different, our fire risk is increasing,[65] and the absence of any requirement for carbon insurance means that we are running an even higher risk. Current NZ ETS settings do require any lost carbon to be regrown if a forest is temporarily damaged (if the owner is to avoid surrender liabilities), but over long timeframes where there is an increasing likelihood of more damage occurring again and again, there is a risk of companies focused on carbon revenue dissolving and leaving the liability for replanting with the Crown.

Forestry losses from adverse events will also have negative implications for New Zealand's ability to meet its emissions budgets and international targets, if large amounts of sequestered carbon are re-emitted into the atmosphere. The CCC has recently highlighted uncertainties regarding the impact of major weather events, such as Cyclone Gabrielle, on large areas of forestry and what that could mean for emission budgets.

Does the NZ ETS even have a long-term future?

A final point, which pulls together the threads cited above, concerns the future of the NZ ETS itself. Once the NZ ETS sectors have reached net zero, will the scheme be extended to cover sectors currently outside its remit? What happens when the entire economy, covering the totality of our gross emissions, reaches net zero? By using forestry as an unlimited offset for emissions, we have implicitly promised that we will retain the NZ ETS indefinitely. Yet, at some point in the mid-2030s, the Crown will no longer earn revenue from the scheme (when the amount of units available to auction will fall to zero). As noted above, later in the 2030s the NZ ETS might become a cost to the Crown when it has to pay to offset ongoing emissions from the EITE sectors or if it has any liabilities from increased forest loss.

The NZ ETS will be needed to enable emitters to continue to buy units from foresters in order to maintain in perpetuity a 'net zero' balance of accounts. Even once we eliminate all gross emissions, the NZ ETS will need to continue to ensure that the accounting triumph represented by all that forest carbon will be managed, maintained and restored in the event of natural disasters. This imposes enduring administrative costs on future generations for little benefit. Future generations might legitimately find themselves asking why we bother having the current NZ ETS at all.

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63 California's forest carbon offsets buffer pool is severely undercapitalised. Badgley et al., 2022.

64 Badgley et al., 2022.

65 The average fire season length is extending and, in some locations, the number of days with 'very high' or 'extreme' fire risk will increase by up to 400% by 2040. See NIWA website https://niwa.co.nz/climate-change-adaptation-toolbox/projected-regional-climate-change-hazards/regional-projections-zone-1

If the NZ ETS is to survive, it is clear some major changes will be needed to make it sustainable. The brief history of the scheme outlined at the beginning of this chapter highlighted some major policy shifts that have occurred in its first 15 years. These have come about as the government of the day encountered issues managing supply and demand in the NZ ETS. As discussed, new supply and demand concerns will materialise in the 2030s. It would be foolhardy to assume that this will not result in major design changes to the scheme. Those changes might include limiting use of forestry or even removing forestry from the scheme altogether.

Removing or restricting forestry in the NZ ETS would mean that other government policies would be needed to incentivise afforestation. The next chapter looks at some of the regulatory, funding and other policy tools currently used.

Japanese cedar *(Cryptomeria japonica)*

10 What's holding back alternatives?

Key points in this chapter:

- Radiata pine is the default species for afforestation in New Zealand because the economics of forestry are hardwired around it.
- There are a number of barriers that prevent greater uptake of alternatives.
- In comparison to clear-fell radiata pine, we know far less about alternative forestry species and management regimes. These knowledge gaps increase investment uncertainty and risk. Filling these gaps would incur significant costs.
- To be cost-competitive across the value chain from planting to processing, alternative forestry must have a large enough presence in a region to achieve economies of scale. This requires coordination across industry players, which can be challenging and costly.
- The policy system inadequately values the environmental costs and benefits of different land management practices.
- Regulatory barriers that perpetuate the status quo (beyond the NZ ETS) exist in the Forests Act 1949, the Resource Management Act 1991 (RMA) and the Building Code.
- Whenua Māori faces unique additional challenges that, in combination with the factors above, further hamper the uptake of alternative forestry approaches.

Introduction

Radiata pine has become the preferred option for production and carbon forestry in New Zealand. Some alternative forestry systems could offer environmental improvements over the familiar clear-fell radiata pine regime. These alternatives could complement the economic strengths of radiata pine afforestation. However, for the time being, most alternative species and management regimes remain confined to niche settings.

There are three main reasons for this. Firstly, the economics of forestry in New Zealand is hardwired around the clear-fell harvest of radiata pine, and coordinating a shift towards alternatives would incur significant costs to fill in the many unknowns. Secondly, there has been a systemic failure of environmental policies to adequately value costs and benefits of forestry, preventing both incentivisation of more environmentally friendly practices and internalisation of the environmental costs of the current regime. Finally, we have a bifocal regulatory system that aims through one lens to protect indigenous forests from harvest while through the other enabling timber production and carbon forests with an implicit bias toward radiata pine. The aggregate of these factors has had particular implications for whenua Māori.

The appeal of radiata

Many stars align in support of clear-fell radiata pine as a land use in New Zealand. As noted in Chapter 2, the species grows just about everywhere. Establishment is simple and relatively inexpensive. There is depth and breadth of knowledge in the industry about silviculture, harvest and processing, markets and consumer demand. Radiata pine forestry is generally well-understood from a landowner's perspective and, where that is not the case, information is readily available.

Clear-fell harvest with radiata pine offers excellent returns compared to other land use options over a significant proportion evidenced by the estimate of more than 261,000 hectares converted to forestry between 2017 and June 2024.[1] The returns from carbon offsetting can make partial conversion an attractive addition to farm revenue. The embedded knowledge associated with radiata pine and its fast-growing accumulation of carbon makes this the default crop.

Rather than necessarily being better or worse than radiata pine, alternative species and management regimes come with different costs and benefits. Alternative forests are not unique in offering co-benefits for soil retention, water quality and biodiversity. In the right locations and managed in the right way, radiata pine plantations can host a surprising amount of native fauna and flora. Aside from the period immediately after clear-felling, pine plantations also offer well-documented benefits to hydrology and soil retention. Nor is it the case that alternatives do not come with their own risks and downsides. What alternatives offer is choice about which values to prioritise and ways to spread risk through diversification. They have remained niche because any advantages they do have over the default are marginalised by the inertia of the existing carbon and fibre regimes. The current forestry system began with government intervention and, for alternatives to succeed at scale, similar intervention may be required.

Policy failure to adequately value ecosystem services

Justifying greater investment in alternatives is unlikely if there is not a better valuation and monetisation of the costs and benefits of the environmental services of different forest systems.

There are two difficulties that limit the use of tools to value ecosystem services: measurement and payment. Environmental and ecological processes are complex and interact in many ways. Ecosystem services have many components which resist combination into a single objective metric. For biodiversity alone, over 570 metrics have already been proposed globally, and the list continues to grow.[2] The value of ecosystem services can also vary substantially depending on the local context and through time.

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[1] Orme, 2024; Satchell, 2021.

[2] Burgess et al., 2024.

Although there are a variety of emergent instruments, much of the public debate tends to focus on biodiversity credits.[3] Unlike commodities, such as timber or even carbon which are descriptively simple and can be priced by weight, defining and measuring biodiversity to determine the value of any improvement is extremely challenging. 'A tonne is a tonne' is a fraught enough contention when it comes to carbon.[4] Defining a universal unit of biodiversity is nearly impossible. Some units can be designed to be locally specific, but that immediately limits the potential for trading credits between systems.

Given these definitional issues, whatever basket of metrics is chosen will either be incredibly complex or imperfectly capture the fullness of biodiversity.[5] In the same way that radiata pine emerged as the go-to for carbon capture in New Zealand, an overly simple biodiversity credit system could result in one type of ecosystem offering the biggest bang-for-its-buck.

Even if measurement methodologies can be agreed and knowledge gaps filled, there remains the challenge of determining who pays for any service provided and how they can be encouraged or required to do so. Voluntary markets already exist for biodiversity credits, but demand is largely driven by corporate reputation and in some cases a desire to head off more demanding, but perhaps more effective, regulation. Some states, such as the United Kingdom, have introduced mandatory biodiversity net gain or offsetting requirements for development, but there remains a very real potential that such well-meaning regulation can be gamed. As such, outcomes should be examined closely if such schemes are to be emulated.[6]

Issues with permanence, additionality and the potential for greenwashing that face carbon credits are also relevant to biodiversity credits when used as offsets.[7] For these reasons, bodies such as the International Advisory Panel on Biodiversity Credits support only limited, local, like-for-like compensation.[8] Instead of offsets, the recommended-use cases for biodiversity claims primarily centre around contribution to biodiversity goals or benefits beyond an organisation's value chain. The challenge for this approach will be generating sufficient demand without a regulatory driver of corporate demand for offsetting.[9]

How much landowners should be rewarded for ecosystem services depends on what society expects should be protected as a matter of course. The idea that ownership comes with an unfettered right to transform or even eliminate ecosystem services is clearly at odds with the 'public' nature of resources, such as water and biodiversity. Degrading these services comes at a cost to other landowners and the public at large. This is where regulated 'bottom lines', and fines or other costs imposed for breaching them, enter the equation. For instance, what is the baseline society expects of landowners in controlling erosion, and how might this be translated into effective regulation?

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3 Subsidies to manage erosion, tradeable water-take credits, insurance, lending and equity funds also offer opportunities to incentivise and manage ecosystem services. For biodiversity specifically, certification (such as through the Forest Stewardship Council requirements, see FSC 2023), resilience bonds and direct payments are alternatives. In Slovenia, grants for silviculture and conservation in continuous cover forests are available in recognition of the wider public benefits of less intensive management (The Connective et al., 2023). Reporting and disclosure of climate and biodiversity-related risks and opportunities can help address the informational deficit limiting recognition of ecosystem services in business decisions.

4 PCE, 2019.

5 For example, see Marshall et al., 2024.

6 Audit Office of New South Wales, 2022.

7 These concerns are not new and have yet to be resolved. See Burgin, 2008; Wunder et al., 2024.

8 International Advisory Panel on Biodiversity Credits, 2024.

9 PCE, 2023a.

Source: James Lee, Unsplash

Figure 10.1: Debate has been growing over how to value the ecosystem services provided by forests, on either a large or small scale, such as on farms as illustrated above. Biodiversity credits are one tool; however questions remain over measuring biodiversity and who will pay.

Ways in which current regulations discourage alternative forestry systems

The current regulatory environment around forests operates at two ends of a spectrum. At one end, the Forests Act 1949 focuses on protecting natural indigenous forests using a prescriptive approach. At the other end, the NZ ETS created under the Climate Change Response Act 2002 and the National Environmental Standard on Commercial Forestry (NES-CF) gazetted under the RMA, are crafted with radiata pine and clear-fell harvest in mind, although natives and alternative species are not excluded. Indirect supply-side incentives are driven by the Building Code, which is biased toward radiata pine.

The Forests Act

The Forests Act 1949 covers activities relating to the harvesting, milling and export of native trees on private land. The Act functions as a handbrake on deforestation of the remaining 2.8 million hectares of privately owned native forest in New Zealand.[10]

Under the Act, harvesting timber from existing or regenerating native forests on private land can only be carried out in accordance with an approved sustainable management plan or permit (except

[10] The management of indigenous forests on public conservation land falls under the Conservation Act 1987. Harvesting of even naturally-felled timber from conservation land is highly contentious, as was seen during debates around the West Coast Wind-blown Timber (Conservation Lands) Act 2014 (Davison, 2014).

for limited harvesting for personal use, which still requires approval). The Act only permits very small rates of harvesting from these forests (~1% of the standing merchantable volume) in a way that must preserve their natural values.[11] Relatively little harvesting currently occurs under these provisions – native timber represented just 0.03% of the total amount harvested in 2022.[12] Only 63,000 hectares (2% of privately owned native forests) have the required sustainable management plans or permits to even allow any harvest.[13]

The main barriers are summed up in the final report of the Tōtara Industry Pilot project:

> "While it is possible [to operate within the constraints of the Forests Act], the high compliance cost and current restrictions regarding conservative calculations of allowable volume present significant barriers."[14]

The strict harvest limits that apply to existing native forests include regenerating native forests. By contrast, there are no limits on the harvesting of planted native forests. This arbitrary distinction has significant implications for native afforestation and ignores the fact that both planted and regenerating forest require active intervention and yield similar environmental benefits. Given the strict rules around felling trees in a regenerating native forest (even where the regeneration is assisted by human intervention), landowners may understandably be reluctant to allow new forests to establish this way, as it would severely limit harvesting options as well as any future land use change. This is unfortunate because assisting natural regeneration has been more widely demonstrated at a large scale and can be more cost-effective than planting. If timber production is an aim, the high costs of native planting and restrictions around harvesting naturally regenerated stands may push native-interested landowners to plant exotics instead.

In some cases, harvesting restrictions under the Forests Act that were imposed to protect forest values may actually be limiting growth rates and regeneration within forests managed for sustainable timber production. A recent assessment of tōtara stands on private farmland in Northland found that the low permitted harvesting rate (often less than one cubic metre per hectare per year) may not cause sufficient disturbance to trigger new regeneration or increased growth rates.[15] There is an opportunity, at least in some cases, for greater flexibility in the permitted harvesting rate to reflect the features of species and site conditions, which could increase returns and environmental benefits within the limits of sustainability.

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[11] A 2004 amendment introduced a requirement to sustainably manage privately owned native forests, including strict rules regulating the harvest of native timber from 'indigenous forest land' but exempting 'planted indigenous forest' and limiting the milling of all native timbers to registered mills. The Forests Amendment Act 2004 also largely prohibited the export of native timber and unfinished timber products. The principle of sustainable management in this instance is to limit the amount of timber that can be harvested to a rate that is no greater than the forest's ability to replace it. In practice, this corresponds to an annual harvest volume of something less than 1% of the forest's total standing volume, or 10% every 10 years provided the forest has returned to its initial stocking.

[12] FOA, 2023.

[13] MPI, 2018.

[14] Dunningham et al., 2020, p.15.

[15] Dunningham et al., 2020.

The Climate Change Response Act and the NZ ETS

In defining what counts as a forest and providing an incentive structure for carbon credits, the Climate Change Response Act and NZ ETS exert a significant regulatory effect on the drivers of, and barriers to, afforestation and existing forest management. Chapter 9 provides a detailed account of the NZ ETS and its effects. The key barriers it poses to alternatives can be summarised as follows:

- The carbon-only focus incentivises fast-growing trees (e.g. radiata pine) for short-term gains, whereas some alternatives (natives, some exotics) take longer to sequester carbon initially but can store carbon for hundreds or thousands of years.
- A lack of data means there is greater uncertainty about the carbon sequestration rates of alternative species.
- There is a lack of regulatory certainty around the permanent forest category, particularly regarding carbon accounting of exotic-to-native transition forests.

The Resource Management Act and commercial forests

The RMA affects all existing land uses and future land use changes in major ways.[16] It regulates the environmental effects of activities rather than the activity itself. The principal way the Act affects afforestation decisions is through the National Environmental Standards for Commercial Forestry.[17]

The National Environmental Standards for Commercial Forestry

The NES-CF provides nationally consistent regulations to manage the environmental effects of the plethora of activities involved in commercial forestry.[18] It includes rules for afforestation, silviculture, harvesting and replanting, and associated activities like site and roadworks, and land preparation. Many of the rules and consenting requirements vary depending on the erosion susceptibility classification of the land.[19]

The standards were amended in 2023 from the previous National Environmental Standards for Plantation Forestry to include exotic continuous cover forests established for commercial purposes. This was in response to concerns about the lack of management requirements for exotic carbon forestry. Other amendments included giving greater control to councils over the location of new forests and changes to rules about slash management and wilding conifer control. These latter rules have since been signalled for further changes.[20]

How well the NES-CF manages environmental effects is hotly contested. While it might bring consistency between regions (which is useful for large inter-regional forestry companies), its one-size-fits-all approach and lack of granularity have enabled inappropriate planting and management practices in some places.[21] It has also been criticised for weak standards around harvesting, leading to increased post-harvest erosion and slash risks. This report, which focuses on alternative forestry systems, is not the place to delve into that debate.

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[16] Primarily through the setting of National Environmental Standards (NES) and National Policy Statements (NPS) by central government and then promulgated through regional and district plans developed and implemented by councils. NPSs state objectives and policies for matters of national significance; NESs prescribe technical standards, methods or requirements.

[17] This NES was amended and renamed from the National Environmental Standards for Plantation Forestry in November 2023. Commercial forestry was defined as any plantation forest (indigenous and exotic) or exotic continuous cover forest.

[18] Standards are implemented by councils in their regional and district plans, with some capacity for variance.

[19] The Erosion Susceptibility Classification (ESC) has 4 risk levels: very high, high, moderate and low.

[20] The Minister of Forestry announced more proposals in September 2024 (McClay, 2024c).

[21] Due to coarse assessments of erosion risk and a lack of consideration for local fire risk, for example.

A key issue that the NES-CF raises for alternative forestry is its reliance on a coarse erosion mapping tool (the Erosion Susceptibility Classification, at a resolution of 1:50,000) for initial risk screening. The absence of fine-grained maps (e.g. 1:5,000 to 1:10,000) is a barrier to small-scale forestry options in erodible landscapes.[22] Greater resolution mapping could support a mosaic approach to forestry, with alternative approaches used in higher-risk areas alongside large-scale operations like clear-fell harvest.[23]

Source: Geoffroy Lamarche, PCE

Figure 10.2: The Gisborne District Council is one regional authority looking to apply stricter rules for forestry in Tairāwhiti, pictured above. It is identifying areas at greatest risk of landslides that could affect waterways, and plans to retire these areas from production.

Regional and district plans

Under the RMA, most environmental effects are managed through policies, objectives and rules in regional and district plans. Those plans must be consistent with national direction unless explicitly allowed otherwise.

This still leaves room for tailoring of some rules, which can create uncertainty and complexity for landowners. For example, harvesting native trees under MPI-approved sustainable management permits or plans issued under the Forests Act may be a permitted activity in some district plans, but a restricted discretionary activity in others. Similarly, periodic clearance and replanting of mānuka or kānuka stands to maintain honey production may require a resource consent or be prohibited, depending on the council. This could discourage native afforestation for productive purposes, as in some areas native forest establishment essentially means permanent land retirement. The typical 10-year timeframe of district plans results in more uncertainty for those interested in native forestry, given the much longer timeframes it requires.[24]

[22] Although not the origin of the lack of granularity, this aspect of the NES-CF has failed to subvert the historical trend of inappropriate planting and management practices.

[23] Some councils have other resources with greater resolution in use, even their own mapping with landslide susceptibility and stream connectivity, but these tools are not universally applied.

[24] Quinlan, 2022, p.113.

Some councils are seeking to impose tighter restrictions on where forestry can be located and how it is managed. Gisborne District Council is identifying the highest-risk areas for landslides affecting waterways (those with a high risk of erosion and high connectivity to waterways) and considering how these areas could be retired from production. This includes areas currently in farmland or production forest. The council is also considering restrictions on clear-fell harvesting activities in other erodible areas that are less connected to waterways. These might include setting consistent rules across the region (e.g. coupe harvest limitations) or developing more catchment-specific approaches, for example, forest catchment management plans. Rule changes such as these are likely to shift the dial in favour of alternative forestry systems, for example, native afforestation or continuous cover forestry. However, not all district councils have been incentivised by extreme weather events to make such changes, or have the expertise and resourcing needed to make them operative.

The current Government has signalled its intention to repeal the section of the NES-CF that allows for council discretion on afforestation. A return to centralised direction could jeopardise the ability of councils to plan for and manage the effects of land and resource use, including different approaches to forestry.

National Policy Statement on Indigenous Biodiversity

The National Policy Statement for Indigenous Biodiversity (NPS-IB) was implemented in 2023 after years of often acrimonious debate about its purpose and function. Part of that purpose was to provide national direction for councils on how to fulfil their duties to manage biodiversity under sections 30(1)(ga) and 31(b)(iii) of the RMA. This was primarily to be achieved through the mechanism of Significant Natural Areas (SNA): places identified in plans notable for their biodiversity, to which rules could be applied to ensure their conservation.

Concern about what SNAs could mean for land management and future option values has been particularly acute in the forestry sector. Well-managed forests (of exotics or native tree species) can support populations of native fauna and flora. Many forest owners acknowledge the benefits of the biodiversity found in their forests and actively take steps to protect it. In some cases, biodiversity is a key motivation behind afforestation. There were concerns from some forest owners that the formal identification of SNAs within forests could lead to limitations on commercial activities without compensation. Perversely, this could have disincentivised the positive actions that many forest owners currently take to protect or enhance biodiversity in their existing forests, or to establish new forests with potentially high biodiversity values (such as native forests and continuous cover forests).

The current Government has paused the requirement for councils to identify SNAs until October 2027 while alternative ways of recognising important ecological areas are reconsidered.[25] Councils are still required to manage biodiversity under the RMA, despite the pause, now without an agreed-upon tool to do so. For landowners interested in a multi-decade venture, such as forestry, there is little long-term clarity about how they may be affected by any future regulation introduced to protect biodiversity on private land.

[25] Hoggard, 2024.

New Zealand Standards and the Building Code

The building industry's demand for timber acts as a significant driver of the types of forests that get planted. Timber is used extensively in New Zealand's residential and commercial construction industry. Several standards that inform consenting and construction and the use of timber and wood-based products are set out in regulations under the Building Act 2004. These regulations provide for 'acceptable solutions' following the approach set out in the standards, and 'alternative solutions' unique to a single application. Radiata pine is the most widely represented acceptable solution in relevant standards.[26] The use of alternative timbers typically requires application as an alternative solution: substantial evidence of fulfilment of the standard is required each time they are used. Not being included as an acceptable solution also reduces their visibility. Some alternative timbers are included as acceptable solutions, but these are largely for non-structural purposes.[27]

As alternative timbers are less widely grown and processed than radiata pine, there is less data on their timber properties. This makes it harder to develop acceptable solutions that embrace the use of alternative timbers at scale. Their exclusion adds costs to their use in designs as consent authorities must satisfy themselves that the alternative solutions comply with strength, durability and other criteria. This is more onerous than simply confirming that construction has accorded with a pre-approved acceptable solution. These alternative timbers are therefore less economically attractive options, which reinforces them as niche uses and further limits the available pool of data and evidence.

Even where good data is available, there are other challenges to improving the visibility of alternative timbers within building standards. The committees that set and review the standards are structured in such a way that industry incumbents can prevent consensus and delay outcomes that would benefit or enable alternative species.[28] The potential for conflicts and perpetuation of vested interests is clear and only compounds the difficulty of adequately resourcing standards for alternative species and technology. This feedback loop lends itself to path dependence, an issue covered by the PCE's 2024 report, *Urban ground truths: Valuing soil and subsoil in urban development,* in the case of concrete slab foundations.

As a result, the potential benefits of using alternative timbers are often overlooked. For example, unlike radiata pine, naturally durable timbers do not require treatment with chemicals like chromated copper arsenate (CCA). Although cheap and effective, the treatment is highly toxic and can cause harm through direct human contact or by leaching into the environment if improperly deployed or disposed of.[29] CCA-treated timber is widely used in New Zealand and, despite regulation governing its disposal, has even ended up (illegally) in compost.[30] Modern kiln-drying techniques help to reduce the risk from leaching, but disposal must still be carefully managed.

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[26] Such as NZS 3604:2011 for timber-framed buildings (Standards New Zealand, 2011) and NZS 3602:2003 for timber and wood-based products for use in building (Standards New Zealand, 2003).

[27] Larch and cypresses are the best represented alternative species included in NZS 3602, although achieving the highest 50-year durability requirement for parts in contact with the ground or exposed to exterior weather conditions is almost entirely confined to treated radiata pine in accordance with NZS 3605:2001 for timber piles and poles (Standards New Zealand, 2001). Flooring, stairs and finishings allow for a wider array of species as acceptable solutions, such as eucalyptus, beech and tawa.

[28] A 2022 letter from the chair of the Forestry Ministerial Advisory Group (FMAG) to the Minister of Forestry raised concerns about the composition of the Building Research Advisory Committee and recommended it should be comprised of independent experts as it was prior to the mid-1990s (FMAG, 2022). The FMAG has since been disbanded.

[29] Soil and water contamination can occur from the use of CCA-treated timber, and inappropriate burning can lead to unsafe levels of arsenic in the air. Options for safe disposal are limited and New Zealand is out of step with jurisdictions like the European Union, the United States and Canada that have heavily restricted or banned its use (Altaner, 2022).

[30] Martin, 2022.

While risk aversion in the building sector is understandable, the disincentives for innovation have led to a 'stick with what you know' approach that risks missing opportunities to add value and achieve greater environmental benefits.

Source: James Anderson, Flickr

Figure 10.3: Standards under the Building Code incentivise the use of radiata pine in construction. Radiata pine is an 'acceptable solution' under various standards, whereas other exotic timbers are 'alternative solutions', which require substantial evidence of compliance each time they are used.

Knowledge gaps

A perennial problem for those seeking to explore alternative forestry options is the sheer path dependency that flows from overwhelming investment by both government and industry into clear-fell radiata pine. Anyone seeking to establish a new rotation pine forest anywhere in New Zealand can easily access reliable information and expertise about every stage of the process from planting to processing. Harvesting and processing methods can be expected to improve over time and markets may change, but anyone planting a pine forest today can rest assured that a mature industry already exists and that ongoing research and development will continue at least for some time. New Zealand's confidence and expertise in growing radiata pine for fibre has carried over to the carbon forestry industry, further solidifying the country's heavy investment in the species. Interest in novel opportunities, such as biofuels, biomass and chemicals, is heading in the same direction.[31]

[31] For example, Scion says radiata pine is the "ideal species" for short-rotation forestry for bioenergy production (Scion, 2024c).

By contrast, we know less about virtually every step involved in establishing and managing alternative forests for timber or any other purpose. It would be naive to assume that we can dial up tens of thousands of hectares of native forest or diversified exotic plantations. There are still large gaps in understanding that need to be filled before some alternative forestry types can be confidently deployed at scale.

Foresters may struggle to find good quality seedstock. Even if they can access seedlings, robust information about how well they grow or how best to tend them is often lacking. The outcomes that can be expected from those forests are similarly less well studied. For example, timber from alternative species can be highly variable, which makes it more challenging to process and develop markets for end products. Even the different regional and species-specific rates at which they sequester carbon are not reflected in policy due to a lack of data. Additionally, understanding how alternative forestry might impact mauri specific to locale is a huge knowledge gap that stands in the way of those who wish to utilise mauri as an indicator for forest health.

Where trials have been carried out, fragmentation and a lack of systematic and coordinated results-sharing has often been a limiting factor. Particularly for native afforestation, opportunities for learnings have been missed because there has often been a focus on upfront planting without ongoing monitoring of success or sharing outcomes. Many native planting efforts have taken place across the country, from small-scale (private landowners) to large-scale (multi-year programmes led by community groups or councils, or funded through grant schemes). If data on methods, survival and growth rates had been systematically collected and shared between these groups, we would already know a lot more than we do about likely cost-effectiveness and success.

Appendix 3 illustrates deficiencies in the state of knowledge concerning alternative forestry.

Ad hoc investment in alternatives

In the twentieth century, there was significant research and investment into alternative forestry species, driven largely by the State Forest Service (later the New Zealand Forest Service). This included trial plantings of alternative exotic species, and research into the ecology and silviculture of native species for timber production. But by the middle of the century, radiata pine was already commanding much of the investment in forest research. Changing policies and social perspectives on native timber harvest in the 1970s–1990s largely curtailed research into native forests for production purposes, and the disestablishment of the New Zealand Forest Service saw most state-owned forests (including alternative exotic trial plantings) privatised. Since then, the majority of private and public sector investment has been directed to growing, harvesting and processing radiata pine. Figure 10.4 illustrates the league table for research and development investment in different forest types from 2018–2024. From time to time, the government has made research investments in alternative species but these investments have been, at best, ad hoc and short-term. Investment has not been of a scale or duration that could lift alternatives above their niche status.

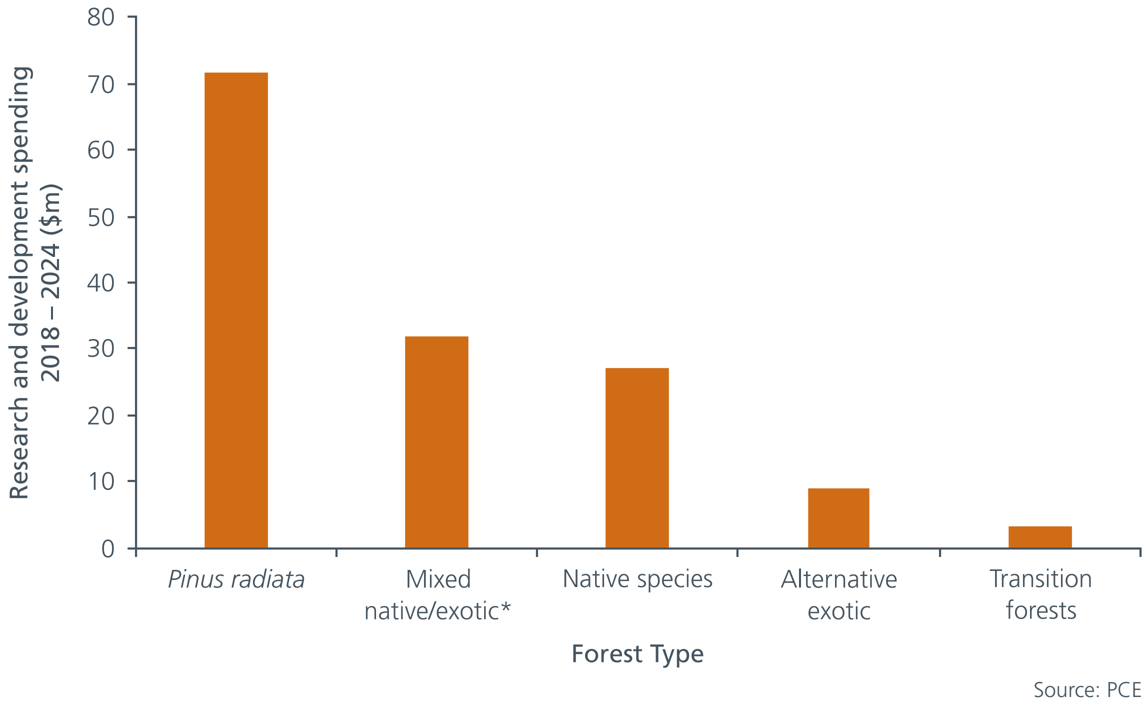

Figure 10.4: In recent years, radiata pine has received almost as much investment as all alternatives put together. Investment data is mainly derived from reporting on public expenditure through various funding schemes, alongside industry co-funding, and should be treated as an estimate only.[32] The mixed native/exotic category included both projects that target mixed-species native/exotic forests and projects that had aims for both native and exotic species separately.

Nevertheless, some passionate practitioners have navigated the vagaries of short-term funding to drive developments in alternative forestry. Forest Growers Research has recently concluded its eight-year programme of research into specialty wood products, and a number of short-term programmes with a particular focus on alternative timber species.[33] New Zealand Dryland Forests Innovation has led the development and commercialisation of durable eucalypts over the past two decades by securing a series of research grants. The New Zealand Poplar and Willow Research Trust continues to invest, particularly in the trees' integration with farmland. Tāne's Tree Trust has focused attention on promoting native tree species for a variety of purposes, and developing knowledge about native forest establishment and management. Partnerships between central government and these kinds of interest groups through One Billion Trees, the Forestry and Wood Processing Industry Transformation Plan, Sustainable Food and Fibre Futures and an array of other programmes have improved our understanding of alternative species and management regimes.[34]

However, many of these government-funded initiatives are winding up. There is no further funding for One Billion Trees grants, and the Industry Transformation Plan has been discontinued.

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[32] Central government is the principal source of forestry research and development funding, although the organisation of funding streams and agencies hinders its quantification (Food and Agriculture Organization of the United Nations (FAO), 2020b).

[33] In their Science and Innovation Strategy, Forest Growers Research anticipated 10–20% of funds would target diversification through emerging species and new models for forestry (Forest Growers Levy Trust, 2020). In 2024, specialty species made up 8% of research spending (Forest Growers Research, 2024).

[34] One Billion Trees and Sustainable Food and Fibre Futures funded science projects for native and alternative exotic species alongside research on radiata pine and other aspects of forestry. The Forestry and Wood Processing Industry Transformation Plan included themes on diversification, native afforestation and continuous cover forestry (MPI, 2022c).

Box 10.1: Developing the durable-eucalypt industry in New Zealand

NZ Dryland Forests Innovation (NZDFI) has been trialling and breeding different durable eucalypt species since 2008 to provide an alternative to CCA-treated timber and imported hardwoods. A key market is making naturally durable fence posts for farming and horticulture.

Breeding can significantly improve traits like productivity, tree form and durability within a single generation. But trials are expensive and require scientific skill and expertise. NZDFI has undertaken first-generation breeding of *E. bosistoana* by collecting seeds from across the native range in Australia to establish breeding populations across nine sites. At a cost of over $500,000 (in 2012 prices), 24,600 GPS-mapped trees were planted. Another $500,000 was required in the following years for assessments and analysis to identify the best families based on survival, growth, form and wood properties. Elite trees were selected to develop high-quality seed orchards, clonal cuttings and a new generation of planting trials. Similar investment has been made to improve *E. globoidea*. In addition, species performance has been monitored in 30 demonstration trials across a range of environmental conditions.

NZDFI's work has been supported by the University of Canterbury's School of Forestry. The school has developed four key research themes for successful durable eucalypt forestry that have been the focus of various postgraduate and undergraduate projects. This has produced multiple research outcomes and developed domestic expertise in this area.

Such research is crucial to improving confidence in species' performance, and there are large gains still to be made. But securing long-term research funding (a necessity for a long-term endeavour like forestry) has been an ongoing challenge. Over the past 16 years, NZDFI secured investment via seven different funding programmes to progress durable eucalypt research. However, further progress is limited as industry and government funding has reduced.[35]

Source: PCE

Figure 10.5: Eucalypt trees planted across a slope in Marlborough to assess environmental effects on growth.

[35] NZDFI, pers. comm., 24 January 2025.

Grant schemes

In addition to what is traditionally captured by the term 'research', central government has invested significantly in forestry following a 'learning by doing' approach. For example, the Government spent $128 million through the Afforestation Grant Scheme and One Billion Trees programme to afforest as much as 49,000 hectares.[36] These projects have had an increasing focus on alternatives, particularly native species. While they have provided a number of benefits and opportunities for learning, the schemes have been hampered by three flaws.

The first is inadequate investment on a per hectare basis: even One Billion Trees programme's highest available planting rate of $6,000 per hectare is insufficient to fully cover the typical costs of native establishment, particularly blanket planting, which averages around $25,000 per hectare (not including the costs of fencing or pest control which can be considerable).[37] Native afforestation projects made up 95% of the contracts withdrawn due to planting failures and all nine of the contracts withdrawn due to costs.[38] When grants do not fully cover establishment costs, let alone maintenance, it is difficult to determine how much of the scheme has incentivised new planting versus accelerating previously planned projects. Data to clarify this is unavailable.[39]

The second policy flaw has been missing the opportunity to capture details of the causes of planting failures. Monitoring, reporting and verification (MRV) are critical to long-term learning and improvement of programme delivery and, ultimately, improvement of environmental outcomes. However, in the short term, MRV may be viewed as drawing resources away from 'doing stuff', such as planting trees. Political risk aversion and output-focused reporting may contribute to this neglect, but whatever the reason, MRV is often at risk of receiving scant policy attention.

Thirdly, afforestation grant schemes more generally have been coloured by short-termism. Each scheme only provided funding for a handful of years. While One Billion Trees will continue until 2028, there is no further funding for grants or partnership projects. This on-again, off-again paradigm leads to uncertainty, limiting the ability to build a business case for investment in alternatives.

Short-termism has also permeated programmes with longer lives, such as the East Coast Forestry Project (later the Erosion Control Funding Programme) and the Hill Country Erosion Programme. Only a fraction of the funding for these two schemes went towards establishing alternative species, and little regard was paid to the trees' long-term survival.[40] More generally, the practice of funding establishment but not ongoing management has had significant consequences for planting survival rates (such as poplars planted for erosion control).[41]

A lack of long-term thinking can have far more serious impacts than low survival rates of trees. The East Coast Forestry Project focused afforestation on highly erodible soils to improve stabilisation. However, during the development of the project in the early 1990s, there was little consideration of

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[36] MAF, 2011; MPI, 2019; Te Uru Rākau – New Zealand Forest Service, 2024; MPI, pers. comm., 19 July 2024; MPI, pers. comm., 18 December 2024.

[37] Forbes Ecology, 2022.

[38] One Billion Trees Fund Annual Monitoring Report 2023–24, Table 9 (Te Uru Rākau – New Zealand Forest Service, 2024). Native species make up 81% of the planted trees that were directly funded by the One Billion Trees programme.

[39] Te Uru Rākau – New Zealand Forest Service, 2024.

[40] Te Uru Rākau – New Zealand Forest Service, 2023; MPI, pers. comm., 19 July 2024.

[41] Marden and Phillips, 2014.

the future impacts that clear-fell harvesting might have on these soils.[42] The ongoing consequences for the East Coast of this lack of foresight will continue to be felt for decades.[43]

Pigeonholing alternatives

Research has been funded into alternative forestry systems. Unfortunately, it has tended to frame alternative species and their wood products in one of two limiting ways. 'Contingency' and 'specialty' frequently replace the descriptor 'alternative' when referring to species other than radiata pine.

The contingency framing positions different species as being worthy of investigation as alternatives in the event that radiata pine is hit by disease or some other existential threat. These contingency species are to 'wait in the wings', receiving sufficient attention to be ready if needed, but insufficient to merit investment in their own right.

The specialty framing focuses on the extent to which species might fill a high-end market niche. Whereas the contingency framing envisions deploying these species at scale, but only in the future if needed, the specialty framing recognises the unique sets of costs and benefits offered by alternatives. However, it suggests these specialty species will only ever play a minor role in the forestry estate.

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[42] Few official documents mentioned the post-harvest risk of increased erosion. One of the only acknowledgements was in an officials' working party document (Officials Working Party, 1992, p.7) which simply noted that after harvesting, "old root systems continue to bind the soil. Adverse effects on any one catchment can be reduced by felling smaller areas (logging coupes)" and that replanting within 2.5 years would be needed. See also Sustainable Land Management and the East Coast Forestry Project (PCE, 1994).

[43] Parata et al., 2023.

Supply chain sticking points

If alternative forestry systems were to play a larger role, significant gaps across the supply chain would need to be addressed.

Table 10.1: Supply chain barriers.

Theme	Barrier	Detail	Alternative forestry type
Planting stock	Seed sourcing	• Land access can be a barrier when collecting native seeds from wild populations. The role of mana whenua as kaitiaki for taonga and places of wāhi tapu must also be considered. • Land access issues and limited native seed sources limit genetic diversity of collected seed, with impacts for resilience and adaptation.	Natives
	Seedstock production	• Production of high-quality seedstock and clones is expensive. • Some species have very low seed viability. • Seed storage and germination can be difficult.	Natives, alternative exotics
	Lack of well-developed seedstock	• Commercial growers need certainty of tree properties (wood, growth, form). All growers want good survival and resilience to pests and diseases. • Genetic improvements for alternatives are far behind that of pine. • Improvements are occurring for some species, but funding is fragmented.	Natives, alternative exotics
Infrastructure	Mills	• Most mills are set up for one or two timber species (normally radiata pine and Douglas fir). • Regional coordination between growers of alternative timber species is necessary to supply sufficient volumes for specialised local mills, but this is lacking.	Natives, alternative exotics
	Transport network	• Much of the marginal land most needing continuous cover forests is too far from ports and railways for low-intensity harvest to be economically viable for export or domestic use (beyond local mills and markets).	Continuous cover forestry
Economics	Establishment and maintenance costs	• All stages of native afforestation are more expensive than pine. • Ongoing pest and weed control may be required (depending on the purpose).	Natives, continuous cover forestry

Theme	Barrier	Detail	Alternative forestry type
Economics	Revenue	• Financial incentives for afforestation are largely limited to fibre production and carbon sequestration. Natives are slower at this than pine and many exotics. • Standard discount rates in forestry (typically around 7%[44]) emphasise upfront costs over long-term benefits, reducing the appeal of investment in slower-growing species. Lower rates would improve the business case for native forestry.	Natives
		• Productivity and economic models for alternatives are less developed than for clear-fell pine. • Markets for alternative timbers are less well-developed than for pine, so the higher timber prices that are necessary to make longer rotations or small volume harvest economically attractive might not be realised. • Markets for non-timber products are niche and underdeveloped (excluding mānuka honey). • There are limited financial mechanisms to reward the non-extractive values of forests (e.g. erosion control, water regulation, biodiversity).	Natives, alternative exotics, continuous cover forestry
		• Low-intensity harvests involve a different economic model to clear-fell regimes, such as smaller, more frequent returns. Low-intensity harvests can be economically viable but require expertise and integrated systems (e.g. on-site processing and direct-to-public sale).	Continuous cover forestry
Expertise	Development and implementation of alternative forestry systems	Specialist skills and knowledge are required to further develop alternative forestry systems through research and development and successfully apply them. This includes: • identifying which systems are suitable for an area • establishing and managing the forest using methods that are appropriate to its purpose, type and location • processing outputs, such as milling alternative timbers for diverse end uses.	Natives, alternative exotics, alternative management regimes

[44] Manley, 2024. For comparison, the Treasury discount rate is 8% for commercial proposals and 2% (decreasing to 1%) for non-commercial ones. See PCE, 2021b, *Wellbeing budgets and the environment: A promised land?* for further discussion of the application of discount rates to long-term environmental investment.

Improved coordination and strategy

For alternative forestry species to be economically viable, there would also need to be a coordinated approach to deciding what to plant where, to justify the development of local infrastructure and markets. Coordination would reduce the costs arising from the inherent uncertainty involved in a natural resource industry with such long time-lags between investment and returns (planting and harvest).[45] It would be pragmatic to focus efforts on a shortlist of the species that show the most promise and about which we already know the most.

Greater coordination at the landscape scale would enable the implementation of a spectrum of forestry systems with varying intensities. This could support overall productivity and resilience, and reduce environmental harm. It could allow for the retention of highly intensive systems where these practices are lower-risk, such as in the central North Island, while encouraging less intensive or non-extractive systems in more vulnerable areas.[46]

Despite the potential advantages of diversification, the forestry sector remains locked into the clear-fell radiata status quo. Part of the reason for this path dependency may lie in the beleaguered history of attempts to create and implement a comprehensive national forest policy.[47] Such a policy could provide the necessary impetus to overcome the costs of coordination, which have proved a significant barrier to the penetration of alternative forestry systems.[48] Instead, strategic thinking on the future of the industry has languished in a series of stop-start initiatives that, while individually promising, have largely failed to endure and sustain long-term direction.[49]

Resistance from within the forestry sector

Sitting above all the barriers described has been the effectiveness of the forestry sector in resisting large-scale change to the well-established clear-fell pine paradigm. For example, the influence of industry incumbents on the committees that set and review Building Code standards has delayed the adoption of alternative timber species and products.[50] To some degree, the system of forestry education in New Zealand also serves to reinforce the refinement of current practices rather than radical innovation.[51] Contextual factors that might otherwise disrupt this dominance, such as ongoing climate change and declines in biodiversity and water quality, fail to do so because alternative species and management systems are effectively suppressed by the status quo.

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45 Simard et al., 2023.

46 Such an approach has parallels with 'triad forestry' where forests fall into three categories: managed for conservation, intensive timber production or ecological forestry with both timber and conservation objectives (Harris and Betts, 2023).

47 From 2015-2019, the forestry sector (through the New Zealand Institute of Forestry) worked to produce a Forest Policy for New Zealand, which included several principles and policies relevant to alternative forestry systems and improving forest resilience (Forestry Policy Project Team, 2019). Its release was followed by a change of government that saw the re-establishment of the New Zealand Forest Service – Te Uru Rākau, and the policy was left by the wayside as the Forest Service pursued its own strategy, culminating in the Industry Transformation Plan (ITP). Before this plan could be progressed very far, another change of government saw the disestablishment of the ITP, leaving the sector without a national strategic policy after 10 years of work.

48 According to the FAO, as of 2020, 164 countries (representing 99% of the world's total forested area) indicated that they have a national forest policy (FAO, 2020a).

49 One such initiative was the FMAG set up by the Government in May 2018 as an independent group to consider and provide advice on a range of forestry topics. The group's focus was on how the Government and industry could work together to develop the sector and deliver on key initiatives. This included building climate change resilience into forestry systems. However, the group was discontinued in May 2023 (for more, see the MPI website, https://www.mpi.govt.nz/about-mpi/structure/government-advisory-groups/forestry-ministerial-advisory-group/). The negative consequences of policy incoherence for ecosystem service provision and forest resilience are explored by Blattert et al., 2022, in the Finnish context. Many of the functions of forests, including amenity, recreation and environmental regulation were under-emphasised compared to fibre provision and economic growth.

50 FMAG, 2022.

51 Although some educational institutes, such as the School of Forestry at the University of Canterbury, have supported research into alternative forestry systems.

Addressing knowledge gaps and improving the environmental and economic case for alternatives will help but is unlikely to lead to transformative change within the forestry sector without also addressing the social barriers.[52]

Whenua Māori

To some extent, all the above barriers are more accentuated in the case of whenua Māori.

Māori face unique challenges and opportunities that must be considered when assessing existing barriers and incentives to forestry, and the implications of any changes to these. Further, the legislative and regulatory framework aligns imperfectly with tikanga Māori and places restrictions on Māori who want to enact kaitiakitanga on their land while also making a profit.

Marginal land

Māori are disproportionately affected by the physical limitations of their land. Much of the land that was deemed Māori land under Te Ture Whenua Māori Act 1993 or returned to Māori during Treaty settlements is remote (sometimes inaccessible by road), steep and marginally productive (Land Use Capability 6, 7 or 8).[53] An analysis by Manaaki Whenua – Landcare Research in 2017 showed that 46% of the 1.5 million hectares of whenua Māori is on LUC 7 and 8 (~80% is on LUC 6, 7, or 8).[54] Production or permanent forestry is therefore the only option for substantial parts of whenua Māori.

In some cases, Māori land that is suitable for clear-fell forestry is landlocked or too far from ports to be economically viable to harvest and transport, and therefore may only be suited to high-value long rotation species or permanent forestry.[55] This makes access to carbon credits a critical determinant of whether Māori can currently earn an income from large portions of their land.

Carbon as a pathway

The physical limitations of marginal whenua Māori are compounded by challenges with securing investment for development. Māori cannot easily sell their land due to restrictions in Te Ture Whenua Māori Act, complex ownership structures and an emphasis on collective decision-making. There are over 27,500 Māori land blocks, with an average of 96 owners per block.[56] Banks have proven reluctant to accept Māori land as security for loans, due to the difficulties with selling. Securing access to capital for land development can therefore be difficult. Governance can also be demanding. New financing tools for mortgaging collectively-owned land have been developed in the context of housing provision, but these are yet to be applied to forestry.[57] Māori therefore need to generate their own funding streams or rely heavily on government funding to support development of their land. This makes business models with high upfront costs and slow returns, such as native afforestation, even more challenging. Exotic carbon forestry has been proposed as

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52 Forestry in Sweden offers many parallels, with a similarly dominant clear-fell regime. Hertog et al., 2022, found that continuous cover forestry remained niche from a lack of attention paid to both the ecosystem services forests provide (other than timber provision and carbon sequestration), and to the social dimension of the industry, including networks, education and other regime-anchoring institutional factors.

53 LUC 6 is generally suited to sheep and beef farming (if it has a low or moderate erosion susceptibility) and/or production forestry, whereas LUC 7 is largely restricted to production or permanent forestry, and LUC 8 is unsuitable for anything other than permanent vegetation cover.

54 Harmsworth, 2017. Across New Zealand as a whole, LUC 7 and 8 make up about 43% of land; LUC 6, 7 and 8 make up about 71% of land.

55 A distance of <100 km from a port is generally considered a requirement for financially viable timber harvest; MPI estimates approximately 36,750 ha of whenua Māori is suited to exotic production forestry but is >100 km from a port (MPI, 2022a).

56 The average block size is 54 ha and there are over 2.5 million owners (TPK, 2013).

57 For example, see Kāinga Ora https://kaingaora.govt.nz/en_NZ/home-ownership/kainga-whenua/kainga-whenua-loans-for-collectives/

an economically viable way of reforesting marginal land, as the rapid carbon sequestration of fast-growing trees can generate revenue that can be invested back into the whenua.

Exotic-to-native transitional forestry is of particular interest to Māori, as it could offer a solution to the challenge of financing native afforestation. In addition to the factors discussed in Chapter 6, the economic viability of this approach is affected by access to the permanent forest category under the NZ ETS, which incentivises carbon credit accumulation to the maximum extent possible. It is also affected by the extent to which any drop in total carbon within a transitioning forest can be minimised (as this affects the number of credits that need to be surrendered in the future – see Chapters 6 and 9).

While there is a risk that those planting carbon forests could plant land in exotic trees and walk away when the carbon revenue dries up, the risk of land abandonment is lower on whenua Māori. Māori have strong connections to their whenua and intergenerational values that encourage long-term thinking. The barriers to selling whenua Māori (if this were even desirable) further reduce this risk. However, active management has costs. If the land is no longer producing revenue to meet those costs, it becomes difficult to maintain.

The limited productivity of some whenua Māori and the challenges Māori face securing capital to invest in their whenua mean that excluding exotic species from the permanent forest category would disproportionately negatively affect Māori. Payments for alternative services, such as biodiversity or erosion control, could swing the balance more towards native species. However, these do not currently exist outside a small voluntary market.

The role that carbon forestry can play in helping Māori develop their whenua depends on the eligibility of that whenua to enter the NZ ETS. But only post-1989 land (see Chapter 9) can earn carbon credits through the scheme. Much of the land given back is pre-1990 forest land, so is not eligible to earn credits in the NZ ETS (following a one-off payment in 2011), but still requires carbon credit surrender if it is deforested.

Exploring additional means of revenue and finance for whenua Māori, including some of the mechanisms described earlier to more adequately value ecosystem services, would greatly reduce the perverse incentives created by the myopic focus on carbon revenue. This is the crux of what is largely an economic issue for whenua Māori afforestation.


Poplar (*Populus*)

11

Conclusions and recommendations

This investigation set out to understand what we know about afforestation using native trees and alternative exotic species. It became clear very early on that we couldn't answer that question without understanding why people plant the trees they do and where they plant them, and how the current shape of forestry reflects the past. Forests take time to grow. The shape, scale and location of forests today reflect policies that in some cases were instigated decades ago.

There are essentially three main motivations behind afforestation:[1]

1. The production of wood and fibre (production forestry).
2. The provision of ecosystem services, such as biodiversity, water regulation and erosion control (forests for ecosystem services).
3. Offsetting fossil fuel emissions for climate mitigation purposes (carbon forestry).

All three motivations present opportunities, challenges and risks. The previous chapters have outlined these in detail for different types of afforestation. This chapter provides some recommendations that could help to realise those opportunities and manage the risks. By far the greatest risks come from carbon forestry.

Reform the NZ ETS to manage risks from carbon forestry

Carbon forestry is the most recent afforestation motivation, and it is here that – in my view – the risks it raises simply aren't worth running.

Afforestation is being latched onto as a cheap, easy way for New Zealand to achieve its climate goals. According to modelling by the Climate Change Commission, under current settings New Zealand could see 929,000 hectares of new forests being established by 2050.[2] Exotic forests are projected to make up 96% (894,000 hectares) of this.[3] Driven by the NZ ETS, the government has incentivised a large increase in afforestation, most of it radiata pine forests. It has been suggested that the NZ ETS could enable greater uptake of alternative forestry systems, particularly native afforestation. The reality is that under current regulatory and economic settings, almost nothing can compete with radiata pine. Radiata pine was already the dominant forestry species in

[1] There are, of course, forests that are managed for multiple objectives that sit across these categories. This includes forests managed for low-intensity harvest and ecosystem services, and production forests registered in the NZ ETS.

[2] CCC, 2024a, Table 4.2, p.97. According to the 'reference scenario' which is based on current policies and measures.

[3] More ambitious scenarios assume that native afforestation would play a greater role.

New Zealand well before the NZ ETS came along. This dominance has been intensified by a 'least cost' climate mitigation policy that offsets ongoing fossil fuel emissions with carbon sequestered in forests.[4] The risks of that policy are becoming increasingly apparent. The permanence of these forests cannot be guaranteed. Meanwhile, unrestricted access to forestry offsetting severely undermines the need to reduce gross emissions while effectively removing the option of alternative land uses over huge areas of New Zealand.

The simplest way out of this situation would be to break the link between the NZ ETS and forest offsetting by phasing out the use of forestry units as a legitimate offset for ongoing fossil fuel emissions. Forests that are already registered in the NZ ETS could be grandfathered to account for the legitimate expectations of forestry participants, but no additional forests should be registered so that over time the supply of forestry offsets would reduce. This would lead to a much simpler fossil-fuel-only NZ ETS which would drive carbon prices up and gross emissions down in a more predictable way.

This does not mean that there should be no afforestation in support of climate action. The reduced availability of forestry offsets could be expected to result in a rising carbon price. A higher price would mean that the government could expect increased income from the sale of credits which could, in turn, be used to fund environmentally appropriate afforestation initiatives in the areas that need it most. An example would be to prioritise permanent native afforestation on areas with highly erodible soils. There would still be a carbon benefit from these forests to assist our climate mitigation goals, but it would be less than for fast-growing exotics – at least initially. The biodiversity, water and soil erosion dividend would be bigger, as the type of forest would be matched to the needs at that location. 'Right tree, right place' in practice.

Whenua Māori would have a high-priority claim to any such targeted funding, given the limited option value for many areas and the need for ongoing maintenance like pest and weed control. Long-term forestry aspirations, such as native afforestation, are particularly well-suited to whenua Māori, given the intergenerational theme of te ao Māori principles, such as whakapapa.

Removing forestry offsets from the NZ ETS would not prevent New Zealand from reporting its climate progress in a way that counts any post-1989 sequestration that we can measure. But it would have a big impact on the pattern of land use change. Given the length of time offsetting has been in the NZ ETS, phasing it out will not be easy. But in my view it is inevitable, because of the boom and bust cycles resulting from the relationship between NZ ETS prices and forestry planting. It would be better to cut the Gordian knot now than kick the pine cone down the forest road. The sooner we do so, the sooner we can start to reduce the unpalatable climate and land use change risks the ETS is driving. Even setting aside those risks, as canvassed in Chapter 9, the current supply and demand dynamics in the NZ ETS mean it will almost certainly need a major overhaul in the 2030s.

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[4] In addition, the way these forests are being incentivised means we are permanently locking up more and more land from any other productive use.

Recommendation 1: Reform the NZ ETS to phase out forestry offsets for fossil fuel emissions.

Recommendation 1.1: Use the increased auction revenue to fund targeted and locally appropriate afforestation in areas that need it most (e.g. permanent native forests on highly erodible lands; whenua Māori).

Afforestation is still an appropriate way to mitigate some of the warming effects of agricultural methane emissions without the same risks that offsetting fossil fuel emissions presents. As set out in *Going with the Grain*, I have previously recommended that radiata pine production forestry could be used as an offset for methane.[5] The main advantages of this approach are that:

1. Unlike carbon dioxide mitigation, a one-off forest planting is all that is needed to offset an ongoing flow of methane emissions. This preserves the option value of the land – if the emissions stop, the forest is no longer needed.
2. It would involve a transaction to offset emissions within the land-based sector rather than having rural land users competing with fossil fuel emitters for access to scarce land. The people who live and work on the land are the best placed to make judgments about how trees form a part of the landscape – environmentally, economically, culturally and socially. Remote intermediaries acting on behalf of urban emitters have no such knowledge or connection.

The detailed reasoning in support of this proposition is set out at length in my previous reports.[6]

Recommendation 2: Create a separate 'biogenic' trading scheme that allows warming from biogenic methane emissions to be offset by production forestry with radiata pine and other suitable species.

If forestry isn't going to be phased out of the NZ ETS in the immediate term, at a bare minimum there are some serious risks that must be addressed. The worst of these relate to the permanent forest category.

To be clear, permanent forests themselves aren't the problem. We will need more permanent forests of some sort to stabilise the land and mitigate some of the harm done by deforesting native forests in the first place. The issue with the permanent forest *category* is that it allows forest owners to earn carbon credits up to the maximum stocks of their forests and then essentially requires them to maintain those stocks *in perpetuity*, despite the fact that the revenue stream from carbon will dry up. This creates a huge liability for the landowner (and ultimately the country if the landowner can't afford to pay) should the forest's carbon stocks degrade in the future. Any form of offsetting fossil fuel emissions through forestry is risky, but at least production forests have an ongoing source of revenue to reinvest in the forest. For forests in the permanent forest category,

[5] Radiata pine was recommended at the time simply because comprehensive growth data was available for the species so it was comparatively easy to estimate the exchange rate for offsetting purposes. Other species may be suitable for this type of offset, but further research would be needed to confirm this.

[6] PCE, 2019, 2022b.

there are big questions about where the long-term funding needed to maintain them as healthy carbon-storing forests will come from.[7]

The nature of a 'permanent forest' (whether exotic, native or transitional) will affect its carbon sequestration profile and ongoing maintenance needs and costs. It will also impact on the likely 'permanence' of the forest. A particular area that requires urgent focus within the permanent forest category is exotic-to-native transitional forestry. This approach is interesting from an ecological point of view. It could help improve our ability to establish native forests and deserves further research. However, there are big questions about the viability of funding such a transition through carbon credits in the NZ ETS, as we have a poor understanding of how the carbon stocks of the forest will change over time.

Modelling suggests there could be large reductions in total carbon stocks over time as the forest switches from an exotic canopy to a native one and before the carbon sequestration rates recover. A shift to native forest could provide long-term biodiversity, water and soil benefits, as well as social and cultural values. But if such a forest is registered in the permanent forest category under stock change accounting, the reduction in carbon during the transition could trigger a (potentially costly) surrender requirement. This is a perfect example of why trying to achieve multiple values through a system that only rewards one thing – carbon – is deeply flawed.

A review of the permanent forest category was initiated by MPI in 2022, including a consultation, but hasn't progressed since.

Recommendation 3: Reform the permanent forest category in the NZ ETS.

Recommendation 3.1: Require the owners of permanent forests to have a realistic long-term management plan for the forest. That should include demonstrating how they will fund the ongoing costs of maintaining the carbon stock of the forest after the forest stops earning carbon credits.

Recommendation 3.2: Create categories, and associated rules, for different types of permanent forest (exotic, native and transition). Rules should, amongst other things, cover carbon accounting for different types of forest, and set out the government's expectations of the long-term management plans (as per recommendation 3.1).

There are obvious threats, such as extreme weather, fire and disease, to the health and survival of forests, and these are being amplified by climate change itself. All it takes is a glance at forests burning around the world to see what we may face. If we are to continue allowing this trade between fossil fuel emissions and forests, we need to consider financial mechanisms to ensure these forests persist. Any forest damage that leads to carbon losses will have a climate impact, but may also trigger a carbon liability. It is essential to clarify who (if anyone) is liable for such a loss and determine that they have the capacity to recover from it. This includes reviewing the magnitude of the liability the government is taking on with mechanisms, such as the Temporary Adverse Event Suspension, and how this can be expected to change, given the likelihood of increasing adverse events under climate change. The Californian experience, outlined in Chapter 9, where the state's risk insurance scheme was exhausted in just a few years is a lesson in how large these liabilities can be.

[7] Low intensity harvesting through continuous cover production systems could be one source of ongoing revenue.

Recommendation 4: The Government should ensure that the long-term physical risks to the nation's forests and the financial risks that may accrue both to the forestry industry and to the Crown are systematically monitored, communicated and managed.

Recommendation 4.1: Review how the risks to forests may change in the future (including from disease, and more frequent and extreme adverse events) and quantify the liability that this may impose on forest owners or the government.

Recommendation 4.2: Recognise in the Crown accounts the Government's potential liability as the effective underwriter of the country's carbon obligations.

Recommendation 4.3: Review private and public foresters' financial capacity to respond to any damage and investigate potential mechanisms that might help facilitate this, such as compulsory contingent liability insurance to cover the costs of forest recovery from adverse events.

Recommendation 5: Investigate how the value of forest carbon sequestration in the NZ ETS could be discounted to reflect the risks of forest impermanence.

Improve the regulation of production forestry, including native forests

In addition to providing timber and fibre, commercial production forests can provide many environmental, economic and social benefits.[8] There's an excellent case for ongoing production forestry and further afforestation with radiata pine in some places. The species' natural advantages for timber production and decades of targeted investment have made it an economic powerhouse for the country. But a radiata pine clear-fell regime won't be the right approach everywhere, such as on the highly erodible soils of the East Coast. In the wrong place, clear-fell production forests can cause serious harm through soil erosion, woody debris and water regulation issues.

Wilding conifers are another issue. A funding mechanism is needed if this problem is to be contained. Responsibility rests jointly with the Crown (as an historical exacerbator) and the industry. Forestry companies would balk at being required to take responsibility for spread caused by historic plantings, some of which the Crown has had a big hand in. But where existing or future plantation forests act as a seed source, a contribution towards wilding control through a mechanism, such as a levy, would be perfectly justifiable. Contributions from beneficiaries, such as hydroelectricity generators and irrigation companies, could also be sought.

It is up to the government to regulate forestry appropriately by setting environmental limits and bottom lines. The RMA and tools that have been promulgated under it, such as the NES-CF, were not reviewed in detail as part of this investigation. But evidently, in some cases there are negative effects of clear-fell production forestry that spill beyond property boundaries. These need to be identified and quantified and become part of the cost of doing business. If the costs of avoiding or mitigating these negative effects make the current regime uneconomic in some areas, then the

[8] It can also be argued that relying on exotic trees for our wood needs has helped save our remaining native forests.

regime must change. Otherwise, we are quite consciously choosing to degrade the environment further.

Ensuring the full costs of forestry operations are paid by their owners would likely require multiple levers, such as levies and greater regulation targeting particular issues, and should be explored in more detail.

Recommendation 6: The Ministry for the Environment should investigate ways to ensure that forestry companies cover the costs of the environmental damage they cause. In particular, MfE should:

Recommendation 6.1: Consider the use of levies, other market mechanisms and revised regulation.

Recommendation 6.2: Consider how the costs of problems, such as wilding conifer control, should be apportioned between the Crown, forest owners (the 'exacerbators') and other landowners (the 'beneficiaries'), especially where there are commercial gains to be made.[9]

Ultimately, in some areas the ongoing environmental, cultural, social and economic costs of the current regime are simply too high and clear-fell harvesting should be banned there. These areas need to be identified and transitioned to alternative management regimes. Note that any such regulation needs to consider equity across land uses – for example on high-risk land, pastoral farming could be required to integrate with agroforestry (such as pole planting) or transition to alternative land uses.

Poor-quality environmental data makes it difficult to proactively determine where clear-fell harvesting should be banned. The NES-CF relies on the Erosion Susceptibility Classification (ESC) for initial assessments of land suitability for forestry. While the ESC is suitable for broad regional scale assessments, it is too coarse for site-level decision-making.[10] Finer resolution mapping of erosion risk is available in some areas but a nationwide risk assessment is needed to identify areas where further finer scale mapping should be prioritised. Such mapping would help to identify where clear-fell harvest is unsuitable and alternative forestry systems are needed.

[9] The Crown may be an 'exacerbator', a 'beneficiary' or both depending on the situation.

[10] This issue is further exacerbated by climate change, since the suitability for various forestry approaches can be expected to change.

Recommendation 7: Ban clear-fell harvest in areas where it is identified as high-risk.

Recommendation 7.1: Improve the resolution of erosion susceptibility data in high-priority areas so that is it suitable for site-level decision-making about land use.

Recommendation 7.2: Identify and map areas, including those already forested and those prior to afforestation, most at risk of adverse environmental impacts from clear-fell harvesting.

It may be that other commercial forestry systems that cause less environmental harm, such as continuous cover production forestry or alternative timber species with beneficial traits, are viable alternatives in some areas. There are also economic risks of taking a single-species approach to production forestry, which might drive a shift to alternative species or management regimes anyway. However, there are barriers to greater use of alternative forestry systems in production forestry.

Some native forests are established or managed for commercial purposes, with harvest regulated by the Forests Act 1949. The Act is an artefact of its time. The original motivation behind regulating the harvest of native forests was, rightly, to protect New Zealand's dwindling native forests after centuries of unsustainable clearance. But to apply its rules to wholly new native forests that would not have regenerated without some form of human intervention seems perverse. It disincentivises landowners from working with nature for fear of limited returns and loss of future option value.

Planted native forests are exempt from the harvesting provisions of the Act, while **regenerating** forests face strict restrictions. But establishing new native forests at scale through assisted natural regeneration is more likely to be successful than widespread planting.

There are also differences in how councils treat native harvest carried out under sustainable management plans and permits of the Forests Act – in some cases it is permitted, in others it requires a resource consent.

Recommendation 8: Review the application of the Forests Act to native forests that are established through assisted natural regeneration.

Recommendation 9: Develop national guidance about how councils should treat native timber harvesting carried out in line with the Forests Act.

Alternative timbers are less well-known and harder to get approved for use, due to a lack of representation as 'acceptable solutions' within the Building Standards. This subdues demand for them. The committees that set and review the standards are structured in such a way that industry incumbents can prevent consensus and delay outcomes that would benefit or enable alternative species.

Recommendation 10: Initiate a process to approve more alternative timbers as acceptable solutions under the Building Code, including reviewing the membership of committees that approve these solutions to ensure they are comprised of independent experts, including some with expertise in alternative timbers.

Recognise the value of forests' wider ecosystem services

Reforesting parts of New Zealand for ecosystem services could deliver clear benefits in some places and will be increasingly important for climate adaptation. These new forests could include more traditional 'conservation forests' formed of native species, as well as those established with exotic species that have beneficial traits.[11]

The main issue is how the establishment and long-term maintenance of these forests will be funded. Upfront costs of establishment can be substantial, but perhaps even more challenging is the ongoing cost of maintenance. Large-scale native plantings have failed in the past due to poor planning and a lack of maintenance. Even mature forests require management. Many of our existing native forests are in poor or declining health, and facing a battery of pressures, such as mammalian browsers and predators. Where there is some form of commercial revenue, such as honey or low-intensity timber harvest, this can help cover ongoing management costs. But it could take many decades for that revenue to begin and may not be an option for all forests.

Possible funding streams that could contribute towards the upfront and ongoing costs of afforestation include NZ ETS auction revenue, payments for ecosystem services from the private sector, or even taxpayer subsidies. Deciding the appropriate balance between regulation (putting the cost on the landowners) and taxpayer subsidies is up to politicians.

I have previously expressed scepticism about the existence of substantial private sector demand to pay for biodiversity credits or other ecosystem services. In heavily populated catchments, the risks from a changing climate may lead to payments for ecosystem services, such as water regulation and erosion control, in order to reduce insurance costs. There is precedent for this overseas. Otherwise, I believe that regulatory drivers such as biodiversity offsets will be needed to provoke demand. Caution is needed with offsets because, on one side of the equation, the destruction of biodiversity is assured, but there is no guarantee that the balancing offset will be permanent or provide a similar biodiversity value to that which is lost.

We know that native afforestation will be easier in some areas than others. To protect the investment, any public funding should be directed to the places where afforestation efforts are not only most needed, but also likely to succeed.

[11] Such as species that coppice or have strong interconnecting root systems and are established for erosion control.

Recommendation 11: Focus future afforestation funding schemes on successful establishment and long-term maintenance.

Recommendation 11.1: Any future publicly funded native afforestation scheme should focus on high-priority sites with the best chances of success based on climate, topography, soil, hydrography, proximity to native seed sources and pressures in the surrounding landscape.

Recommendation 11.2: Provide funding sources or mechanisms for the ongoing maintenance of forests for ecosystem services, whether newly established or existing. These might include revenue from NZ ETS auctions, payments for ecosystem services, and direct taxpayer funding where there are clear public benefits without commercial gains.

Recommendation 11.3: Make maintenance, monitoring and reporting plans mandatory for any publicly funded afforestation projects. The costs of ongoing maintenance and how it will be funded (recommendation 11.2) should be considered before any funding is provided.

Investing in knowledge for future afforestation

Both managing the environmental costs from commercial forestry and the phasing out of forestry from the NZ ETS could result in greater demand for alternative forestry systems that have greater net benefits for (or fewer negative effects on) the environment.[12] Finding a way to fund the establishment and maintenance of forests for ecosystem services would also shift the dial. However, even if these changes occur, there are still some significant barriers to alternative forestry systems.[13] One of the biggest is that we simply don't know as much about these alternative forestry systems as we do about the conventional radiata pine regime.

One particular area requiring long-term research is the successful establishment of native forests at scale. Native afforestation initiatives often focus on upfront activities, like planting, but don't factor in ongoing monitoring and reporting, making it difficult to determine how successful these initiatives have been. Linked to this is the issue of ongoing maintenance. Large sums of public money have been spent without knowing the long-term outcomes of that spending.

Large-scale native afforestation through widespread planting is unlikely to be feasible due to high upfront costs and challenges with maintenance. Promising alternative establishment approaches include assisting natural regeneration through enrichment planting and seed islands, but there are still many unknowns. Transitional forestry could also prove to be an ecologically viable way of establishing native forests in some areas. Research is underway into the efficacy of these approaches, but this needs to be a dedicated, long-term priority area.

While improvements are being made over time, many other knowledge and development gaps remain that make alternative forestry more challenging than the status quo. Many have been identified in this report (see Appendix 3). It will not be feasible to tackle all of these, at least in the

[12] Not all alternative forestry systems will offer environmental benefits compared to a radiata pine clear-fell regime; some could bring greater risks. Those that could offer environmental benefits include species and management regimes that are tailored to particular objectives, such as greater erosion control or biodiversity gains.

[13] See Chapter 10.

short-term to medium-term. The most pressing issues should feature in any strategic guidance on the allocation of environment and forest-related research. The multidecadal nature of forestry means that, in many cases, this will require a dedicated, long-term focus. This is how radiata pine has achieved its dominance. Any alternatives are likely to require similarly sustained investment in the knowledge base.

Recommendation 12: Ensure that alternative forestry systems (including native and exotic species as well as different management regimes) are given prominent treatment in any future prioritisation of environment and forest-related research.

There is already a large amount of embedded knowledge within the community, industry and research organisations about alternative forestry systems as a result of learning by doing. This knowledge is very valuable but not necessarily widely available. A failure to broadcast the learnings about successes and failures risks ongoing inefficiencies in efforts and spending.

Recommendation 13: Improve the availability and usability of existing knowledge about alternative forestry systems through developing and maintaining a publicly accessible data system that enables that knowledge to be easily disseminated and applied.

Coordinated, long-term government policies and interventions

This report emphasises how much economic and regulatory drivers support the dominance of radiata pine in New Zealand's planted forest estate. That is, in itself, not a bad thing. Radiata pine can and should remain a significant economic and environmental sector. But such dominance comes with costs and risks, some of which could be managed by a more diversified forest estate. The preceding recommendations provide a start, but something more overarching is also needed if alternatives are to get a look-in.

If our society wants to support a more diversified forestry estate, any policies or measures designed to encourage it would need a more deliberate, long-term view. The multidecadal nature of forestry means that short-run policies will just be static or white noise. Building knowledge, learning by doing and linking foresters, landowners and researchers in a productive way requires policies and measures, including funding, that are as consistent as possible over time. That will require some degree of cross-party agreement on forestry policy. That is perhaps the easiest thing to say, and the hardest thing to achieve. But it needs to be said.

Recommendation 14: Governments should try to develop a level of cross-party agreement on the broad strokes of forestry policy, including the degree to which diversification of the forestry estate is desirable and what will be needed to achieve that.

The essential interests of Māori – a warning

Māori have significant commercial forestry interests. They are best placed to decide how to develop those. But they also have familial links through whakapapa to the ngahere, and those links bring with them a unique perspective on how to manage forests and how a more environmentally focussed forestry regime could evolve.

Those who are responsible for forestry policy must engage with Māori. As in so many areas, one size does not fit all. The recommendations of this report, as they relate to the NZ ETS, will be confronting for mana whenua who have seen the revenue opportunities that access to fossil fuel offsets can provide. I am acutely aware of these sensitivities and wish to emphasise that any changes must put Māori interests at the heart of any considerations. But, to put it bluntly, I don't believe Māori landowners should be having to rely on a deeply flawed and environmentally unstable ETS to restore the mauri of their remaining indigenous forests and convert land unsuitable for plantation forestry to its former state.

The proceeds of the NZ ETS, along with any arrangements for offsetting agricultural emissions, could provide an alternative revenue stream. They could also supplement the (inadequate) resources the Government currently devotes to pest and weed control on Department of Conservation lands. Through the same whakapapa connection, Māori see themselves as kaitiaki in land owned for conservation purposes by the Crown.

Recommendation 15: Any reframing of forestry policies along the lines suggested in this report must engage Māori from the outset.

Douglas fir *(Pseudotsuga menziesii)*

Appendices

Appendix 1: Examples of alternative exotic species

Coast redwoods (*Sequoia sempervirens*)

Coast redwoods are fast-growing, long-lived softwood conifers originally from California that can reach great heights. The tallest known tree in the world is a redwood in California, measuring 116 m in 2019. Redwoods can be extremely long-lived, with some individuals living for more than 2,000 years within their native ranges.[1] In New Zealand, some of the oldest existing plantings date back to 1901 in Whakarewarewa Forest, Rotorua. There are more than 10,000 hectares of redwoods planted in New Zealand, with some estimates suggesting the actual area is much higher.[2] Redwoods are the second most planted species in commercial forests over the past decade, particularly in southern Waikato, King Country, Taranaki and inland Manawatū.[3] The two biggest growers are Rimu Forestland Ltd (which recently acquired theNew Zealand Redwood Company) and Kingheim Ltd, both of which are overseas owned, but interest in redwoods from domestic growers is also increasing.

Site suitability

Redwoods are very site-specific, growing well in warm areas of New Zealand with good summer rainfall and deep, fertile, well-draining soils, but performing very poorly on the coast or in colder, drier areas. There were a number of failures with historic plantings due to poor site selection, poor management and a lack of appropriate soil fungi, but redwood popularity has increased over recent decades as knowledge has improved.[4] Redwoods are generally wind-firm and resistant to breakage, but do not do well when exposed to strong prevailing winds.[5] They can withstand some sedimentation and flooding so can be planted in areas where surface erosion or landslides may occur.[6]

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[1] Similar to the lifetime of kauri.

[2] Nursery sales over the past two decades suggest the area planted could be closer to 27,000 ha – but the ownership and location of many smaller redwood stands is not known (Dale et al., 2024, https://nzif.org.nz/event-manager/ViewEvent/203).

[3] Dale et al., 2024, https://nzif.org.nz/event-manager/ViewEvent/203

[4] Meason et al., 2013.

[5] Satchell, 2018.

[6] While redwoods can withstand some sedimentation, deep deposits can cause tree death (Marden, 1993).

Pests and diseases

Redwoods have thick bark that make them resistant to insects, fungi, disease and fire. Currently they have no significant pests or diseases within New Zealand, although boring insects can damage the sapwood.

Seedling stock, establishment and silviculture

Seed availability, viability and storage have been challenging, so larger redwood growers have tended to rely on propagating clonal material from trees with desirable traits.[7] Improved clonal varieties (with superior growth, form, heartwood durability and density) are available from some nurseries, but are costly and take time to produce via tissue culture. Technological developments may bring costs down in the future. Producing clones in the nursery can also be difficult. In recent years, supply hasn't been able to keep up with demand.[8]

Seedling production would be cheaper than clonal production but can be challenging, due to winter flowering and low rates of viable seed production by mature trees.[9] Controlled pollination attempts have so far been unsuccessful. A long-term selection and breeding programme could drive improvements in desirable qualities.[10]

Establishment techniques and silviculture regimes have been developed for redwoods in New Zealand, but some areas require further research.[11] For example, silviculture of coppicing redwoods is not well understood. Up to 100 sprouts can regrow from a single cut stump, so manual thinning is often needed.

In contrast to radiata pine, redwood timber is primarily used decoratively, so trees need to be pruned to achieve clear heartwood.[12] This also protects against boring insects and stem rot. But pruning redwoods can trigger epicormic shoot growth, which varies in intensity between trees and can be costly to address in 'hairy' trees.[13] There is interest among redwood growers in New Zealand to develop lines that are less prone to epicormic growth, although this could have implications for the degree of resprouting when coppiced.

Environmental considerations

Redwoods have a very low risk of wilding because of low seed viability and the inability of seed to travel more than a few metres from the parent tree.[14] They are suited to longer rotations and mixed-age, mixed-species forests which could enable greater biodiversity benefits.

Unusually for a conifer species, redwoods coppice after felling. The roots also interlink and graft with neighbouring trees, forming a wide stabilising root network. These properties indicate that redwoods may be suitable for erosion control on lower slopes with good soil depth (on shallow soils, tall trees, such as redwoods may be more susceptible to falling over during strong winds).

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7 The radiata pine industry has access to plants produced from both cuttings and seedlings. Young radiata pine plants come with a rating system to indicate the growth and form of that batch.

8 Dale et al., 2024 (https://nzif.org.nz/event-manager/ViewEvent/203).

9 Meason et al., 2013; Dale et al., 2024, https://nzif.org.nz/event-manager/ViewEvent/203

10 Rapley, 2018.

11 Rapley, 2018.

12 In comparison, about 59% of radiata pine forests are currently unpruned due to a lower price differential between pruned and unpruned wood. Reduced demand for unpruned timber in China might shift this (NZFOA, 2023b).

13 Epicormic shoots grow from dormant buds under the bark of trees in response to increased light levels, such as following removal of foliage or branches. If not removed, they can undo the work of pruning.

14 Wallwork and Rapley, 2009.

Redwoods are being considered by some growers on the East Coast for this reason. Quantitative data on the root cohesion and erosion control effects of coast redwoods is limited.

Their rapid growth, long lifetimes and resilience make redwoods particularly suitable for long-term carbon sequestration. They continue sequestering carbon for longer than other exotic species, providing a potentially long-term source of revenue from carbon that could be used to fund forest management.[15] While they appear to be excellent candidates for climate mitigation, an understanding of precise carbon sequestration rates by redwoods is limited, due to high variability in wood density and above-ground and below-ground biomass between individuals. Work is being undertaken by MPI to develop specific carbon-yield tables for redwoods.[16]

Commercial opportunities

Redwoods growing on suitable sites have high growth rates and can outperform radiata pine in warm, wet regions. In the North Island, redwoods are on average 8% more productive than pine by age 30, and 45% more productive by age 50.[17] These gains are even greater in the Waikato, Taranaki and Bay of Plenty. Substantial timber volumes are achievable. The King Country resource alone (some 3,700 hectares) would be capable of producing an annual sustainable cut of 400,000 cubic metres by 2045, provided that current planting rates are maintained for the next decade. This volume would be sufficient to support a large sawmill.[18]

The rapid growth and tolerance of high stocking rates makes redwoods attractive for timber production, and their shade tolerance makes them suitable for continuous cover forestry.

However, redwood is not a timber substitute for radiata pine. The wood has low density, strength and hardness, which restricts its structural uses. The heartwood is moderately durable but durability varies between trees.[19] The timber is valued for its attractive appearance, workability, dimensional stability, and ability to hold paint and stain.[20] This makes it suitable for decorative uses, and an acceptable solution under the Building Code for exterior cladding. There is interest in testing whether redwood timber can be treated to improve durability.

There could be a market for New Zealand-grown redwood timber in the United States, where the harvest of native redwoods is reducing. The importation of raw redwood logs into the United States is prohibited, but sawn redwood timber which would support domestic processing in New Zealand can be imported.[21] While New Zealand-grown redwoods were previously thought to produce poor-quality timber, the outlook has improved thanks to better site selection, management, genetic stock and testing. Research has shown that New Zealand can produce redwood timber with similar qualities to Californian-grown redwoods.[22] There is a need for further genetic and silvicultural improvements to enhance the value of, and market for, redwood timber from New Zealand.

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15 Salekin et al., 2024.

16 Te Uru Rākau – New Zealand Forest Service et al., 2024.

17 Watt et al., 2021.

18 This is based on a harvest age of 40 years (Dale et al., 2024, https://nzif.org.nz/event-manager/ViewEvent/203).

19 Research has shown that a rapid assessment of redwood durability can be done using near-infrared spectrometry. This allows growers to grade timber for durability and identify trees with high natural durability, which is linked to genetics, for inclusion in breeding programmes (Scion, 2018).

20 Rapley, 2018.

21 Rapley, 2018.

22 Rapley, 2018.

Knowledge gaps

Key knowledge gaps and research priorities for redwoods remain, including:

- a long-term tree improvement programme to select or breed for desirable qualities
- better understanding of the efficacy of redwoods for erosion control, including after coppicing (in terms of root survival and cohesion)
- a more detailed understanding of how redwood growth rates, wood properties and carbon sequestration vary across suitable areas of the country
- the impacts of different silvicultural practices on growth rates and wood quality, including after coppicing
- whether nutrient application could address issues with site suitability
- how to stimulate earlier flowering and improve seed production/viability
- to what extent epicormic growth can be mitigated through selection or management.

Source: Arthur Chapman, Flickr

Figure A1.1: The timber from Coast redwood (Sequoia sempervirens) has a low density, strength and hardness which restricts its structural uses. However, it is valued for its workability, dimensional stability and ability to hold paint and stain, making it suitable for decorative uses. It is an acceptable solution under the Building Code for exterior cladding.

Eucalypts (*Eucalyptus* and *Corymbia* spp.)

There are hundreds of eucalypt species, most of which are native to Australia, with a smaller number found in Indonesia and Papua New Guinea. A large number of species have been trialled in New Zealand over the decades; some have thrived, others have failed. Research has continued on the most promising species. There are now about 22,000 hectares of eucalypts planted in New Zealand.[23]

Eucalypts can be broadly grouped into durable and non-durable species. Durable species produce timbers from heartwood that are naturally resistant to decay and insect attack. The durable eucalypt species that have received the most research and recent interest in New Zealand are coast grey box (*E. bosistoana*), white stringybark (*E. globoidea*) and, to a lesser extent, sugar gum (*E. cladocalyx*) and white-topped box (*E. quadrangulata*). Research is also underway into hybrid species that may offer even greater durability. Non-durable eucalypt species, such as brown barrel (*E. fastigata*), mountain ash (*E. regnans*) and shining gum (*E. nitens*), have received more investment in the past.

Site suitability and species selection

Reflecting the vast diversity of ecosystems in their native range, different eucalypt species can be highly variable in terms of their timber properties such as colour, strength and durability, and tolerances for different environments. Some species can tolerate challenging conditions, such as frost, drought, periodic flooding or infertile soils; others require warmer, wetter, more fertile sites. This makes it important to match species to sites.

The tolerance of some species to harsh conditions also offers the opportunity to afforest challenging areas such as drylands where other species would struggle to establish (e.g. *E. cladocalyx* can tolerate very hot, dry conditions).

E. fastigata is considered one of the healthiest and most adaptable eucalypts grown in New Zealand and is one of the most widely planted species.[24] It has been referred to as the radiata of eucalypts, due to its tolerance of a wide range of sites and high-volume production.

Pests and diseases

Pests and diseases have caused issues for some non-durable species. *E. nitens* was previously the most widely planted eucalypt species in New Zealand but is affected by the eucalyptus tortoise shell beetle (*Paropsis*), and leafspot fungi. Although research into possible solutions for these problems has continued, interest in planting this species has waned. *E. regnans* has previously suffered issues with leader dieback and fungal diseases in some warm, wet areas but seedlings with improved resistance have been developed.[25]

Myrtle rust poses a threat to both durable and non-durable eucalypt species, although the current strain present in New Zealand appears to have little impact on eucalypts established here.[26] Greater risks exist from other strains found in South America that could invade New Zealand or if greater pathogenicity for eucalypts evolves in the current strain.[27]

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[23] MPI et al., 2024.

[24] Scion, 2014.

[25] Scion, 2014.

[26] There has been no significant damage to eucalypt species in New Zealand, and outside of nurseries the disease has not been reported on any eucalypts (although the lack of systematic surveillance means there may be low-level infections that are not currently being reported). In Australia, the same strain is only found sporadically in nurseries and plantations but has caused damage to seedlings and coppiced eucalypts in the natural environment (Scion, 2022).

[27] Scion, 2022.

Given New Zealand's proximity to Australia, there is a real risk that more pests and diseases will spread from Australia and impact on plantations here.[28]

Seedling stock, establishment and silviculture

Some eucalypt species have been the subject of targeted breeding trials to develop lines with favourable qualities, and reduce variability. The most developed species have had three (*E. fastigata*, *E. nitens*) or four (*E. regnans*) generations of selective breeding, which is similar to radiata pine. A single generation of selective breeding can greatly improve traits, such as durability or form. Breeding has also improved resistance to pathogens, such as leader dieback in *E. regnans*. Seed production is generally prolific – there can be 1.3 million seeds per kilogram collected from *E. nitens*, for example, with germination rates exceeding 95%.[29]

Scaling up production of some species (e.g. *E. nitens*, *E. bosistoana*, *E. globoidea*) is feasible with existing seedstocks, as some nurseries have seen the value of maintaining good plantings in case demand increases.[30] Other species would require more lead-in time.

The New Zealand Dryland Forest Initiative (NZDFI) has developed a large amount of information about durable eucalypts, including species selection, growing regimes, establishment and silviculture.[31] The most appropriate silvicultural regimes will vary between species. Some eucalypt species, such as *E. fastigata*, *E. cladocalyx*, *E. nitens* and *E. regnans*, require high light levels so are well-suited to coupe or clear-fell harvest. Others, such as *E. bosistoana* and *E. globoidea*, are moderately shade-tolerant so are suitable for continuous cover regimes and mixed-species assemblages.

Environmental considerations

Many, though not all, of the eucalypt species grown in New Zealand are coppicing species. As such, they offer more protection on erodible soils following harvest than non-coppicing species like radiata pine. There hasn't been a great deal of research into the root structures and erosion benefits of different eucalypt species but, given the variation in above-ground characteristics and site requirements, there could be substantial differences between species. One study reported that mature eucalypt trees can reduce soil erosion by 95% on erodible hill country – however, the actual species involved was not reported.[32] Smaller-statured eucalypt species may be more suited to steeper and upper slopes than larger species that are attractive for timber production.[33]

The potential biodiversity outcomes of eucalypt forests in New Zealand are unclear, as there have been few written accounts of native fauna or flora within eucalypt forests. The greater light levels under the sparser canopy of eucalypt trees compared to denser canopy species (like radiata pine) might be expected to support greater native regeneration, but could also enhance weed growth. A study from Golden Bay found that planting blue gum (*E. saligna*) and brown barrel as nurse crops resulted in a predominantly native understorey.[34] Anecdotally, eucalypt forests in some locations have been observed to support diverse native understories including species, such as

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[28] Scion is currently working on a 5-year, $11m Endeavour Fund (MBIE) research programme looking to plug the 'aerial invader hole in our biosecurity net'. This work includes trying to better understand how pests such as myrtle rust arrive in New Zealand (Scion, 2023a).

[29] Christian, 2010.

[30] Proseed New Zealand.

[31] See https://nzdfi.org.nz/grower-information-guidelines-for-growers/guidelines-for-growers/.

[32] Douglas et al., 2011.

[33] Bulloch, 1991.

[34] Forbes, 2021.

tānekaha, karaka and tōtara.[35] Additionally, growing eucalypts on dry, exposed sites could provide microclimate conditions that enable other species to establish.[36]

The timber from durable eucalypts can be used in the ground without chemical treatment. This provides an alternative to CCA-treated pine, which can cause leaching and can only be burned in specialised facilities.[37]

Eucalypts have inherent properties, such as flammable leaves and peeling bark in some species, that mean there is a lot of highly flammable material on the trees themselves and in the leaf litter.[38] This can increase the risk of fire, depending on the type of landscape. High-flammability tree species in high fire risk environments pose greater hazards than their lower-flammability counterparts, especially when they are intended to function as permanent carbon sinks.

Fires can trigger eucalypt seed dispersal and increase seedling recruitment.[39] This is beneficial in keeping a eucalypt forest alive after a fire, but it could also increase post-fire wilding risk in the surrounding area. The wilding risk of eucalypts in the absence of fires is generally considered to be low in New Zealand, but that risk is increasing with climate change.[40,41] Eucalypts have caused wilding problems overseas in California, South Africa and Portugal.

Commercial opportunities

When sited appropriately, eucalypts can have high growth rates. Depending on the species and purpose, rotations can take 15–20 years (for non-durable species for wood chips or biomass, or durable eucalypts for posts or veneer), 25–30 years (for non-durable species for sawlogs or veneer) or 30–40 years (for durable species destined for peeler log or sawlog regimes).[42] Eucalypts can be grown for carbon, timber production or both under continuous cover regimes. Essential oils from eucalyptus leaves are another option for commercialisation.

There is a developing market for naturally durable posts and poles in vineyards as an alternative to CCA-treated radiata pine. The durability of eucalypt timber depends on several factors, including the species, age of the tree, which part of the wood is used and how it is used.[43] The highest-durability eucalypts produce timber that lasts for over 25 years below ground and 40 years above ground under typical environmental conditions.[44] The natural durability and high strength of some species make them suitable for external uses, such as fencing and posts, structural uses and decking.

Eucalypts can also produce high-value appearance timbers, such as for flooring, exposed beams and joinery, although wood from non-durable species has predominantly been used for pulp and paper. Eucalypts are included in the Building Code for a variety of non-structural purposes. Some speciality milling occurs, but at a small scale.

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35 Tāne's Tree Trust, pers. comm., 14 November 2024.

36 Although if the aim is to restore native forest, coppicing exotic species may be unsuitable as they are more challenging to eventually remove.

37 EPA, 2020.

38 Younes et al., 2024.

39 Calviño-Cancela et al., 2018.

40 Millen et al., 2018.

41 Watt et al., 2019.

42 MPI, 2023.

43 Eucalypt durability may also be affected by where trees are grown, but knowledge in this area is limited.

44 Page and Singh, 2014. In comparison, structural grade radiata pine is treated to last for at least 50 years, with the treatment level chosen depending on use and environmental conditions. The highest level of treatment, Hazard Class H6, can ensure it lasts for 50 years even in a marine environment (Standards New Zealand, 2003).

Australia, where restrictions on native forest felling on state land came into effect in 2024, could become an export market although there are some challenges.[45] Eucalypts could also replace some of the hardwoods currently imported into New Zealand. For example, eucalyptus is already the standard timber for crossarms in New Zealand, but this is mostly supplied through imported timber.

Knowledge gaps

Key knowledge and research gaps remain, including:

- mapping the optimal sites and growing locations for different species
- productivity and timber durability data across different environments and genetic lines
- improved understanding of the optimal management regimes for different species
- the efficacy of different eucalypt species for erosion control after coppicing
- greater understanding of the biodiversity benefits of eucalypt plantations
- improved understanding of management options for pests and diseases, including those that may arrive from overseas
- further germplasm introductions and breeding selections of durable species to improve desirable qualities and consistency, including developing hybrid species
- coordinated data collection to test the qualities of eucalypt timbers for Building Code purposes.

Source: Greg Briner, PCE

Figure A1.2: Eucalypts, such as these trees in Southland, can be grown for carbon, timber production or both. Different products can be produced from a single stand by thinning to allow some trees to grow to sawlog sizes and using the thinned material to produce poles or other short-rotation products. Essential oils from eucalyptus leaves are another option for commercialisation.

[45] The demand for naturally durable timbers in Australia is limited because termites preclude the use of insufficiently treated timber for in-ground building purposes. Alternative foundations such as ground screws are therefore more attractive. In addition, the differences in conditions, including climate, mean it is harder to grow stiffer timbers in New Zealand than in hotter areas like Australia (Beets et al., 2007; Bayne, 2015; Wright, 2023). This makes market access challenging, given the differences in the building codes.

Cypresses (*Cupressus* spp.)

Cypresses are conifers native to the northern hemisphere but have been grown in New Zealand since the late nineteenth century. A number of species have potential in New Zealand, but two of the most developed species are macrocarpa (*Cupressus macrocarpa*) and Mexican cypress (*C. lusitanica*). Hybrids, such as Ovens cypress (*C. lusitanica* x *Chamaecyparis nootkatensis*), are also attracting research investment.

There are roughly 9,500 hectares of cypresses planted in New Zealand, with the largest areas found on the West Coast, Otago/Southland and the central North Island.[46]

Site suitability

In general, cypresses are frost-tolerant and tolerate altitudes up to 600–800 metres, although they grow best at lower elevations. Moderately fertile free-draining soils are needed to achieve good growth rates while avoiding windthrow, particularly on exposed sites.

Different cypress species are suited to different conditions. Due to issues with cypress canker, macrocarpa is best located away from warm areas with high rainfall. It is wind-hardy and tolerates the colder, drier conditions found in the South Island but is susceptible to heavy snowfall. Mexican cypress is better suited to warm, inland, sheltered sites with good rainfall in the North Island. Ovens cypress is relatively adaptable and appears to grow well throughout much of the country but is vulnerable to salt-laden winds.

Pests and diseases

The existing planted stock of macrocarpa, the dominant species, is dwindling due to canker and a resulting loss of grower confidence. Cypress canker is a fungal infection caused by two species (*Seiridium cupressi* and *S. cardinale*) that can lead to dieback, stem malformation and tree death. It is a widespread and serious issue for macrocarpa, but less problematic for Mexican cypress, and Ovens cypress appears resistant.

Overseas threats include various root diseases caused by *Armillaria* fungi and *Phytophthora*, including *P. lateralis* which mainly affects Lawson cypress (*Chamaecyparis lawsoniana*) and can cause high rates of mortality.[47] The cypress aphid, which has caused serious damage to cypresses in Europe, Africa, South America and the Middle East, poses a serious threat. So far, no insect pests have caused significant damage to cypresses in New Zealand.

[46] MPI et al., 2024.

[47] Bulman and Hood, 2018.

Seedling stock, establishment and silviculture

New Zealand's cypress breeding research started in the 1980s, with macrocarpa and Mexican cypress now into their third generations. Current breeding programmes aim to develop populations with good canker resistance, form and growth rates, to increase the availability of improved seedlings for growers. In the meantime, efforts to scale up production of cypresses in nurseries are focusing on cuttings from clones of trees with desirable qualities. Some nurseries now stock macrocarpa and Mexican cypress cuttings with improved canker resistance and good form, but tree performance varies. It is more expensive to produce cuttings than to grow plants from seed. Breeding programmes would help bring establishment costs down.

Cypresses are shade-tolerant so can tolerate higher stocking rates than light-demanding species like radiata pine, and can be managed under continuous cover regimes. The best returns are achieved through pruning and growing for around 40 years, as this results in clear heartwood that can be used in high-value products, but pruning can be expensive. Good timber volumes can be achieved in 25–40 years from unpruned trees on good sites.

Growth models are available but need expanding to include new hybrids and a greater range of regions and sites.[48]

Environmental considerations

The wilding potential of cypress species is not well-documented and, although they are generally considered low-risk, they are included on DOC's list of environmental weeds.[49]

When managed under continuous cover regimes, cypresses could provide environmental benefits like long-term carbon storage and erosion control. Although cypresses do not coppice, the roots are slow to decay so they continue providing some erosion control while replanting occurs.[50]

Commercial opportunities

Cypress timbers are appreciated for their fragrance, appearance, strength and durability. The timber can be used in a range of applications, from decorative to higher-strength uses. Macrocarpa has well-established domestic supply chains in New Zealand, including a small-scale sawmilling industry. There are also well-developed markets in Asia where cypress is regarded as a premium timber and the supply of high-quality logs cannot keep up with demand. Mexican cypress grows as fast as macrocarpa and produces high-quality timber, but its market is less well-developed. There is the potential for domestically grown cypress timbers to substitute some imported timbers like red cedar.

Both macrocarpa and Mexican cypress are Class 2 – durable.[51] Some cypress hybrids are producing timbers with very high durability and increased resistance to canker.[52] Research has also shown that thermal modification of cypress timber can significantly improve durability, but longer-term durability testing is still required.

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[48] Kearns, 2022.

[49] McAlpine and Howell, 2024.

[50] Satchell, 2018.

[51] Dungey et al., 2020. Class 2 means the heartwood is naturally durable for 15–25 years based on a 50 x 50 mm stake used in-ground.

[52] The natural durability of cypress wood offers an alternative to chemically treated radiata pine for some purposes.

A New Zealand Cypress Strategy was produced in 2022, led by the NZFFA.[53] The strategy aims to develop the future supply of cypress timber by scaling up production of improved stock and developing innovative products and markets.

Knowledge gaps

- wilding risk of different species
- quantified levels of resistance to canker of different species and hybrids
- how disease incidence can be reduced with optimal site and climate selection
- likely impacts of climate change on site suitability
- optimal silvicultural regimes for different species and hybrids
- potential gains to be made from densification and thermal modification of timber.

Source: John Steel, iNaturalist NZ

Figure A1.3: Macrocarpa (*Monterey cypress*) trees such as these have well-established domestic supply chains in New Zealand, including a small-scale sawmilling industry. There are also markets in Asia where cypress is regarded as a premium timber with ongoing demand for high-quality logs.

[53] Kearns, 2022.

Poplars (*Populus* spp.)

Poplars are part of a diverse genus of deciduous trees *(Populus*) from the Northern Hemisphere. There are over 30 different species that are highly variable in form and growing requirements.[54] Poplars readily hybridise and there are numerous sub-species, hybrids, varieties, cultivars and clones. The most popular poplars in New Zealand are hybrids related to black and balsam poplars.

Poplars have been planted in New Zealand since around 1840. Planting for erosion control on grazed hill country and for timber became more widespread from the 1940s. In 1956, the National Plant Materials Centre initiated a poplar improvement and selection programme which involved introducing a large number of clones from Europe.[55] This was followed by a breeding programme and clonal propagation of the best individuals. By the early 1970s, one million poplars were being planted a year. The arrival of several leaf diseases, including two *Melampsora* rusts (likely to have been carried on winds from Australia) necessitated the introduction of more disease-resistant clones and the development of hybrids.[56]

Today, poplars are one of the most commonly planted species in agroforestry settings, where they are used for soil stability, timber, fodder, shelter and shade. They are often integrated into hill country pastoral land as widely spaced plantings that allow grazing to continue. While poplars might not typically be considered a forest when planted in this way, they are planted on a large scale and can provide many of the benefits sought from afforestation.

Site suitability

Poplars generally grow best on moist sites with good soil depth. Some varieties are hardier than others and tolerate windier, drier conditions, and being sited further up slopes.[57] Good siting can increase timber production by a factor of three compared to poor sites.[58]

Drought is likely to be an important limiting factor for poplars under climate change.[59]

Pests and diseases

For some poplar varieties, rusts cause defoliation and reduce growth rates by up to 30%.[60] In contrast, insect pests have tended to have relatively minor impacts on poplars in New Zealand. For example, the hairy poplar sawfly (*Cladius grandis*), first detected in 2019, can cause some defoliation but only leads to dieback on branches after repeated infections.[61] Palatability to possums can also be an issue for some varieties.[62]

Seedling stock, establishment and silviculture

As poplars are often planted within agricultural settings, livestock can make initial establishment challenging. Large 'poles' can be planted in the presence of stock, but the best results are achieved

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[54] Some taxonomists recognise up to 80 distinct species.

[55] Wilkinson, 2000.

[56] Wilkinson, 2000.

[57] Plant and Food Research, 2022b.

[58] Satchell, 2018.

[59] Plant and Food Research, 2022a.

[60] McIvor and Sivakumaran, 2009.

[61] Biosecurity New Zealand, 2019.

[62] Plant and Food Research, 2011. Balsam poplar hybrids tend to be less palatable than black poplar hybrids (Plant and Food Research, 2022b; Plant and Food Research, 2022a).

where cattle are excluded for the first few years.[63] Reintroducing stock too soon can result in extremely low survival rates, as can poor species/site selection, drought or erosion.[64]

Poplars can be pollarded to control tree height, which can improve light levels for pasture growth, provide fodder and reduce wind damage.[65] However, pollarding reduces root mass and length, lowering erosion control effectiveness.[66]

Pruning is essential to achieve knot free timber but, as with redwoods, epicormic shoots are prolific.

Environmental considerations

Poplars rapidly grow extensive root systems that bind soil and graft with the roots of other neighbouring trees. Despite their popularity for erosion control, there is limited empirical evidence showing the effectiveness of widely spaced poplars in reducing erosion. What we do know is that mature trees, with a trunk diameter of 30 centimetres or more, can provide effective soil protection: estimates range from a 70–95% reduction in soil erosion on erodible pastoral land when present at densities of 30–100 stems per hectare.[67] Young trees require higher densities and at least five years of growth to develop a root system that effectively binds the soil.[68]

Erosion control effectiveness varies between poplar varieties and sites. Higher-density plantings that develop a closed canopy are likely to be needed for effective soil protection in areas of extreme erosion risk.

Populations of poplars could cause serious wilding issues if sexually reproductive, as seed production is prolific and the seeds are readily dispersed by the wind and waterways. However, the most common clones in New Zealand are either non-breeding hybrids or planted as single sexes, so wilding behaviour is rarely observed, although asexual reproduction via suckering can lead to thickets of poplars developing where they are planted.[69,70]

Commercial opportunities

Poplars reduce surface run-off and provide soil erosion control on farms with negligible disruption to farm management.[71] Poplars can be planted on wet areas, such as valley floors, to dry them out. They can be pollarded every three to four years to provide timber or fodder during summer droughts.

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63 Poles are young tree stems which root and sprout when planted in the ground.

64 An analysis of poplar and willow plantings on the East Coast found that 78% of planted poles died within 5 years, and the greatest losses were due to poor stock management, unstable terrain and a lack of aftercare (Marden and Phillips, 2014).

65 Poplars are well-known for providing quality feed for livestock, which can be particularly helpful during drought, but the use of this resource by farmers around the country is highly variable. See Poplar and Willow Research Trust, no date; Poplar and Willow Research Trust, 2016. While coppicing involves cutting trees close to ground level, pollarding involves cutting the main trunk about 2 metres above ground level so that grazing animals don't eat the new shoots.

66 This can be managed to some extent by only pollarding a few trees at a time or through closer planting (Plant and Food Research, 2023a).

67 McIvor et al., 2011.

68 McIvor et al., 2011.

69 In dioecious species such as poplars, individual trees are either male or female. Both sexes need to be present for sexual reproduction to occur, so planting a single sex prevents this from occurring.

70 Wilkinson, 2000.

71 Plant and Food Research, 2022c; Plant and Food Research, 2023b.

Poplar timber has been used on farms for vehicle decking, stockyards and fence posts (when chemically treated), and can also be used for interior wood, pulp and paper products, furniture-making, and in veneers and plywood.[72] Poplars are important for timber production in some countries. For example, about 45% of Italy's domestic roundwood comes from poplars.[73]

Landowners can earn carbon credits for poplars registered in the NZ ETS if they are planted and maintained at a sufficient density to achieve 30% canopy cover. Work is underway to develop specific carbon yield tables for widely spaced plantings of poplars.[74]

Knowledge gaps

- the effectiveness of poplars of different ages, sizes and planting densities at controlling erosion
- the effect of environmental factors (e.g. soil types, climates, slopes) on erosion control by poplars
- the impact of pollarding on erosion control
- which poplar varieties are the most resistant to possum browsing
- wood quality and density of different varieties, and potential improvements from thermal modification or further breeding.

Source: Ed Abraham

Figure A1.4: Poplars are commonly planted in agroforestry settings, where they are used for soil stability, timber, fodder, shelter and shade. They are often integrated into hill country pastoral land as widely spaced plantings allow grazing to continue. While poplars might not typically be considered a forest when planted in this way, they are planted on a large scale and can provide many of the benefits sought from afforestation.

[72] Plant and Food Research, 2011.
[73] Di Stefano et al., 2024.
[74] MPI, 2024.

Radiata-attenuata pine hybrid

Alternative pine species could act as a contingency species for radiata pine. As the pine family is large and diverse, pests or diseases that are damaging to radiata pine may not have the same effect on other pine species and hybrids. Conversely, many of these other pines are susceptible to pests and diseases of their own.[75]

The radiata-attenuata hybrid is a cross between radiata pine and knobcone pine (*P. attenuata*). A targeted breeding programme started in the 1990s to develop the hybrid as a potential option for high-country areas in the South Island. These areas are typically too cold and dry for radiata pine and have historically been planted with species now known to be prolific wilding species, such as lodgepole pine and Douglas fir. The hybridisation sought to combine the drought, snow and frost tolerance of knobcone pine with the faster growth rates of radiata pine, with apparent success.[76] The hybrid's popularity has grown in recent years to such an extent that seedling demand has been exceeding supply.[77]

Site suitability

The radiata-attenuata hybrid is being commercially planted in dry and cold areas in the central South Island and is replacing Douglas fir in some areas where wilding conifer spread is of concern.[78] The hybrid is restricted to these areas due to its extreme susceptibility to Dothistroma needle blight (caused by *Dothistroma septosporum*) which thrives in warm, wet areas, and the superior growth of radiata pine in other areas.[79] Furthermore, the hybrid's suitability to cold, dry, high-altitude sites means its limited potential range is likely to diminish with climate change.

Pests and diseases

Beyond the radiata-attenuata hybrid's vulnerability to Dothistroma needle blight, little is known about the impacts of other pests and diseases.

Seedling stock, establishment and silviculture

Seeds have been commercially available since around 2010, but production is fairly small-scale. The optimal establishment and silvicultural techniques are not known, but radiata pine standards are thought to be suitable.[80]

Environmental considerations

The radiata-attenuata hybrid has previously been incorrectly labelled as being sterile.[81] While this is not the case, the hybrid is believed to have a lower spreading risk than radiata pine or Douglas fir, as it produces serotinous cones that only open under high temperatures.[82] However, the full wilding risk is yet to be determined. Other environmental impacts are likely to be similar to radiata pine.

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[75] Dungey et al., 2020.
[76] Dungey et al., 2013.
[77] Manley, 2024.
[78] Rae, 2024.
[79] Dungey et al., 2020.
[80] Dungey et al., 2020.
[81] Herron, 2022.
[82] The cones of attenuata pine typically require fire to open them (Dungey et al., 2013).

Commercial opportunities

Some hybrids can present superior qualities to their parent species. The radiata-attenuata hybrid has kept the high growth rates of radiata pine while also offering a viable option for snow-prone, dry and exposed areas where other pine species might struggle. The wood properties appear to reflect those of knobcone pine more than radiata, but more evidence is required.[83] The wood products would likely fit into the existing radiata pine market.

Knowledge gaps

- wood properties and suitable end uses
- wilding risk
- suitable range in future under climate change and any shifts in Dothistroma distribution.

[83] Dungey et al., 2020.

Appendix 2: Challenges with collecting, storing, germinating and growing native seeds

Seeds

Seed collection

Compared to the exotic tree industry which has access to a number of commercial seed orchards, native nurseries largely rely on seed collected in natural habitats. Seeds are often collected by hand, which is time-consuming and drastically limits the quantity of seeds available for large-scale restoration projects. Seed collection and propagation can take several years, so nurseries require large orders of native seedlings to be made well in advance of the actual planting.

There are logistical challenges with collecting seeds from native trees. Some species – including beeches, conifers, such as rimu, and broadleaf species like tawa – exhibit masting behaviour. Masting involves synchronised seed production within narrow periods of time that can occur years or even decades apart. Mature seeds may only be readily collectable for a month or less, and the optimal collection time can be difficult to predict as it can change from year to year. The use of tools such as seed nets can help improve efficacy and reduce the costs of seed collection for some species.

Securing access to land for native seed collection can also be challenging: a permit from DOC is required to collect seeds on conservation land, and permission is required to collect seed on private land. Seed collectors may therefore stick to more accessible trees, restricting genetic diversity and local representativeness.

Guidance for seed collection has been developed.[1] This includes collecting seed from a number of parent trees spread across the landscape, while avoiding planted trees of unknown origin and cultivars. However, it can be difficult to verify if these practices have been followed when ordering plants from a nursery.

Any steps to widen sources of seed collection need to consider the role of Māori as kaitiaki responsible for taonga species including their kākano (seeds). Mana whenua aim to protect the rākau, the area in which it was sourced and the area in which it may be grown. Seed collection conducted using tikanga ensures the viability of the seeds but also its mauri through connection with the rohe and its people.[2] Seed collection should not be undertaken in places of wāhi tapu without prior consent or knowledge. For example, for some hapū, pūriri is an important species as it is utilised in tangihanga (funerals) and before colonisation tūpāpaku (the dead) were hung in its branches before being interred in caves. Today these stands continue to be wāhi tapu.[3] Nationally, seed banking practices do not acknowledge tikanga and the relationship that Māori have with taonga species of rākau. By informing mana whenua of intentions to collect in areas of cultural significance, seed gatherers can benefit from the knowledge of local Māori regarding the area and rākau that are best for seed collection.[4]

Selective breeding of native trees could support the development of tree lines with favourable traits for timber production, such as high growth rates, resilience to pests and diseases, or good wood

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1 This guidance can be found on Tane's Tree Trust's website https://docs.tanestrees.org.nz/collecting-and-handling-seed-of-native-trees-and-shrubs/

2 Scheeles, 2015.

3 Paul and Laird, 2023.

4 Schnell and McGill, 2018.

quality. Selective breeding of exotic species already occurs for this purpose both in New Zealand and overseas, and domestic expertise in this area could be extended to key native species of interest.[5]

Sourcing seeds

There is general agreement that matching seed sources to site conditions will improve the chance of successful establishment. For instance, seedlings that are being planted on exposed sites should be sourced from plants that grow well in similar conditions.

There are more divergent opinions about seed sourcing from a geographical perspective. Eco-sourcing is the concept of collecting seeds from areas close to where they will be planted. This approach is often recommended for restoration plantings to maintain local adaptation and genetic patterns as well as whakapapa.[6] However, little information exists on what constitutes a desirable distance to move genetic material.

Genetic studies into several native tree species have found substantial genetic variation in growth rates and form between different provenances for some species but less so for others.[7] Recent research found there is little genetic structuring (i.e. distinct genetic patterns) at a local level for most of New Zealand's tree species and suggests current eco-sourcing approaches may be "unnecessarily restrictive".[8] Using wider seed collection zones could reduce the risk of inbreeding, improve resilience and increase conservation options for threatened species.[9]

Some also argue that the horse has bolted – we have already moved plants considerable distances from their parent populations.[10] Without the use of good record-keeping by nurseries and local knowledge of seed collection and plantings, it may be difficult to know if an eco-sourced 'local' seed supply actually reflects local genetics.

Looking ahead, current approaches to eco-sourcing don't consider how climate change is affecting local conditions and whether plants that are naturally present in the area are well-adapted to current and future changes. Climate change is particularly relevant to forests as individual trees can live for centuries and forest ecosystems can persist for millennia. This question has triggered discussions on 'assisted forest migration', which involves purposefully moving species to areas with more favourable future climates.[11] Recent research suggests this could even increase carbon stocks held in future forests.[12] However, moving species or genetic populations outside their natural area could lead to unforeseen consequences, such as triggering weedy behaviour or outcompeting species that are within their natural range.

The debate around eco-sourcing is ongoing and likely to remain polarising for some time.

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5 Most efforts in New Zealand have gone into radiata pine, but improvements have been made to some alternative exotic species too.

6 For more information, see https://docs.tanestrees.org.nz/ecosourcing-of-native-species-for-planting/.

7 Wilcox and Ledgard, 1983; Bergin and Kimberley, 1992.

8 Heenan et al., 2024.

9 Heenan et al., 2024.

10 Historical planting programmes by the NZFS from the 1940s moved many podocarp species considerable distances from their parent populations through replanting areas that had been harvested. Central North Island rimu (*Dacrydium cupressinum*) has been established in Westland, while kauri can be found growing in Dunedin and on Stewart Island (Dungey et al., 2025).

11 Xu and Prescott, 2024.

12 Chakraborty et al., 2024.

Seed viability, storage and germination

Collecting native seeds is only the first step: seeds need to be viable, stored appropriately and able to germinate successfully when needed.[13]

From the little we know, native seed viability is highly variable. One study collected 45 kilograms of seeds and stems from rimu trees and found many seeds were split or empty, and only 1.4 kilograms were viable seeds.[14] For some species, viability can decline rapidly after collection unless seeds are chilled (short-term) or appropriately preserved (longer-term). Data is missing for many New Zealand species, but the available information suggests that the seeds of most woody native plants in New Zealand can be stored in conventional seedbanks, following a drying and freezing process.[15,16]

Seeds from some species have been found to be sensitive to desiccation and unable to survive the drying process. These species tend to be those that have heavier seeds, produce fleshy fruits, grow into taller plants, occur in warmer regions and are dispersed by biotic means.[17] These include many of our bird-dispersed, lowland, dominant canopy tree species. They also include some species that undergo mast seeding events, such as tawa and hīnau, which further restricts access to seeds in non-masting years by reducing storage options. Beech, by contrast, appears well-suited to conventional seed banks. Whatever the treatment, testing a few of the collected seeds to check if they are viable before any large-scale seeding will reduce the risk of failures.

When it comes to germinating native tree seeds, our level of understanding is rather basic. Some seeds are dormant and require treatment to stimulate germination.[18] Methods vary between species and include stratification (chilling), light exposure, scarification and chemical treatment.[19] Although we know the appropriate techniques for some common species such as mānuka and kānuka, and threatened species, such as swamp maire, knowledge is lacking for many others.[20]

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13 https://docs.tanestrees.org.nz/collecting-and-handling-seed-of-native-trees-and-shrubs/

14 Beveridge, 1964.

15 Seedbanks allow large volumes of seed to be stored at relatively low cost, in minimal space and for long periods.

16 Wyse et al., 2023.

17 Wyse et al., 2023.

18 The seeds of some species take time to germinate, and it may be difficult to speed up that process.

19 Douglas et al., 2007.

20 Van der Walt et al., 2021; Ford and Lloyd, 2023.

Figure A2.1: While we have good knowledge for germinating seeds of some native plants like mānuka, pictured above, we lack information for many others.

Box A2.1: Extinct megafauna and seed dispersal – were moa the key to faster germination? [21]

It used to be widely assumed that large-seeded, slow-germinating native tree species, such as hīnau (*Elaeocarpus dentatus*), were once dispersed by moa. The giant birds' gizzards, containing up to 5.6 kilograms of stones, were thought to accelerate germination by wearing down the tough seed coating, a process called scarification. However, while large seeds have been discovered in moa gizzard remains, analysis of fossilised moa faeces found the faecal consistency to be very fine-grained – only small seeds of herbs and shrubs survived. Large seeds were therefore unlikely to have survived moa gut passage intact, instead being ground up into finer particles. Even when hīnau seeds were mechanically scarified in a concrete mixer (in an attempt to simulate passage through a gizzard), germination took just as long as if they had not been scarified – up to seven years. However, the proportion of hīnau seeds that eventually germinated was higher in those that had been scarified. This suggests that moa were not effective dispersers of viable large seeds. It remains unclear what role other large birds with less destructive gizzards may play in accelerating germination.

[21] Carpenter et al., 2018.

Growing native seedlings in nurseries

Nurseries produce native seedlings in different ways. Most often, seedlings are grown from seeds but sometimes cuttings are taken from 'mother' plants. Growing seedlings is cheaper and easier than growing cuttings, but cuttings enable the production of plants even when viable seed supplies are limited. Cuttings also enable greater control over genetics during breeding programmes and can be used to produce copies of taonga individuals or those with important properties. Both approaches can lead to low or high genetic variation depending on the diversity of the source plants. Growing from seeds can run into issues with seed availability, viability and storage, but cuttings take longer to grow and develop fewer roots than seed-grown plants. Although some native species are amenable to being grown from cuttings, not all are.

Large-scale afforestation requires the production of robust seedlings that will survive in the natural environment. But there can be considerable differences in the physiology of seedlings raised in a nursery and those arising through natural regeneration. Nursery-raised seedlings are well cared for and grown rapidly. This means they do not experience the challenging conditions they will be exposed to in the natural environment. Good nursery practice involves hardening seedlings off by either leaving them outside to face the elements or withdrawing nutrients and water for a period. This helps seedlings to develop a tolerance to the climatic perturbations they may experience once planted.

The survival of seedlings in the field is strongly affected by other nursery-level decisions, such as pot size and type, planting media, growing conditions and the use of fertilisers. To improve survival, native seedlings have traditionally been grown in larger pots than forestry grade exotics, which increases costs related to soil provision, transport and planting. Recent research by Scion has found that the seedlings of some native species, such as tōtara, can be grown in smaller pots (which are more aligned with large-scale commercial planting practices) and still perform well in the field.[22] This is particularly the case when planted by experienced crews on good sites with pre-planting preparation and weed control. However, on poorer-quality sites larger pots may still be needed to achieve good survival rates, and some species, such as mataī, are not suited to smaller pots regardless of the site.

[22] Ford et al., 2022.

Appendix 3: Knowledge gaps that limit alternative forestry uptake

Table A3.1: Knowledge gaps identified throughout this report that limit alternative forestry uptake.

Theme	Knowledge gap	Alternative forestry type the gaps apply to
Establishing new forests	Suitable growing conditions	Native and most alternative exotic tree species
	Robust mapping of species suitability and productivity across the country	Multiple alternative tree species. Detailed maps exist for cypresses, *E. nitens* and redwoods
	Mapping suitability for transitional forestry	Transitional forestry
	How to predict masting events and collect viable seeds from masting trees	Multiple native tree species
	Seed storage and germination	Multiple native tree species, some alternative exotic species
	Genetic improvements for resilience and commercial properties (including genome sequencing)	Native and most alternative exotic tree species
	Optimal site preparation methods for afforestation	Native forests
	Impacts of previous land use on optimal afforestation approach	Native forests
	Impacts of different planting approaches (e.g. densities, species mixes, nurse crops, seed islands) on survival, composition, growth rates and economics	Native forests, transitional forestry
	Direct seeding – amenability of species, sowing method and volumes, germination, success rates, etc.	Native forests
	Mycorrhizal fungi impacts and inoculation methods	Native forests
Managing forests	Safe herbicide usage to control weeds	Native forests
	Impacts of different silvicultural practices on growth, form, wood properties, timeframes and economics	Native forests, alternative exotic forests, transitional forestry
	Suitability to different management approaches	Native and some alternative exotic tree species
	Impacts of pathogens and management options	Native and alternative exotic tree species
	Impacts of location and management on growth rates	Native forests, some alternative exotic forests
	Timeframes to mature forest	Native forests, transitional forestry

Environmental considerations	Variation in carbon sequestration rates	Native forests, transitional forestry, alternative exotic forests
	Comparability to old-growth native forests at maturity	Native forests and transitional forestry where restoration is an aim
	Potential climate change impacts on forest health and productivity	Native and alternative exotic forests
	Risk of disease spread from afforestation	Native and alternative exotic forests
	How soil erosion control varies with species, establishment method, densities, age, management regime and site	Native and alternative exotic forests
	Erosion control benefits of coppicing species following harvest	Some alternative exotic species
	Water yield and quality impacts of afforestation over time	Native and alternative exotic forests
	Wilding risk	Some alternative exotic species
	Biodiversity benefits of different species and management regimes	Transitional forestry, alternative exotic species
Commercial	Improved data on timber properties	Native and alternative exotic species
	Technological timber improvement opportunities (e.g. thermal modification)	Some native and alternative exotic species
	Product development	Some native and alternative exotic species


Cluster pine *(Pinus pinaster)*

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This report has been produced pursuant to subsections 16(1)(a) to (c) of the Environment Act 1986. The Parliamentary Commissioner for the Environment is an independent Officer of Parliament, with functions and powers set out in the Environment Act 1986. His role allows an opportunity to provide Members of Parliament with independent advice in their consideration of matters that may have impacts on the environment.

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April 2025

ISBN
978-0-473-74223-2 (print)
978-0-473-74335-2 (electronic)

Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata