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Assistant Editor

Helen Greatrex

Subscription inquiries and changes of address

Administrator
NZ Institute of Forestry
PO Box 10-513
Level 9, 93 The Terrace
Wellington 6143
Phone: 04 974 8421
Fax: 04 473 9330
Email: admin@nzif.org.nz

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The Administrator
Email: admin@nzif.org.nz
Phone: 04 974 8421
Fax: 04 473 9330

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Front cover photo: Modified natural forest. Photo courtesy of Greg Steward

Back cover photos: (top) These naturally recruited kahikatea emerging from secondary broad-leaved forest in Tairāwhiti are an example of what successful enrichment planting would look like. Photo courtesy Adam Forbes; (bottom) Semi natural planted forest. Photo courtesy of Greg Steward

A new step change

Mark Bloomberg

A step change is defined as a large and/or sudden change, especially in business or government. In 1987, New Zealand forestry went through a major step change. The Forest Service which had managed the state's forests for nearly 70 years was abolished. Much of its indigenous forest estate was taken over by the new Department of Conservation and state-owned exotic commercial forests were subsequently sold to the private sector. The remaining state-owned commercial indigenous forests were closed to timber management in 2002.

These changes set the pattern for the next three decades and have become the norm. Most forest managers now see themselves as working for commercially-oriented plantation forest owners, usually in the form of international corporations, timber investment organisations or small private landowners.

Enough history, on to the present. It seems to me that New Zealand forestry is now entering a new step change, the first since 1987. This step change has been occurring for several years, but perhaps foresters have been so busy dealing with the consequences that they haven't had time to acknowledge just how rapidly it has happened! This major step change underlies the theme of this issue – Management of Permanent Forests – and the drivers for it are succinctly described in Tim Payn's leading article, as follows:

> *'New Zealand needs to look after its existing forests and develop new ones if we are to respond to the multiple challenges of climate change, biodiversity and environmental degradation, and the need to shift to a zero or low carbon economy.'*

Tim then shows how the dichotomy of privately-owned commercial exotic plantations versus state-owned indigenous conservation forests that was created in 1987 needs to be replaced by a more diverse classification – one that recognises that all forests can provide both marketable and non-marketable goods and services, differing only in the proportions they provide of the different goods and services. Multiple use by another name, perhaps.

This more diverse approach to forest classification and management is reinforced in the papers by Sean Weaver, Peter Casey et al. and Adam Forbes. Both Sean Weaver and Casey et al. make the case for use of exotic plantation forests to achieve the twin goals of indigenous forest restoration and sustainable carbon sequestration.

Casey et al. note that permanent forests using exotic plantation forest are not simply a case of plant and leave. These forests need an active management programme to deliver short-term carbon benefits, while also ensuring the long-term succession to a biodiverse indigenous forest ecosystem. Adam Forbes describes a more conventional approach to restoring indigenous forests on the east coast of the South Island. But his recommendations still entail an active ecosystem management approach – the control of both pest and domestic animals, enrichment planting, mimicked forest disturbance, fire protection and the control of plant pests are all required.

So the new types of forests being created due to this step change still need management, just of a different kind. New Zealand forest managers are adapting to these changing needs but there are important challenges to meet. One is in the area of education. For a generation now, forestry education has focused on commercial exotic plantation forest management, for good reason. Not least of all, it was what the forestry employers wanted. The new educational challenge is to cover the wider range of skills, knowledge and attitudes needed for the more diverse forestry of the future without falling into the trap of teaching everything 'once over lightly'.

The second major challenge relates to the management of existing forests. The diverse forests described by our authors are being created to meet the expectations of a new type of owner, focused as much on carbon sequestration and ecosystem services as they are on timber harvesting. Thus, there is no mismatch between these owners' expectations and the way the new forests will be managed.

In contrast, most existing exotic plantation forests were acquired or planted as strict commercial timber investments, yet the management of some of these forests must change in order to meet the multiple challenges described by Tim Payn. Here the challenge is to find ways to make a 'just transition' to forest management systems where a forest owner's financial objectives are balanced with society's expectations. It won't be an easy challenge to meet, but we have to do it if we are to make this new step change successfully.

Putting purpose first – 10 functional forest types for New Zealand

Tim Payn

Figure 1: Productive plantation

Abstract

New Zealand needs to look after its existing forests and develop new ones if we are to respond to the multiple challenges of climate change, biodiversity and environmental degradation, and the need to shift to a zero or low carbon economy. This paper introduces a new framework of functional forests to enable us to have wider discussions on the purpose of our forests and how they may be developed over time. The framework is based on a continuum of level of human disturbance or naturalness, underpinned by an ecosystem services framework. The intent is to broaden debate past the dichotomies of 'exotic plantations versus natural conservation forests' and 'native versus exotic species'. The functional forests will have species and management regimes tailored to sites and landowner preferences, putting function or purpose first.

Introduction

Key challenges currently confronting New Zealand are climate change, water quality, economic growth, and individual, whānau and community wellbeing. Trees and forests are all closely tied to these challenges and are themselves affected by climate change – increased temperatures and atmospheric carbon dioxide (CO_2) levels, increasing storm impacts, droughts, pests and diseases.

There has been much recent discussion in the media about trees and forests, and much of this has focused on carbon and climate goals and the effect of large-scale plantings on communities. Some has focused on the value of indigenous species versus pines (exotics). A third thread has focused on the adverse environmental impacts of clear-fell harvesting of pines. Generally, the focus is on the negative. However, there are many positives and the role of trees and forests in confronting our key challenges needs careful thought and changes in perception.

With the undoubted role of trees and forests in helping New Zealand meet its climate obligations and other challenges, there has not been a better time to look at how forests fit within this country's future landscapes or to have discussions on what we would like New Zealand to look like in the future and where trees fit. We are going to need more trees and forests.

The simple and widely-held dichotomous view of this country's forest as productive exotic plantations and natural forests is an issue (Figure 1). New Zealand is unique in its split between privately-owned exotic plantations for timber and fibre production and natural forests managed in the public estate for conservation values. There was an excellent reason for this – taking the harvest pressure off our rapidly shrinking natural forest resource with consequent loss of our unique biodiversity. New Zealand has always had a bio-based economy and we depend on forestry, agriculture and horticultural products for international exports, and our conservation estate to support a very significant international tourism industry. Our society depends on them. However, we need to move past this dichotomy and open up a wider discussion that considers the function of our trees and forests more widely. Production and conservation are too simplistic.

Current land use

An analysis of the most recent landcover database (LCDB5) launched in January 2020 (Manaaki Whenua Landcare Research, 2020) shows us the current land use mix. For the purposes of this paper, we focused on the forests and agricultural lands (exotic and indigenous forests, high and low-producing grasslands and shrub and scrub landcover). We also explored the distribution of exotic forests by land use capability (LUC) (Manaaki Whenua Landcare Research, 2020) and Erosion Susceptibility Classification (MPI, 2016), these being two commonly discussed areas of interest. Analysis was done using ArcGIS Pro (ESRI, 2021).

Forests make up 31% of New Zealand's land area, low and high-producing grasslands 38%, and scrub and shrub 10% (Table 1). Focusing on exotic forests we find 80% are in LUC 6 to 8, with most of the remainder in classes 3 to 5 (Table 2). With respect to erosion susceptibility class, 24% are in the high to very high class with the remainder low to moderate (Table 3).

Developing a framework for defining functional forests

The LCDB shows us location, area and land use type, but not function. We are becoming more interested in why the forests are where they are and what their function is, and also what forests we might establish in the future and for what purpose. The two functions of timber and fibre production and conservation dominate today, but there are other functions we can consider. Carbon forests for climate mitigation is probably the third most recognised function, but there are more. Identifying these functions and considering them in terms of opportunities is a first step to moving beyond the timber versus conservation paradigm.

Ecosystem services framework

Forests are a highly multifunctional land use, providing many products, goods and services. These ecosystem services can be categorised into supporting, provisioning, regulating, and social and cultural, as shown in Figure 2. These services all contribute to overall human wellbeing in a variety of ways, and also have very significant environmental benefits.

Table 1: Indigenous, exotic forest, high and low-producing grassland, and scrub and shrub area in NZ from LCDB5 analysis

Land use	Area (ha)	% of NZ land area
Indigenous forest	6,307,010	23%
Exotic forest	2,037,710	8%
High-producing grassland	8,639,543	32%
Low-producing grassland	1,721,966	6%
Indigenous scrub/shrub	2,407,537	9%
Exotic scrub/shrub	239,817	1%

Table 2: Area and percent of exotic forest by LUC class (noting that class 8 is considered unsuitable for productive use)

LUC	Area (ha)	Percent
1	1,661	0.1%
2	13,711	0.7%
3	94,132	4.6%
4	295,985	14.6%
5	14,304	0.7%
6	972,069	47.8%
7	607,032	29.9%
8	34,079	1.7%

Table 3: Area and percent of exotic forest by ESC class

ESC	Area	Percent
Low	783,564	39%
Moderate	768,195	38%
High	345,188	17%
Very high	136,332	7%

These ecosystem services are provided to varying degrees by all our forests and include timber, fibre, energy, chemicals, food, medicines/rongoa, carbon storage, erosion control, water flow regulation, clean water, recreation, human health and wellbeing, spiritual and cultural values, biodiversity conservation, climate regulation and aesthetics. All forests provide a mix of services and in New Zealand we have worked on biodiversity, carbon, erosion control, nutrient regulation, recreation and timber (Yao et al., 2021).

Using the framework will allow us to design and manage forests for specific purposes or functions. Obviously, we have been most successful at designing and managing planted forests for timber production, as evidenced by the more than $6 billion export industry, but much less focus has been put on designing forests for other purposes or functions. This is a big opportunity for New Zealand.

Definition of functional forests

Using the ecosystem services framework in the context of our national environment we have developed a suite of 10 functional forest types that are relevant/most important for the New Zealand context.

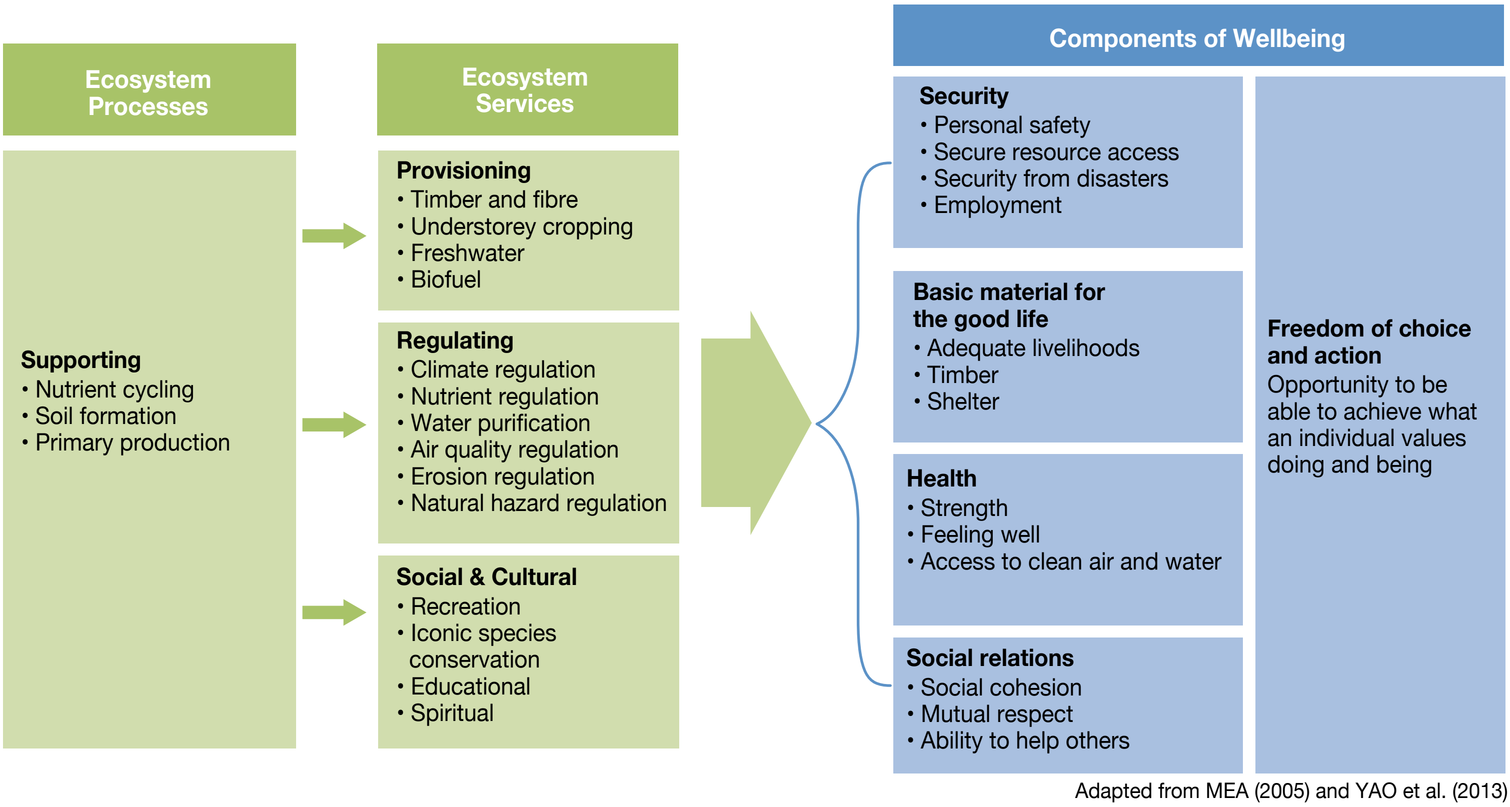


Figure 2: Forest Ecosystem Services Framework (from Yao et al., 2013)

These are:

- Biodiversity conservation and restoration forests
- Timber and fibre forests
- Energy and bio-based chemical forests
- Water regulation forests
- Nutrient control or regulation forests
- Erosion control forests
- Food and nutraceutical forests
- Health and wellbeing forests
- Climate regulation forests – urban forests
- Climate mitigation forests – carbon forests.

Some of these functions are well known and well established (e.g. timber and fibre, carbon forests, erosion control), others much less so (e.g. health and wellbeing, climate regulation).

All forests, whether indigenous or exotic, natural or planted, can provide these functions and these functions may be provided singly or in combination in a forest. Each functional type will require a different management approach. Species selection, silvicultural regimes and siting will all have to be considered and developed to best fit the function. Species selection is important for function. A paper by Smaill et al. (2014) evaluated a range of species for functional traits, such as rooting density for erosion control and carbon sequestration rates. This demonstrated that different species were best suited to different functions. Complexity will increase if the forest is being designed for multiple functions. Significant new work will be required to develop regimes for the range of functions identified.

To further broaden the discussion of forests in New Zealand we have adapted the United Nations Food and Agriculture Organisation (UN FAO) forestry classification (Figure 3). The framework is internationally applied and is a foundation for the five-yearly Global Forest Resources Assessment (UN FAO, 2020).

The classification is organised on a continuum of the level of human intervention, or degree of naturalness, and has seven categories from primary forests where there are no signs of human activity, through to trees outside forests where the trees occur in agricultural or urban landscapes and the level of human intervention is at its highest. Each category has a description.

Primary forests are those that are untouched by human hand and would include those forests, for example, in South Westland with no harvesting history (Figure 4). However, the indirect human hand of anthropogenic climate change will be affecting them, as will the impact of introduced pests, such as possums. Most of our natural forests would fit solidly into the **modified natural forest** category due to their history of timber extraction. In the public conservation estate, this timber extraction ceased finally in the early 1990s and the forests are re-growing. Small areas of privately-owned natural forest are still being harvested under sustainable management plans where only a small proportion (10%) of the annual growth can be harvested.

Semi-natural forests are those where natural regeneration of species originally occurring in the forest is assisted by human interventions (such as weed control) or pest management (such as control of grazing animals). This is a rare type of forest currently in New

Zealand, although there is interest. Even more unusual and rare here are semi-natural forests where there is active planting of seedlings to either improve growth or change forest quality.

The **planted forest** type most common in New Zealand is plantations. These plantations are generally managed for economic returns from timber and fibre and tend to be exotic species, although interest in indigenous species is increasing. The dominant New Zealand type is therefore **productive plantations**. However, forests have been planted in the past for their protective function. In the early days of the NZ Forest Service, **protection plantation forests** were a prominent category with several forests established, usually for erosion control (Figure 5). An example of this is Mangātu Forest in the Te Tairāwhiti|Gisborne District. Other examples of these can be found on erosion-susceptible slopes in both the North and South Islands. However, with the sale of the state's plantations in the late 1980s, the dominant function has shifted to productive as new owners require an economic return from the trees they purchased.

The seventh category is **trees outside forests** – these are plantings that do not meet the international definition of a forest (>1 ha in area, able to achieve a height greater than 5 m, and with a tree canopy occupying more than 30% of the planted area). These plantings tend to be trees planted as an integral part of agricultural systems – so-called agroforestry systems. The most commonly recognised example of these in New Zealand would be spaced poplar plantings for control of soil erosion on steep agricultural lands. Windbreaks and shelterbelts also fall into this category, as do trees along the banks of waterways and water bodies, and trees in urban settings.

We mapped forests to the FAO categories using LCDB5 and other data sources (GFRA data, Te Uru Rākau, Poplar and Willow Trust) (Table 4). We used GFRA 2020 data for primary forest area and subtracted this from total indigenous forest area in LCDB5 to split indigenous forests into primary and modified natural forests. We could not find a source of data for semi-natural forests, although there is likely to be some activity in this category in the privately-owned indigenous forests.

We estimated protection plantation area from a combination of Erosion Control Forestry Programme, Afforestation Grant Scheme and One Billion Trees programme data, plus the deciduous hardwoods category in LCDB5, noting that there is no single data source for the area of poplars and willows planted for protection. This protection-production is an underestimate as it does not include the area planted under the Sustainable Land Use Initiative (SLUI). We approximated the trees outside forests area by calculating the area of exotic forests in LCDB5 of less than 1 ha, giving a small area of 13,864 ha, not including urban trees. We modified the FAO definition to trees and stands of less than 1 ha to align with the New Zealand Emissions Trading Scheme (NZ ETS) area definitions.

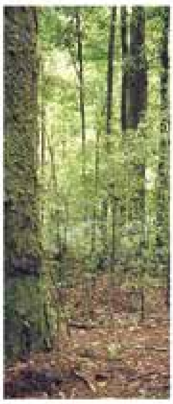
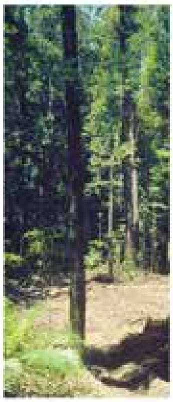
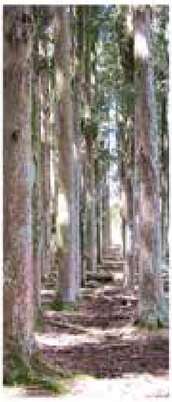
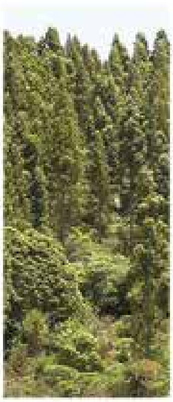
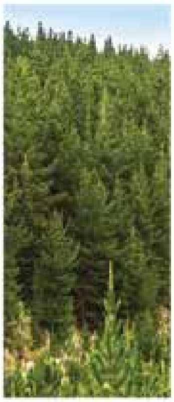
Natural forest		Planted forest				Non-forest
Primary	Modified natural forests	Semi-natural forests		Plantations		Trees outside forest (TOF)
		Assisted natural regeneration	Planted component	Protective	Productive	
						
Forest of native species, with no clearly visible indications of human activities and the ecological processes are not significantly disturbed.	Forest of naturally regenerated native species with clearly visible indications of human activities.	Silvicultural practices for intensive management (weeding, fertilizing, thinning, selective logging).	Forest of native species, established through planting, seeding or coppice of planted trees.	Forest of native or introduced species, established through planting or seeding mainly for *provision of services*.	Forest of introduced or native species established through planting or seeding mainly for production of wood or non-wood goods.	Stands smaller than 0.5 ha; trees in agricultural land (agroforestry systems, shelterbelts, orchards); trees in urban environments; and scattered along roads and in landscapes.

Figure 3: UN FAO forest types

Table 4: Areas of forest under each UN FAO forest category

UN FAO Forest Category	Area (ha)
Primary	1,971,000
Modified natural forest	4,389,910
Semi-natural forest (assisted regeneration)	No data
Semi-natural forest (planted)	No data
Protection plantation	161,699
Production plantation	2,023,955
Trees outside forests	13,864

In summary, as expected the two dominant categories in New Zealand currently are a combination of **primary and modified natural forests** (mainly in the Department of Conservation estate) and **productive plantations** (the commercial exotic forestry sector).

Future functional forests

We mapped the 10 functional forest types to the most relevant FAO and ecosystem services classes (Table 5). This shows biodiversity and health and wellbeing functions linking to natural and semi-natural forests and trees outside forests (Figure 6). New protection plantations will provide forest with regulating functions – water, nutrients, erosion and carbon. New and existing production plantations provide provisioning services – timber and fibre, energy and chemicals, and food and nutraceuticals. Urban trees fit within the trees outside forests and provide climate regulation functions.

If we consider New Zealand in the context of these types of forests and their function, we can gain a broader perspective of how things could look in the future and a more nuanced partitioning of the landscape into different types of forest.

To respond to the challenges outlined earlier, forests will have to play a greater role in New Zealand's future. We need to restore our environment, future-proof our landscapes against climate change, conserve and restore our biodiversity, and move to a low/zero-carbon economy. We will have to create new forests, and also enhance the functions of existing forests.

Enhancing the function of existing forests

With our indigenous forests, it may be possible to enhance the rate of carbon sequestration in some areas and thus mitigate some of New Zealand's greenhouse gas (GHG) emissions. As part of a study for Beef + Lamb New Zealand, Norton and Pannell (2018) identified 2.8 million ha of indigenous vegetation on private lands, with 1.4 million ha (or 13% of the area of sheep and beef farms) being native forest. They suggested that with active management these forests could provide a range of functions, such as enhanced biodiversity and potentially increased rates of carbon sequestration. The recently completed Tōtara Industry Pilot Project (TIP, 2020) undertaken in Northland showed that there is a significant resource of naturally regenerated tōtara, which (if managed well and harvested) could provide up to 3,000 m^3/year of high-value native timber (Scion, 2020a). Harvesting this volume would potentially allow us to reduce imports of other high-value timbers and to expand our semi-natural forests.

On public lands, pest control within indigenous forests also has the potential to enhance biodiversity and possibly carbon stocks. However, a study by Carswell et al. (2012) concluded that such benefits may only occur over a very long period. This work was expanded by Dymond et al. (2013) to identify areas to prioritise for indigenous forest restoration. The work to quantify the added benefits continues with recent work on carbon stocks and biodiversity conservation in indigenous vegetation on agricultural lands (Case & Ryan, 2020; Pannell et al.; 2021, Norton et al., 2020) and ongoing work through the Ministry for the Environment to better understand carbon stocks and fluxes (MfE, 2020).

The potential for enhanced functions within our exotic plantations may be greater than in the indigenous forests. Recent work by the Ministry of Business, Innovation and Employment (MBIE) and the Forest Growers Levy Trust Programme 'Growing Confidence in Forestry's Future' (Scion, 2013) has shown that the forests are not growing to their full potential, and there is an opportunity to enhance both timber and fibre production and carbon stocks through more intensive management. Several forestry

Table 5: 10 functional forest types and their primary ecosystem services

Forest function	Most relevant FAO forest types	Primary ecosystem service	Future
Biodiversity conservation and restoration	Natural, semi-natural	Social and cultural	Enhance
Timber and fibre production	Production plantation	Provisioning	Enhance
Energy and bio-based chemical production	Production plantation	Provisioning	New forests
Water regulation	Protection plantation	Regulating	New forests
Nutrient control or regulation	Protection plantation	Regulating	New forests
Erosion control	Protection plantation, trees outside forests	Regulating	New forests
Food and pharmaceutical production	Production plantation	Provisioning	New forests
Health and wellbeing	Natural, trees outside forests	Social and cultural	Enhance
Climate regulation – urban	Trees outside forests	Social and cultural	Enhance
Climate mitigation – carbon	Protection plantation, semi-natural	Regulating	New forests

companies are now applying recent research results to achieve such benefits, for instance, Timberlands Ltd has a strategic goal to double their average growth rate by 2050 (Forest Growers Levy Trust, 2020). This would also increase their standing carbon stocks significantly.

Such enhancements might, however, adversely affect other functions (such as biodiversity or catchment water yield). There is also the opportunity to enhance the environmental protection of forests planted on highly erodible slopes by either not harvesting and retiring the land, modifying the harvesting regimes, or redesigning the forests to establish new permanent riparian buffers of native vegetation to protect land downstream of the forests from debris flows as recently announced by Aratu Forests (Scoop, 2021).

Establishing new forests

Numerous studies have identified the potential area available for the establishment of new forests in New Zealand. These estimates have ranged up to 2.9 million ha (e.g. Watt et al., 2011) and are mainly located on pastoral agricultural land. It is likely new forests will mostly be established for climate mitigation (carbon), erosion control, nutrient and water regulation and possibly energy and chemicals. Other new forests may also be established for biodiversity values, food and nutraceuticals, health and wellbeing and climate regulation.

Erosion control: Climate impacts are increasing, and we are expecting more extreme and more frequent storm events. New Zealand has some of the highest soil erosion rates in the world. Once lost, topsoil can take centuries to rebuild. We therefore must plan for new forests for erosion control. We will need to protect our most erosion-susceptible sites and also consider other sites. The national ESC indicates there are 164,872 ha of grassland in the very high ESC class and 599,0874 in the high class. This totals 763,946 ha, or 7% of the grassland area. To be most effective in erosion control we need to consider the type of forest that would best suit. Permanent forest cover might be best, or a regime with very low impact harvesting.

The Climate Change Commission suggests native species, but these come with significant establishment challenges on very erodible sites. In addition to the severely erodible sites, consideration must be given to less erodible sites and the potential expansion of the spaced planting programmes on pastures using poplars and willows. These spaced plantings on pastures also have the added benefit of providing shade for animal welfare and fodder under drought conditions.

Nutrient control or regulation: Most of New Zealand's rivers are polluted, with nitrogen and phosphorus the main culprits. Trees have two roles to play in mitigating this – one is through riparian plantings that reduce nutrient movement into waterways, especially phosphorus. We calculated from LCDB5 and NIWA's River Environment Classification (REC) (NIWA, 2021) that there are 156,404 km of waterways within low and high-producing grasslands. If these all had a 10 m buffer of trees planted on each bank this would equate to 312,808 ha of new forest that would also contribute to carbon sequestration and, depending on what species were planted, biodiversity values both on land and within the waterway.

Figure 4: Primary natural forest

The second role trees can play is phytoremediation, which is stripping nutrients out of the soil using short-rotation cropping with trees. Phytoremediation could be used in a fallowing system for land with a history of high nitrogen and phosphorus inputs. Soil cadmium can also be high from superphosphate application. Multiple cropping of short-rotation poplars and willows is also an option to lower cadmium levels (Robinson et al., 2000).

Water regulation: This is an emerging area, with increasing interest in both regulation of water flows by forests to future-proof against increased storm events, but also to manage overall water yields from forests and availability of water to downstream land users. The smoothing effect of forests on storm rainfall peaks is well known (MfE, 2008), but the perceived benefits may be outweighed by concerns about adverse effects of planted forests on catchment water yields. This concern may lead to increased regulation of where a new forest can be established. This is an area of increasing research focus (Scion, 2020b) as landscape-scale climate adaptation plans become more important.

Energy and biochemicals: Bioenergy feedstocks are normally seen as a by-product of existing timber and fibre forests, with the collection of residues for use in energy plants. However, there are issues with the collection and transport of material from remote sites. Dedicated new bioenergy forests may be a more effective route for the production of feedstocks, potentially with shorter rotations and on higher-quality land than current exotic plantations. Scion's Biofuels roadmap (Scion, 2018) identified that an area of forest the size of Taranaki (~725,000 ha) harvested on a 28-year rotation would provide 30% of New Zealand's current liquid biofuels need. There are a few examples of the nascent biochemical opportunity, with Douglas-fir essential oil extraction from wilding conifers in the South Island (Estate Aromatics, 2018), and high-pressure reactive extrusion technologies that turn wood residues into biochemicals that are being trialled at Scion (2018).

Food and nutraceuticals: These could be new specialist forests or modifications to existing forests to enable understorey cropping of, for example, ginseng. Food forests are currently mainly an urban concept with some interest in nut crops, for instance, new Chilean hazelnut plantings in the Bay of Plenty (Holt et al., 2019). Areas established are likely to be small, but the crops could be of high value. Multi-tiered silvopastoral/agroforestry systems and associated value chains are common internationally and are worth exploring further in New Zealand.

Climate mitigation – carbon: New Zealand has committed under the Paris Agreement to decrease its GHG emissions by 30% below 2005 levels by 2030 (MfE, 2018). In 2018, the Government launched the One Billion Trees programme aimed at offsetting emissions through carbon sequestration in new forests. Additionally, the ETS encourages tree planting for carbon sequestration. Most recently, the Climate Change Commission (2020) released draft advice on emissions reductions. In that advice, they recommended up to 780,000 ha of new carbon forests. These initiatives will contribute strongly to developing a low carbon economy. The question is what type of forest – fast-growing exotic plantations will store carbon more rapidly and in a shorter period than indigenous species. So, we would need a larger area of new forest using indigenous species to store the same amount of carbon as with faster growth exotics. From a pure carbon perspective, fast-growing plantations seem the best and most effective approach. Also, consideration of where these forests might be located is very important.

Climate regulation – urban environments: By area, urban trees are tiny compared with other functional forest types in New Zealand, but they have a very significant potential climate regulation function. Shade provides temperature regulation within the urban environment and soft surfaces help lessen water run-off peaks. New urban design is including more and more trees for their environmental functions. They also have a significant impact on human wellbeing, both physiologically and psychologically (Salmond et al., 2016).

The future

If New Zealand is to achieve its climate goals, improve its environmental quality, protect and enhance its biodiversity, and grow its economy, we will need more trees and forests. We can have these, as well as other land uses, woven into the landscape. However, the scale of expansion will need to be large and there are potential barriers to achieving such expansion.

In an environment of rapid change, people can worry about proposed changes and often prefer stability and the status quo. The unknown or different can be scary. We have seen these concerns raised in rural communities when increased tree planting and forest establishment is proposed. One example of this is worry about blanket planting of pine trees, and potential adverse economic and community impacts. This has led to campaigns, such as 50 Shades of Green (2020), and their calls for limits to tree planting on higher agricultural productivity lands. Their campaign is not against trees per se, but one type of forestry.

This is interesting as there did not seem to be the same concern in the mid-1990s when there was a planting boom with new investments in forests, mainly through retirement funds. In the 1990s, the annual area planted peaked at around 90,000 ha. It is possible that social media use has increased the profile and awareness of these concerns.

A further concern is on community impacts – effects on school rolls, local employment, declining rural populations, plus issues such as traffic nuisance. Again, I do not remember this coming up in the 1990s. Recent studies should have allayed some of the concerns though they still rumble on. An economic analysis of forestry and sheep and beef land use for Te Uru Rākau by PWC (2020) showed that the economic and employment intensity of forestry was higher on a per hectare basis and that the areas of both land uses were

Figure 5: Protection plantation

Figure 6: Assisted natural regeneration forest

significantly different. However, permanent carbon forestry – plant and leave had a much lower employment level than normal rotational radiata regimes. They also demonstrated that integrating plantation forestry into sheep and beef operations gave better value chain impact per 1,000 ha than sheep and beef alone.

These concerns are valid and must be addressed as we consider what New Zealand might look like with more trees and forests. We must consider the purpose of the planting, but also any potential impacts – environmental, social and economic. Generally, tree planting is environmentally beneficial, but economically it will be displacing another land use. The common assumption is agricultural returns on-farm will decrease. However, some recent studies and expert opinion suggest that 5–15% of a farm may be planted into trees without a significant impact on agricultural returns, and often with a long-term additional economic benefit. This equates to between 517,881 ha and 1,553,644 ha in total. The percentage possible will depend on a specific farm.

If the opportunities for new forests are generally on agricultural land, then the trees will mostly be established by individual landowners based on their values and preferences. There is a need for commonly understood and used facts to underpin decisions, for example, how much carbon is in a native forest as opposed to a planted forest, the effect that planting of trees will have on local employment, or the possible forest options that are available on a given type of land. This information is often unavailable, hard to find, or can be of dubious provenance. Discussion and communication around perceptions, understanding and purpose and value of new forests will be critical, supported by a sound and commonly-used evidence base. Using a broader framework of functional forests should help this dialogue, considering the purpose of forests, and their wide range of potential benefits to landowners and the wider community.

Conclusion

To sum up, developing a new forest or enhancing an existing forest requires a clear definition of purpose followed by the development of the appropriate forest type and management regime to suit that purpose. It also needs an in-depth analysis of potential unintended consequences at the local regional and national scale to avoid future issues, such as environmental damage or community impacts. Trees and forests have a very significant amount to offer New Zealand. There are many areas where more trees would be beneficial for many reasons and many ways we can expand our thinking beyond the 'commercial plantations, locked-up conservation forests' dichotomy. We should explore a range of future scenarios for our forests using the 10 functional forest types as the framework. These scenarios will then give us a great foundation for discussion and ultimately the design of future landscapes.

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Tim Payn is a Principal Scientist at Scion. His work focuses on planted forests, sustainability, climate change and the environment. Email: tim.payn@scionresearch.com

Carbon financed conservation forestry

Sean Weaver

Figure 1: Native understorey in mixed exotic and indigenous forest at Milnthorpe Reserve, Golden Bay

Abstract

The arrival of the forest carbon sector over a decade ago heralded a new era in forest conservation financing. In New Zealand, the restorative reforestation of erosion-prone rural landscapes and native forest habitats would be limited only by the appetite for carbon credits among carbon buyers and a return on investment for investors. However, a native forest carbon industry has not yet materialised apart from a relatively small collection of projects on the margins, in spite of a carbon price that is (at the time of writing) just shy of $40/tCO_2e$. For forest conservation to be carbon financed at scale it needs to be commercially viable without the help of grants. The commercial viability of native forest carbon is challenged, however, by high costs and low revenues.

A remedy that does not require blunt government intervention in the carbon market is a middle path that combines native and exotic carbon forestry, to deliver an economic performance profile sufficient to cross the stop/go threshold. This paper looks at the economics of this middle path and recognises it as an emerging sub-sector poised to take off in the coming decade.

Restorative afforestation benefits

Restorative afforestation of permanent forest delivers a range of ecosystem services including, but not limited to: soil conservation, watershed protection, soil moisture retention, cooling and regulation of micro-climates (Chen et al., 1999), stream water quality enhancement, carbon sequestration and enhanced biodiversity outcomes. Subject to appropriate site selection, all of these ecosystem services can be delivered by 'ecological infrastructure' in the form of exotic tree species in a permanent forest setting.

The conceptual framework of production forestry and non-production indigenous forestry in New Zealand has tended to exist along a polarised spectrum (e.g. the public backlash against whole farm conversions to plantation forestry include the campaign by the group '50 Shades of Green'), with exotic monocultures managed under a clear-fell regime at one end and 100% native forest at the other. A middle path beckons, with mixed species approaches that deliver ecosystem service benefits while providing ongoing investment returns for the landowner/investor.

Native forest economics

Small-scale native afforestation is common with riparian and habitat restoration projects. These are often funded by grants and/or rely on voluntary labour, but some are supplemented with carbon income. However, native afforestation at a landscape scale is beyond the reach of grants and voluntary labour inputs, and to be successful the economics must be self-sustaining.

At first glance, the carbon market may appear the obvious solution where native afforestation costs are offset by carbon income. The economic realities of self-funding native carbon forestry, though, are challenging for two main reasons: the native 'carbon credit factory' is expensive to build; and native carbon credits accrue at a relatively slow pace.

Both of these realities combine to deliver internal rates of return (IRRs) typically close to or below zero. To gain access to private capital the IRR typically needs to be both above zero and compete with alternative sustainable investment offerings. In the forestry space, these alternatives include the afforestation of eligible farmland with pure exotic forests where the Emissions Trading Scheme (ETS) allows carbon (New Zealand Units or NZUs) to be generated at a cheaper and faster rate.

Cost-benefit analysis

The cost-benefit of native carbon afforestation varies, depending on the forest establishment method adopted. These range from full restorative planting of potted indigenous tree species at high densities and with high species diversity at one end, to minimalist regenerative methods employing pest management and limited indigenous enrichment (if any, using low-cost indigenous species) at the other.

Table 1 shows the cost-benefit analysis of a hypothetical 50 ha project under three planting approaches where the key variable is stem density per hectare. Also included are two alternative methods for natural regeneration, one where the regeneration starts today and the other where the regeneration commences 20 years prior.

Cost-benefit analysis assumptions

Net present value is calculated using a 6% discount rate under three carbon price projections (as below, in real terms) and land costed at an annual rental at 3% of land value:

- CP1 $39/NZU rising at $1.50 p.a.
- CP2 $39/NZU rising at $4.75 p.a. (average of CP1 and CP3), and
- CP3 $39/NZU rising at $8 p.a.

The rationale for applying these carbon price projections is as follows:

- The Year 1 carbon price is slightly lower than the NZU spot price at the time of writing
- CP1 models a conservative, but plausible, average annual carbon price increment
- CP3 models an aggressive, but plausible, average carbon price increment (being similar to NZ Productivity Commission (2018) recommendations for carbon pricing of $75–$200/tCO_2e in the coming few decades)
- CP2 is an average of CP1 and CP3 and aligns broadly with the rate of carbon price increase in recent years.

Project development costs include project initiation costs, forest establishment, contracting and associated management. For the natural regeneration projects, the project development costs include initial inventory work to determine ETS eligibility, tree age and opening carbon stock.

Cost-benefit analysis results

Six different establishment methods were analysed against the three CP1, CP2 and CP3 carbon price projections. The results are presented in Table 1.

Interpretation

The full native afforestation method established at 8,333 stems/ha (N8333) is perhaps the ideal from the perspective of maximising near-term biodiversity outcomes on each hectare treated. The challenge is that this method is cost prohibitive at capital expenditure of $78,000/ha. In a capital constrained market, this severely limits the area of land that can be treated and therefore dilutes the overall delivery of ecosystem services. The IRR for this scenario ranges from –10.5% for CP1 to –4.9% for CP3. This high-intensity afforestation approach is the least financially viable option.

This contrasts with mānuka planted at 1,000 stems/ha (M1000). Here, capital expenditure is of the order of $10,750/ha. At scale, mānuka honey rental (priced here at $200/ha/year) may add to revenues. Including the honey rental, this establishment method delivers an IRR of 0.7% for CP1 and 6.7% for CP3. The establishment of mānuka at 1,000 stems/ha is the highest financially performing establishment method where the objective is pure native afforestation. A mānuka honey rental placeholder of $200/ha/year is used here to provide an indication of what might be possible and is consistent with Clarke (2020).

Table 1: Cost-benefit analysis of establishment methods (ranked by projected IRR)

Establishment Method	Cash Capex	Cash Capex/ha	IRR CP1	IRR CP2	IRR CP3	NPV per ha CP1	NPV per ha CP2	NPV per ha CP3
N8333	$3,901,194	$78,024	–10.5%	–6.9%	–4.9%	($69,969)	($66,697)	($63,424)
N2500	$1,232,268	$24,645	–5.6%	–1.6%	0.7%	($20,464)	($17,192)	($13,920)
N1000	$545,934	$10,919	–1.7%	2.7%	5.3%	($7,733)	($4,461)	($1,189)
M1000	$537,596	$10,752	0.7%	4.3%	6.7%	($5,462)	($2,189)	$1,083
NRY0	$57,713	$1,154	2.9%	7.6%	10.2%	($1,067)	$842	$2,750
NRY-20	$57,713	$1,154	15.6%	24.6%	31.2%	$1,250	$3,684	$6,119

Key:

N8333	Native afforestation planted at 8,333 stems/ha
N2500	Native afforestation planted at 2,500 stems/ha
N1000	Native afforestation planted at 1,000 stems/ha
M1000	Mānuka afforestation planted at 1,000 stems/ha
NRY0	Natural regeneration commencing in Year 0 (via retirement of grazing and pest control)
NRY-20	Natural regeneration commencing in Year 20 (20 years prior)

The challenge is that mānuka honey rentals vary greatly, depending on a range of factors determined by honey contractors, and will only last for the period when mānuka forest remains productive. Mānuka is a seral tree species that forms a natural nursery and will typically be succeeded by taller tree species after 50 years, and mānuka honey productivity reduces through time as trees mature and market prices vary season to season. Moreover, this model does not maximise near-term biodiversity outcomes, but has the advantage that limited capital can be used to treat a larger area and generates positive IRRs at all three carbon price projections.

High stem densities (such as 4,000 to 8,000 stems/ha) result in interplant competition and natural mortality within the first 20 years. In contrast, lower stem densities reduce the likelihood of natural mortality, and instead provide an environment conducive to promoting natural regeneration of broadleaf species, depending on the availability of resident seed sources. Here, nature contributes to the capital stock and biodiversity outcomes and in addition increases project returns.

Both natural regeneration methods (NRY0 and NRY-20) deliver positive IRRs, which is because the capital expenditure burden is low. For establishment method NRY0, it is assumed that it will take 12 years following the retirement of grazing for natural regeneration to meet the forest land definition in the ETS. This creates a lengthy delay in the receipt of carbon income to offset the opportunity cost of retiring the land from grazing.

The most economically viable option modelled is where the natural regeneration is both well established and the land meets the post-1989 forest land definition under the ETS. This permits the ETS registration at a time when carbon sequestration rates are more favourable.

Mixed forest economics

The above analysis demonstrates that native afforestation of bare land is economically challenging and is unlikely to be adopted voluntarily at scale by investors and rural communities. Gaining access to capital at scale requires an afforestation method that delivers appropriate cashflow and financial returns.

Figure 2: Community planting of native seedlings in mixed exotic and native planting, Manapouri

Impact investors tend to preferentially support high co-benefit initiatives, but still require a commercial or semi-commercial return. Either way, an indicative return of 0.7% at CP1 is unlikely to be sufficient to trigger a decision to invest, particularly at a scale needed to change the course of landscape history. Note that impact investing is an investment strategy designed to deliver beneficial social or environmental impact alongside a financial return (Chen, 2021).

Ultimately, the IRR will need to march northwards to enable any investment at scale to proceed, irrespective of the capital structure and security arrangements. This necessitates lifting the financial performance of restorative carbon projects above those delivered by the least cost, highest performing pure native reforestation scenarios.

One way to do this is to introduce exotic tree species to the restorative afforestation strategy. Figure 1 shows the native understorey of natural regrowth beneath an exotic nursery crop canopy 40 years after the exotics were planted (Golden Bay). Figure 2 depicts the native reforestation element of a mixed exotic and native forest carbon project undertaken as a community planting day at a site in Southland. Figure 6 shows contour ripping for the adjacent exotic hardwood element at the same site in Southland.

Where the strategic focus is to maximise biodiversity and sustainable land management co-benefits, exotics can be introduced at a scale sufficient to nudge the financial performance above the required rate of return. This can include exotic woodlots in a portfolio focused primarily on native forest restoration. Here, the purpose of the exotic species is to fund the natives. Furthermore, the hectares planted in exotic species can be managed to transition to a pure native forest in the long term through adaptive management and continuous canopy forestry.

Mixed native/exotic afforestation methods

Two alternative mixed native/exotic afforestation methods are considered:

- **Method 1: Mixed afforestation where natives initially dominant (Mix N Dom)**

  This afforestation method applies the same assumptions as for native afforestation, including the same 50 ha area, but with exotic hardwood stands introduced into the initial planting area until the IRR at CP1 delivers a 4% return. [Exotic hardwoods (angiosperms) were used in this analysis because they deliver the highest carbon sequestration rates in the ETS. Exotic softwoods deliver similar financial results to those of exotic hardwoods and are also compatible with this mixed model approach.] This resulted in planting 33 ha of natives (mānuka and tōtara) and 17 ha of exotic hardwoods. The exotic hardwood stands involve planting hardwoods at 833 stems/ha, thinning and then harvesting 10% of the total exotic area and replacing with natives (mānuka and tōtara), repeated in a five-yearly cycle until all exotics are removed. The afforestation method conservatively assumes that the exotic hardwood crop will generate a net stumpage of $10 per cubic metre (similar to firewood returns), although higher valued returns for higher valued exotic hardwoods are certainly possible.

- **Method 2: Mixed afforestation where exotics initially dominant (Mix E Dom)**

  This afforestation method applies the same assumptions as Method 1 (Mix N Dom), but with only 10% of the total area initially planted in natives and the remaining 90% of the area planted in exotic hardwoods. Here, the exotic hardwood element is harvested and replaced with natives in the same manner as Method 1 and is designed to transition to pure native forest by year 57.

Cost-benefit analysis results

The economic returns of the two mixed native/exotic afforestation methods are presented in Table 2.

Interpretation

As illustrated in Table 2, the IRRs are consistently higher than those for the pure native plantings presented in Table 1. There is an infinite variety of different proportions of stand areas allocated to native and exotic species. These results are therefore only indicative of the range of possible scenarios. In both cases, the long-term outcome is the managed transition to a pure native forest but where the short-term forest establishment strategy delivers financial returns more likely to enable access to private capital investment at scale.

Summary of afforestation methods considered

Table 3 below combines the results of Tables 1 and 2. Figures 3–5 provide a graphical interpretation of these results.

Interpretation

As can be seen, the economic pathways to native forest restoration and the provision of ecosystem services at scale reflect varying degrees of financial viability, with high planting density ecological restoration at one end and mixed exotic and native forestry and natural regeneration at the other. The afforestation method employing the initial establishment of exotic species and the managed transition to a pure native forest is an effective means of financing the delivery of permanent native forests at scale.

Discussion

Having a dream to heal and re-cloak entire landscapes is commendable. However, if we cannot finance our dream, then dream is all we get to do. Financing this dream necessitates the strategic design of an afforestation programme capable of delivering the sustainable land management outcomes and attracting finance for the task at the scale required.

Strategic design

The perfect is the enemy of the good. The only way to deliver permanent native afforestation at scale is to deliver an economically viable solution without the need to rely on grant funding. This analysis has shown that the forest establishment methods that meet this criterion are: a) natural regeneration of existing (ETS eligible) stands of native forest; and b) planting a mix of native and exotic trees. Given that the registration of existing and eligible native forests (already protected under district plans) does not create additional ecosystem services, the dream of healing the landscape and providing additional ecosystem services requires the realisation that planting exotic species is a means to the end goal. Despite this, the registration of eligible naturally regenerating forest land in the ETS can provide seed capital to invest in mixed native/exotic afforestation.

However, the sustainable land management challenge requires active afforestation at scale if it is to have a meaningful impact on meeting New Zealand's Paris Agreement obligations, i.e. this country's aspiration to be a net zero carbon economy by 2050 and help build

Table 2: Cost-benefit analysis of two mixed native/exotic afforestation methods

Establishment Method	Cash Capex	Cash Capex/ha	IRR CP1	IRR CP2	IRR CP3	NPV per ha CP1	NPV per ha CP2	NPV per ha CP3
Mix N Dom	$466,069	$9,321	4.0%	8.7%	11.8%	($1,875)	$3,288	$8,451
Mix E Dom	$338,734	$6,775	11.2%	17.1%	21.2%	$85	$12,546	$20,824

Table 3: Cost-benefit analysis summary of all establishment methods considered in this paper

Establishment Method	Cash Capex	Cash Capex/ha	IRR CP1	IRR CP2	IRR CP3	NPV per ha CP1	NPV per ha CP2	NPV per ha CP3
N8333	$3,901,194	$78,024	−10.5%	−6.9%	−4.9%	($69,969)	($66,697)	($63,424)
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NRY-20	$57,713	$1,154	15.6%	24.6%	31.2%	$1,250	$3,684	$6,119

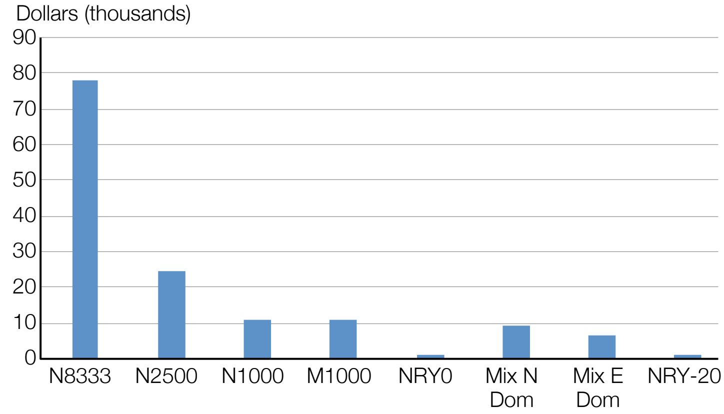

Figure 3: Capital expenditure per ha across afforestation methods discussed

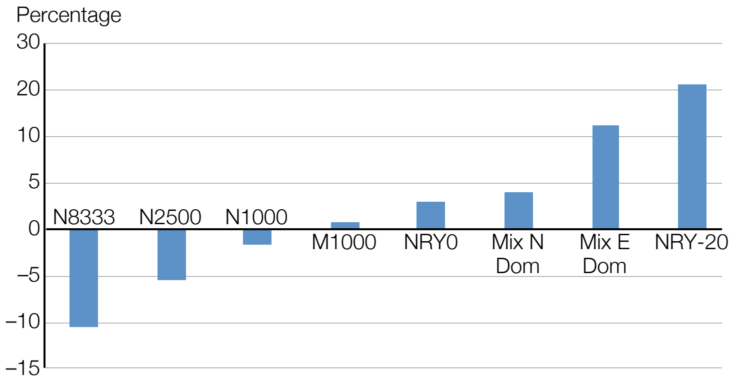

Figure 4: IRRs for carbon pricing model CP1 across afforestation methods

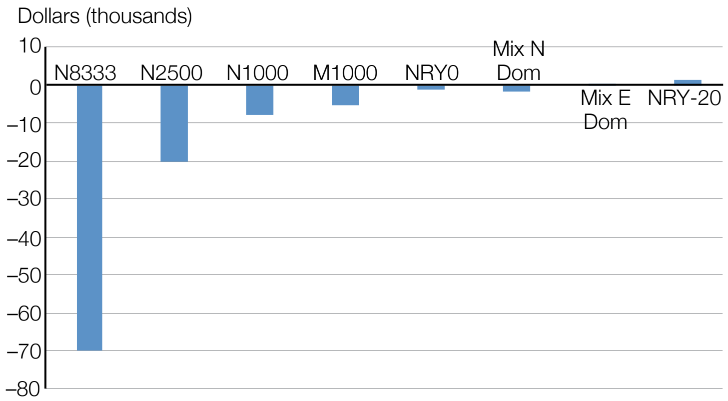

Figure 5: Net present value per ha for carbon pricing model CP1 across all afforestation methods

climate resilient landscapes. According to Bloomberg (2020), small-scale indigenous reforestation is unlikely to sequester enough carbon to meet this challenge.

The mixed exotic/native method to afforestation is a middle path that is considerably more beneficial than business-as-usual pastoralism on erosion-prone land. It avoids the sedimentation impacts of clear-cut plantation forestry on this land type and is much more affordable than a pure native approach. Research into mixed exotic and native forestry is limited in New Zealand (e.g. Forbes et al., 2019), and recent work on the notion of 'right tree right place' has highlighted a number of factors necessary for durable afforestation solutions (Clarke, 2020).

A mixed exotic/native method also needs ongoing management and the adoption of a reliable strategy to ensure the successful transition from an exotic to a native canopy. One possibility is a continuous canopy approach. The method originally considered (and since discarded by the author) involved interplanting natives and exotics in the same stand through either single tree removal, a single tree narrow corridor, or small coup removal and replacement. The logistics of exotic extraction and replacement with a subsequent generation of trees without damaging the originally planted native element can prove challenging.

Planting discrete (adjacent) exotic and native stands, followed by exotic corridor creation wide enough to enable machinery harvesting and replacement, mitigates both the logistics and the capital expenditure problem. This approach also enables adaptive management in the replacement of corridors of harvested exotics with either natives or a subsequent generation of exotics in a shelterwood setting, particularly if the native element proves to require a longer timeframe to transition to site dominance.

The nature of pioneering is living with higher uncertainty. If we are to respond to a climate emergency with an outlook that recognises the emergency we will need to take risks – because the risk of non-action or business-as-usual pastoralism on erosion lands is also unacceptable. Furthermore, this approach is not proposed as the only approach to climate action in the rural landscape. Instead, it comprises a complementary measure to commercial plantation forestry, particularly in landscapes that are too erosion-prone to be suitable for large-scale clear-cut forestry practices (see Bloomberg et al., 2019) or pastoralism.

Financing the dream

Landscape-scale, permanent restoration forestry for the combined purpose of sustainable land management, biodiversity conservation and community economic development will need to gain access to capital in proportion to the task. The order of magnitude of capital required for the afforestation of 200,000 ha (as is needed in regions like Hawke's Bay, Gisborne District and the Central North Island) is well over a billion dollars for each region. If not deployed in a market-based mechanism, this funding would need to be provided as a grant or subsidised. There is not enough money available in the grant sector for this level of financial commitment.

Partnership approach

Impact investment at scale will require a capital structure capable of unlocking money at the volume required, and at a cost of capital capable of delivering the range of co-benefits that are possible within a profitable business model. Clean development the world over often struggles to gain access to private capital, which is partly because clean development is a new thing, and any new thing comes with greater uncertainty. Accordingly, the investment community tends to look at new things as higher risk investments than old things that are more predictable.

Figure 6: Contour ripping for exotic element of mixed exotic and native planting, Manapouri

Higher risk profiles require higher returns on investment to cover that risk. This drives up the cost of capital, often to levels beyond the reach of social enterprise solutions designed to maximise social good whilst delivering a profit, rather than maximising financial return on investment (Weaver, 2015). More conservative investors like pension funds can provide large volumes of money at a relatively low cost of capital, but typically require financial risk mitigation to guarantee the more modest returns (Ward, 2010).

Financial risk mitigation to enable large-scale private capital investment in 'look after the place' enterprise solutions is a key strategic piece of the 'save world' puzzle. Indeed, if we are to realise the sixth industrial revolution and deliver a climate-resilient, low-carbon, sustainable future, we will need someone to underwrite private sector financial risk. An ideal person for this role is the Government (investing using taxpayers' money on behalf of all New Zealanders) – whose discount rates are lower, whose time horizons are longer, and who can socialise this risk for a common purpose – as happens in war, COVID and other crisis economies.

Conclusion

The Government has created the ETS to change behaviour and encourage investment in reducing emissions and sequestering carbon. The ETS provides an opportunity to change the course of history in rural New Zealand and heal our erosion lands. Most of the key ingredients are already in place for land management systems change capable of healing our broken hillsides nationwide. The last piece of investment readiness is a nation willing to walk a middle path, and an underwriter who can unlock private capital at scale to enable sustainability entrepreneurs, landowners, investors and communities to get on with it.

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Sean Weaver is a Forest Carbon and Environmental Financing Consultant at Ekos based in Christchurch. Email: sean@ekos.co.nz

New Zealand Carbon Farming – regenerating native forests at scale using an exotic plantation nurse crop

Peter Casey, Bryan McKinlay and James Kerr

Figure 1: Regenerating ferns, native understorey species, broadleaf and *Coprosma* species under a 20-year-old production pine crop

Abstract

Since the establishment of the New Zealand Emissions Trading Scheme (ETS) in 2008, planting trees for the purpose of sequestering carbon has become a growing sector in New Zealand. At present, most existing exotic forests and recent afforestation projects continue to be managed under the traditional model as rotational timberland forests. The yield of carbon credits from these forests as they grow is of value, but typically a supplementary benefit.

The ability for ongoing sequestration of carbon in the longer term, and associated cashflow, has led to the development of permanent forests using exotic plantation species. In addition to the ability to store more carbon for a given area compared to rotational forestry, these permanent forests are able to act as a nurse crop for the regeneration of native plants and trees. The nurse crop provides the right environment to actively manage the regeneration of native forest cover at scale.

While well supported by local and international research, this regeneration process is not well known, or at least not well understood. A common misunderstanding is that all permanent forests using exotic forest are simply 'plant and leave'. New Zealand Carbon Farming (NZCF) is demonstrating that a comprehensive and active management programme is necessary to deliver the short-term carbon benefits needed to meet New Zealand's international climate commitments, while also ensuring the long-term success of a biodiverse, indigenous environment.

The process also offers real advantages over a solely native planting programme, which can be extremely costly and highly vulnerable to predators, disturbance and environmental conditions. The modelling has demonstrated that permanent regenerating forestry can remove between five and 10 times more carbon over 70 years than planting a native forest from scratch.

In this paper NZCF is introduced and the science behind the use of an exotic forest nurse crop to accelerate regeneration of native forest cover is reviewed. This is followed by a discussion about what NZCF is doing in setting the platform and actively managing for succession to native forest at scale.

New Zealand Carbon Farming

First established in 2010, New Zealand Carbon Farming (NZCF) is one of the biggest contributors to New Zealand's climate change response. The company owns and manages the country's largest privately-owned conservation estate of permanent forests. NZCF's trees are never harvested, but instead are carefully managed to regenerate over time into a 100% indigenous and biodiverse conservation estate.

The company is a science-based organisation that has for the last decade followed a key philosophy of planting the right tree in the right place. Over 95% of NZCF's 66.7 million trees are planted on marginal land (grade 6 and above) – often in steep or erosion-prone areas.

The company is the largest participant in the NZ Emission Trading Scheme (ETS) with its trees currently sequestering one tonne of carbon every 13 seconds. Over the past decade more than 20 million tonnes of carbon have been captured by NZCF's trees – the equivalent of taking every car off New Zealand's roads for a year. The company believes that through its planting practices and management regime it can play a vital role in this country's climate response until other strategies and new technologies for reducing emissions have a realistic chance of being implemented.

The company also works with landowners to diversify land use and income through afforestation using tailored carbon lease options to support the effective use of marginal areas of their properties. NZCF uses the income derived from carbon capture to reinvest in further plantings, as well as active management of its permanent forest estate to a native state, while also providing a complementary income for more than 6,000 landowners across the non-freehold forest lands.

The science behind the NZCF regeneration regime

The following is a review of some studies relating to the use of woody species, particularly exotic trees, as a nurse crop to facilitate regeneration of native forest species. In contrast to the more than 100 years of research, development and collective expertise in New Zealand of establishing and managing exotic radiata pine plantations for logs and wood products, the establishment and management of exotic plantation species as a nurse crop for succession to native forest cover is at a comparatively early stage. However, there is compelling evidence (both locally and internationally) that confirms that not only is this achievable, but it provides a sustainable alternative pathway to establishing native forest cover.

Regeneration of native forest using a woody nurse crop is a natural part of forest ecology. In New Zealand, the most effective woody pioneering nurse crop species depends on a variety of factors, including the location around the country. It includes native species such as mānuka and tōtara, as well as exotic weed species such as gorse and broom. There are plenty of examples of mānuka scrub naturally succeeding to emergent broad-leaved and podocarp species around the country.

Hinewai on Banks Peninsula is an example of a successful large-scale application of using gorse as a nurse crop for managed succession to a native forest cover (Wilson, 1994). Also, the less intensively managed succession from gorse to native forest cover along the Remutakas has and continues to give residents of the Wellington area an evolving vista of native forest regeneration.

Radiata pine and other similar exotic plantation species grow to be much larger and longer-lived plants than gorse, mānuka and many other colonisers. Yet despite their size, radiata pine forests develop a diverse understorey of shade-tolerant native species within a typical production rotation (Brockerhoff et al., 2003; Norton, 1998). The older the nurse crop is, the longer the period in which the understorey can develop and therefore the more advanced the understorey becomes (Forbes; 2015) (see Figure 1). This can result in the establishment and growth of sizable native trees in amongst the production trees. Radiata pine stands of old age, such as open grown seed-tree stands in Kaingaroa, provide good examples of such ongoing forest successions.

The potential for stands of exotic trees to facilitate native forest restoration has been recognised for some years (Lugo, 1997; Brockerhoff et al., 2003), with an increasing number of studies focused on this topic for New Zealand (Paul et al., 2020; Forbes et al., 2019; Norton & Forbes, 2013), Chile (Onaindia et al., 2013; Guerrero et al., 2007), Sri Lanka (Ashton et al., 2014) and South Africa (Geldenhuys, 1997). The results of these studies have shown that the use of an exotic tree nurse crop can facilitate and, if actively managed, accelerate native forest regeneration compared to other regeneration pathways. So how does this occur?

An exotic forest nurse crop creates micro-climatic conditions similar to a native vegetation nurse crop that are favourable for the establishment and ongoing development native forest species (Forbes et al., 2019; Lugo, 1997). They have the added benefit of a significantly higher rate of carbon sequestration in the short-to-medium term and a much lower establishment cost than a native nurse crop alternative. This is especially if the latter has to be planted, and accelerates the process compared to letting nurse crops establish themselves initially.

The nurse crop allows a wider range of native species to successfully establish (naturally or with intervention) and regenerate compared to if the site was left as retired pasture, resulting in increased site biodiversity and an accelerated rate of regeneration (Pratt, 1999; Zimmerman et al., 2000). The benefit of the micro-climate created by the woody nurse crop is greatest on harsher sites (Sullivan et al., 2009; Pardy, 1987; Bergin & Kimberley, 1987), and sites with high competition from light-demanding species, such as grasses, which increase the barriers to the successful establishment of native regeneration (Parrotta et al., 1997).

These studies, and others in the native restoration space, have identified and started to refine the understanding of the benefits, key drivers and their interactions to progress the use of regeneration of native forest cover using an exotic trees crop. Critical key factors influencing regeneration under exotic nurse crops include the availability of seed, soil moisture, site characteristics, pressure from browsing pests, competition from weeds, and the duration since and intensity of disturbance events.

Proximity to a suitable seed source and the presence of an effective seed dispersal mechanism are key factors in the establishment of native species in a new site (Forbes et al., 2019, Brockerhoff et al., 2003). As such, even the protection of small pockets and isolated individual native trees is an important factor in enhancing natural establishment across a site (see Figure 2). This is particularly so if the seed sources are composed of species that can form the upper canopy of a climax forest, such as broadleaf trees with emergent podocarps (Forbes et al., 2019; Brockerhoff et al., 2003). Where a suitable seed source is not present locally, it has been shown that native vegetation, including long-lived species such as podocarps, can be successfully established under an exotic plantation forest (Pardy, 1987; Forbes et al., 2015; Bergin & Kimberley, 1987).

Ungulate browsers (including goats, deer and pigs) have been demonstrated to be a major contributor to long-term vegetation change globally. The combination of introduced browsers has been shown to reduce vegetation diversity, cause increasing stand instability,

Figure 2: The difference even one tree can make – dense podocarp regeneration around a surviving mature tree

Figure 3: Understorey of a mature tawa-podocarp forest on one of NZCF's recently planted properties – almost completely browsed out by deer and goats prior to the commencement of pest eradication

and can ultimately contribute to the canopy collapse of established native forests in New Zealand (Rogers & Leathwick, 1997; Cunningham, 1979). The distribution and density of ungulates has steadily increased over recent years, as has the population of possums in unforested areas (Department of Conservation, 2020). Protecting the regenerating forest from browsing damage is one of the key factors in ensuring the successful regeneration of a site (van Galen et al., 2021; Smale et al., 2008) (see Figure 3).

Studies to date have shown that active management of the nurse crop has numerous benefits. The growth rate is increased if the seedlings or seed are located in a light well or other gaps within the nurse crop (Forbes et al., 2016a; Smale & Kimberley, 1986). In fact, the existence or creation of gaps may be a key determinant in the ability for desirable climax species, such as podocarps, to establish and develop (Onaindia et al., 2013, Forbes et al., 2019). The growth of desired regenerating species can be optimised to the detriment of competing vegetation by matching gap size to the species-specific light requirement of desired species (Forbes et al., 2016a). While the nurse crop helps with the establishment of native regeneration, over time it may increasingly compete with the developing future canopy species and may need to be managed out (Norton & Forbes, 2013).

From a risk point of view, there may also be an increasingly likelihood of significant wind damage (Moore & Watt, 2015) and insect attack (Chou, 1991) to untended radiata pine forests, particularly at higher stockings, as age increases. So, the benefit of ongoing active management to progressively monitor and manage the nurse crop to promote native regeneration and maintain forest stability is strong. While it is related to native restoration on a pine cutover, a recent study of native forest restoration predicted that without active management most of the site studied would likely not successfully regenerate to native forest cover (Forbes et al., 2021).

The existing body of research therefore gives clear evidence that not only is it possible to regenerate native forest cover using an exotic tree nurse crop, but if well managed it will also accelerate the process of native forest regeneration.

Every tree counts – regenerating native forests using an exotic tree nurse crop at scale

Setting a strong foundation for the establishment of a permanent regenerating forest has been a key focus for NZCF in recent years. When it comes to forest establishment there is one chance to get it right, and the window to do so can be a small and at times moving target. To get it wrong for a permanent forest potentially means having to deal with the consequences for many decades and may incur costly rehabilitation measures. With older forests on the NZCF estate that have been previously managed under various timberland regimes (or not managed at all), the window to intervene to facilitate the forest transition is typically larger and less time sensitive.

Figure 4: Forest design retains existing indigenous forest as a seed source of prevalent local vegetation species

Internal organisation capability key

For NZCF, a key part of laying the right foundation has been the ongoing development of its own in-house permanent forest estate management capabilities. Having this in-house has enabled the company to build capability, expertise, experience and – importantly – accountability for delivering the vision of preserving the trees for future generations. The company continues to further enhance its long-term management capability and capacity for the regeneration of its permanent forests to native forest cover. The company operates an 'every tree counts' mindset to drive optimal carbon sequestration and accelerated regeneration to complete native forest cover.

Best practice and research

As the company has grown its conservation estate of permanent forests with new plantings, it has continued to review and monitor the optimum regime for regeneration. Modelling and economic analysis has shown that the optimum regime to be applied when establishing forests on isolated, erosion-prone and marginal hill country of Class VI, VII, VIII is 1,200 stems per hectare. This ensures site occupation is achieved quickly, which among other factors reduces weed presence.

The company obtains and uses objective, independent information and guidance from a group of individuals with expertise in various aspects of ecology, regeneration, land use and conservation. This group, the Regeneration Independent Advisory Group, has provided and continues to provide science-led oversight and review of the regeneration programme.

Foundation blueprint – the forest design process

The company's establishment operations in the last two years involved the permanent afforestation of 9,000 ha of new land spread through the North Island. The selection of properties for planting is subject to a set of criteria, which forms the first phase of the forest design process. This process involves careful planning and a combination of site visits and other assessments using a range of information sources and detailed mapping of the vegetation and typography of the entire site. Relevant district and regional plans are also carefully incorporated into the forest design and establishment plan.

Following the selection of a new property, the forest establishment plan is fully developed. In addition to typical setbacks required and protection of any sensitive or significant sites, all existing indigenous vegetation is protected, given its ongoing key value as a seed source (see Figure 4). Waterway setbacks are also a key part of the forest design – the proximity to water creating preferential conditions for native regeneration, providing further future sources of seed and corridors for seed dispersers to move about the forest (see Figure 5).

Nurse crop species selection

While radiata pine is the species of choice for most sites, alternatives are used where it is not suitable and to manage specific risks, reflecting NZCF's focus on planting the right tree in the right place. Planting of mānuka was undertaken to provide further waterway protection on areas deemed critical source catchments, where downstream properties could be adversely affected by flooding events. Eucalypts (*E. regnans, E. fastigata* and *E. globoidea*) have been planted in areas on steep sites with shallow soils that are considered unsuitable for radiata pine.

Critical role of pest management

At all stages, managing pest animal numbers is vitally important. Most new NZCF properties have had very high existing populations of wild animals in the past, requiring a concentrated programme to remove hares, goats, pigs and deer on an ongoing basis. More than 11,500 animals have been removed in the past two years. This has been achieved mainly through ground

Figure 5: Forest design protects existing unfenced riparian zones of native vegetation with exotic planting up to the native vegetation edge

Figure 6: Fern and seedling regeneration within an unfenced native remnant a year after the cessation of grazing and commencement of pest eradication operations

shooting with the use of multiple specialist contractors and techniques, including the use of thermal imaging, indicator dogs and drone surveillance to gain best results.

To avoid damage and losses to the nurse crop and native regeneration, NZCF's focus on pest management is viewed as a focus on eradication, rather than control. This is a challenge to maintain, as there is regular reinvasion from the surrounding area. In response, the company is undertaking a multifaceted approach to dealing with this, including working with neighbouring landowners to obtain permission to eliminate pest animals on their property. This creates a buffer zone around the regeneration area, and helps with exploring and developing systems and technologies for more effectively locating and removing pests from areas of dense cover (see Figure 6).

A focus on the local community

A key focus for NZCF is to provide employment opportunities and ongoing investment within the regions it operates in. Given the nature of the range of work required over the decades of the regeneration process, this provides long-term jobs, skills and investment in rural communities across the country.

Wherever possible, the company's preference is to use the services of local people and support local businesses. Long-term supply contracts are in place with key suppliers, such as the local nurseries used in the North Island. These have been put in place to build trust, reliability and credibility – important considerations given the past volatility of carbon and broader afforestation projects. Local contractors are also engaged where possible for a wide range of services, including tree delivery to site, planting crews, operations supervisors, pest controllers and property maintenance activities.

With over 95% of its permanent forest area on lower quality Land Use Capability (LUC) land VI, VII and VIII, NZCF also proactively subdivides better land from its forestry blocks and sells it back to the community.

Optimising site occupancy and regeneration in establishment phase

In establishing the nurse crop, the aim is to achieve full site occupancy and canopy closure as quickly as possible. In all cases where access and grass and weed growth allows, spot release spraying is carried out post-planting. Spot spraying, as opposed to aerial release spraying, offers a number of key benefits. It not only has the effect of reducing the amount of chemical being used, it also supports site stability and provides a less confronting visual change to rural landscapes (see Figure 7).

This preparation sets the forest on the optimum carbon curve and provides the best Field Measurement Approach (FMA) plot measurement result. Importantly, the early canopy closure helps control competing grasses and weeds, assisting the early stages of forest regeneration of shade-tolerant native species under the forest canopy. Ultimately, the benefits of this approach are far-reaching: the more trees that survive and grow well, the more carbon is sequestered. For NZCF, this means there is more to invest in new planting, as well as supporting the costs of actively managing the forest to optimise carbon and the native regeneration process.

Nurse crop interventions to promote forest health and regeneration

Nurse crop interventions, including stem removal, serve to maintain the health and stability of the nurse crop while creating the conditions to accelerate native regeneration. The regime and the exact timing and intensity of interventions will be site-specific and dependent on growth rates, regeneration and other operational factors. Forests are monitored and further nurse crop interventions can be carried out to facilitate the ongoing native regeneration process.

It is in relation to the intervention phase where there is the most ongoing work required to understand the interaction of the nurse crop and native regeneration. Native ecological systems in a single location are complex. Given the location of existing NZCF forests across different parts of New Zealand there is often a requirement for significant customisation by site.

Tailored carbon leases for other landowners

In addition to managing its freehold estate, NZCF provides a carbon lease option to other landowners. This is aimed at providing a regular, complementary income for landowners at no cost to them on marginal or sub-economic areas of their property. In close consultation with the landowner, NZCF steps through the forest design process to establish a forest that meets the landowners' near- and long-term requirements. The forest regime delivers a framework for harvest or the potential for managed regeneration as a permanent forest.

The carbon rights to the forest area are intended to be registered in the ETS by NZCF under averaging. At the end of the averaging period the forest owner is free to decide how they manage the forest going forward – if they wish to continue as a permanent regenerating forest or take the full harvest proceeds should they decide to harvest. The structure of payments to the landowner is tailored to their cashflow requirements and can support a strategy for further on-farm investment, diversification and even succession planning. All establishment and ongoing management costs of the forest crop are met by NZCF.

Summary

Through the use of an exotic tree nurse crop to facilitate regeneration to native forest cover, NZCF is committed to continuing to make a significant contribution to New Zealand's climate change targets while regenerating flourishing, biodiverse native environments for long-term carbon sequestration. This approach provides a business model that is self-funding, with revenue from carbon sequestered by the exotic nurse crop, providing the means to invest in and manage the native regeneration process.

Many exotic plantation forests around New Zealand and the world already have significant regenerating native vegetation present within them, given the suitable micro-climatic conditions that these forests create. The existing body of research confirms that rather than harvesting the nurse crop, it can continue to be managed to facilitate and accelerate the regeneration process to a native forest cover. It identifies key factors critical to the success of the regeneration process, including the importance of effective pest management, which has the potential to stop the whole regeneration process if not well executed. The existing research confirms this forest management approach. While successfully demonstrating this approach across its estate, in both new and existing forests, NZCF is constantly working to further enhance and refine the approach to execute this strategy at scale.

Figure 7: High initial stocking to establish canopy closure quickly and starve competing grasses of sunlight. Spot spraying helps reduce the visual impact of afforestation, as well as in maintaining land stability and reducing chemical usage

NZCF believes that every tree counts and places a significant focus on getting the foundation of the regeneration process right, through developing internal expertise and capacity, as well as careful due diligence and the forest design process. This starts with protecting existing areas of native vegetation, undertaking intensive and ongoing pest management, selecting the right tree for the right place, and ensuring that the nurse crop is well established and high performing.

The company believes that through its planting practices and management regime it can play a vital role in New Zealand's climate response. By regenerating marginal land to native forest cover, the company is making a difference today while creating a valuable legacy asset for tomorrow – meeting its core vision of planting trees to preserve the planet for future generations.

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Peter Casey is the General Manager of the NZCF Group. Bryan McKinlay is Chief Forestry Advisor to the NZCF Group. James Kerr is Forest Estate Manager for the NZCF Group. Corresponding author: peter.casey@nzcarbonfarming.co.nz

Permanent forestry requiring improved forest management – a North Canterbury example

Adam S. Forbes

Figure 1: Regenerating native vegetation on hill country in the PQF project area

Abstract

Part of the response to the November 2016 Kaikōura M 7.8 earthquake was an investigation by Forbes Ecology Limited into permanent native forestry options across 420,500 ha of earthquake damaged hill and high country land to assist the affected communities (herein the Post-quake Farming/PQF project area). The affected land features rough topography, is typically farmed at low intensity, and individual farm units are often large (i.e. many exceed 2,000 ha in area). Secondary native vegetation is a significant feature of both grazed and ungrazed areas and covers a large proportion of public and private land. This paper outlines the work that was undertaken to better understand this permanent forestry opportunity and develop information to inform the future permanent forest management decisions of forest managers and owners.

Native forests of the PQF project area

Prior to the arrival of humans, the mild to cool, seasonally-dry lowland environments of the PQF project area supported diverse forests comprising dry conifer and conifer/broad-leaved forests with pockets of beech forest. In contrast to today, widespread scrubland was not a feature of this pre-human vegetation cover (McWethy et al., 2010). Most native forest cover was eliminated by human-lit fires, initially by Polynesians followed by more intensive burning by Europeans. Following burning, at sites of low-to-middle elevations and those with dry climates, typical of much of the PQF project area there was little recovery of the pre-existing closed-canopy forest (McWethy et al., 2010).

In today's landscape, old-growth forest remnants have been largely eliminated or are otherwise spatially scarce, with reduced forest health and functionality

(Forbes et al., 2020). Still, approximately 22% (91,650 ha) of the land is covered by native forest and scrubland (see Figure 1 as an example). A similar distribution of native cover occurs at a national scale, with 24.5% (2.8 million ha) of native vegetation and 17% (1.4 million ha) of native forest estimated to be on Aotearoa's sheep and beef farms (Pannell et al., 2021).

Secondary forests such as these present major environmental and economic opportunities for landowners and for wider society where they are managed as permanent forests. For instance, carbon farming may be possible, and the forests might provide suitable nursery conditions in which to raise native trees for sustainable timber supply. Many native tree species provide excellent honeybee forage, as both pollen and nectar sources. Further, economic drivers can lead to pest control, which benefits the forest ecosystem, such as programmes to control possums (TB vectors), feral pigs and ungulates that farmers often control because they damage or consume forage species, and wasps which predate bees.

In addition to the above benefits, a diverse range of ecosystem services may eventuate that yield environmental and social benefits (Ausseil et al., 2013; van den Belt & Blake, 2014; Brockerhoff et al., 2017; Maseyk et al., 2017) such as: climate regulation, control of soil erosion, regulating water flows, provision of clean water and natural habitats, cultural heritage, provision of taonga (treasured) species for whakairo (carving) and rongoā (medicine), stock shelter, recreation and ecotourism, aesthetics and inspiration, landowner wellbeing, education, sense of place, soil formation and nutrient cycling.

Permanent native forestry issues in the PQF project area

Dispersal limitation

Due to past forest clearance in the PQF project area, old-growth forest remnants are today scarce, and this means forest tree seed sources are equally scarce. Infrequent or low densities of long-distance (landscape scale) dispersal of forest tree seeds means that the probability of dispersal decreases rapidly with increasing distance from seed source (Wotton & Kelly, 2012; Canham et al., 2014).

The absence of those species which represent intact mature natural forest limits the potential of forest succession. Old-growth tree species bring traits of: high biomass, large stature, large fruit size and, in time, high levels of habitat complexity; tree holes for roosting; and host opportunities for epiphyte communities (Weiher et al., 1999). Therefore, those secondary forests which are missing old-growth tree species, whether they have been eliminated or their distribution is strongly aggregated (e.g. to gullies as shown in Figure 2), are limited in their ability to succeed to more advanced forest phases.

Attributes of these secondary forests such as biomass (and carbon sequestration), biodiversity and habitat will be profoundly limited (Forbes et al., 2020). These limitations are particularly problematic where secondary forests are needed to support the biodiversity and sequestration of atmospheric carbon through the accumulation of forest biomass, such as in Aotearoa and also in most parts of the developed world that would be naturally forested.

Figure 2: These isolated old-growth species tōtara and matai have survived in a gully position and are now surrounded by secondary forest

Enrichment planting in the PQF project area

An emerging restoration action, enrichment planting, is the planting of desirable species (in this case old-growth species) into secondary, exotic or degraded forest to overcome the limitations of ecological isolation and dispersal limitation. The seedlings of old-growth forest tree species have specific micro-climate requirements (i.e. they need some shelter) and this means their planting needs to occur into the shelter of existing vegetation cover (Tulod & Norton, 2020). This approach mimics the shelter provided by a forest, where old-growth species would establish naturally (see Figure 3). A challenge with planting seedlings into existing cover is to ensure levels of competition between the existing vegetation and the planted seedlings are sufficient to provide shelter, but not too great that planted seedling growth rates are reduced.

As ecological isolation and dispersal limitation are significant native forestry issues for the PQF project area, the project funded demonstration enrichment planting projects across nine farms in North Canterbury and south-eastern Marlborough. The purpose of this was to show how enrichment planting can be applied in practice in an area subject to significant ecological isolation and dispersal limitations for forest regeneration. Enrichment planting sites featured a range of existing vegetation types, including mānuka and kānuka forest and scrub, native broad-leaved scrub, radiata pine, tree lucerne, exotic broom and gorse, and small-leaved shrubland. Species were selected that represented pre-human mature forest compositions and, due to the current population sizes of feral browsers present across this area of Aotearoa, the species chosen for planting were those recognised as being avoided by ungulates (Table 1; Forsyth et al., 2002).

Herbivory

Since the latter stages of humans arriving in Aotearoa, a range of mammalian species have been introduced and today they form significant domestic and feral populations (hereafter domestic or feral herbivores). Introduced herbivores can significantly alter forest community composition and structure by reducing the abundance of palatable species and promoting non-palatable species.

Feral herbivores can also compete with domestic livestock or place them at risk of disease and damage other aspects of primary production (e.g. horticultural and sylvicultural systems). Although for a period around the 1980s national feral deer populations declined due to the effect of commercial hunting, their numbers were determined to be increasing in the 2000s (Forsyth et al., 2011). Anecdotal evidence from interactions with farmers across mainland New Zealand suggests that feral deer numbers are gradually increasing as of 2019/2020 (Adam Forbes, Personal observation).

While herds of domestic herbivores tend to be well controlled through fencing, populations of feral herbivores such as possum, deer, goat and pig are subject to differing levels of control. The home ranges of the more mobile species can be large, so population management should be expected to cross property boundaries. For instance, red deer (*Cervus elaphus*) can range 100–2,074 ha and up to 11,000 ha (Nugent et al., 2001).

Due to their slow-growing nature, the recovery of our temperate forest ecosystems following herbivore

Figure 3: These naturally recruited kahikatea emerging from secondary broad-leaved forest in Tairāwhiti are an example of what successful enrichment planting would look like

Table 1: Species chosen for inclusion in PQF enrichment planting demonstration project

Scientific name	Common/Māori name	Palatability class
Dacrydium cupressinum	Rimu	Avoided
Fuscospora fusca	Red beech	Avoided
Fuscospora solandri	Black beech	Avoided
Myoporum laetum	Ngaio	Avoided
Olearia paniculata	Golden akeake/ akiraho	Not classified
Pittosporum eugenioides	Lemonwood/tarata	Avoided
Podocarpus laetus	Thin-barked tōtara/ tōtara-kiri-kotukutuku	Not selected
Podocarpus totara	Lowland tōtara	Avoided
Sophora microphylla	Small-leaved kōwhai	Not selected

Note: Palatability classes follow Forsyth et al. (2002). Classes are defined as: Avoided, Not Selected or Preferred. No classification is available for Golden akeake (*O. paniculata*). When considering the palatability classes, it should be considered that ungulates will consume species classed as Avoided, but consumption is less than expected based on availability (Forsyth et al., 2002)

control typically takes decades. The recovery of floristic composition and structure is recognised to require an ecosystem management approach, rather than being achieved by just simply reducing herbivore abundance (Coomes et al., 2002; Wright et al., 2012). In this context, ecosystem management could include interventions such as mimicking disturbance (Forbes et al., 2016; Tulod & Norton, 2020) to optimise competitive interactions, re-introducing lost propagules (enrichment planting), or managing other pests such as invasive vines or shade-tolerant weeds which may inhibit forest regeneration.

While fencing standards exist for feral herbivores, such as deer (see Figure 4) or goats, fencing to protect forests from feral herbivores at large scales or on steep or difficult topography (see Figure 5) is often logistically and economically unviable. Installation costs of >$30 per metre plus earthworks for tracks and fence lines have been reported by farmers in the PQF area. The cost of maintenance, essential to ongoing functionality, is also a significant factor. In addition to the barriers to installing the fence, ongoing maintenance is essential to effective fencing.

Fences near forests are susceptible to damage from tree fall, they may be overgrown by pest plants such as blackberry allowing animals to climb, and over time they lose their structural integrity. This can occur within several years where animals such as goats are pushing against and loosening stables and wires, soon rendering the relatively new fence ineffective. Even when built to standard, the configuration of fencing can lead to weak spots where spooked animals are concentrated/funnelled into and will eventually find their way through, or over, out of desperation (Adam Forbes, Personal observation).

With fencing being out-of-reach as a practical and cost-effective option to defend native forest from feral herbivores at large scales, or on difficult topography, the only viable approach is to actively manage feral animal populations. A range of non-fencing methods for feral mammal control exist, with the main options being poisoning, trapping (including capture and removal), ground-based shooting (professional or recreational and with or without dogs), aerial shooting, Judas animals, fertility control, mustering and commercial harvest. Population management by its very nature needs to be carried out at landscape scales. Suitably resourced cooperative action at a community level therefore presents opportunities for forest restoration at large scales that are practically unattainable through fencing alone.

The important social dimension

Most feral herbivores are viewed collectively as both a pest and a resource (Hughey & Hickling, 2006). Hunting has recreational, economic and social benefits and maintaining feral mammal populations is desirable from these viewpoints. Proposals to control feral animals can conflict with public preferences and create strong negative perceptions and controversy (e.g. the relationship between red deer and New Zealanders, Figgins & Holland, 2012; the 1080 debate, Parliamentary Commissioner for the Environment, 2013). Thus, the topic of feral mammal control is one with the potential to either unite or divide communities and is therefore an issue that requires careful investigation and engagement. A balanced and well-reasoned approach is needed. Unless people are in agreement over types and levels of control, there will be ongoing discord and inefficiency in achieving desirable outcomes for both forests and people.

Several examples exist in the PQF project area where neighbouring landowners have together commissioned aerial hunting operations that have been cost-positive due to the commercial meat salvage and sale, alongside reduced feed competition with livestock. This approach is beneficial in that the control is executed at landscape scales and at very little cost or risk to the landowner. Despite this, sustained, professionally-led and strategic approaches to guide control operations based on current and emerging best practice are needed, with a focus on outcomes rather than animal population numbers per se.

Herbivore management in PQF project area

To investigate the effects on forest composition and structure from differing levels of herbivore access, we surveyed 18 10 x 10 m vegetation plots using the RECCE method (Hurst & Allen, 2007), in part. Plots were located randomly into forest protected (see Figure 6) and unprotected from domestic herbivores. Neither forest was protected from feral ungulates. Plots were on face landforms over an elevation range of 76–187 m above mean sea level on two farms in the southern part of the PQF project area.

Figure 4: Example of a deer fence in the PQF project area installed to protect native forest

Figure 5: Example of steep hill country backed by extensive mountainous wildness area where deer fencing is impractical. Here managing herbivore populations across boundaries is a more achievable (yet still demanding) approach to addressing the effects of herbivory on forest health

A total of 25 woody species were surveyed across all plots, 24 (96% of all species) species in retired and 11 (44% of all species) in non-retired forest. In forests fenced/retired from domestic herbivores, woody species with meaningful levels of cover (Importance Value (IV) >15) were evenly split in levels of cover between species that are preferred by ungulates (combined IV 163) and those that were either not selected or preferred (combined IV 167). In contrast, of the species making up meaningful levels of cover in non-retired forests, only one preferred by ungulates was present (i.e. five finger, IV 14; Table 2). The remaining species were all not selected or were avoided in the diets of ungulates (combined IV 123; Table 2).

No sites were protected from feral ungulates and even the retired site showed signs of deer presence (see Figure 6). The forests where all ungulates were uncontrolled (stock could access freely) had less than half the number of woody species compared to that found in fenced forests. Unfenced forests were missing species of a stature that could form part of the forest canopy in the future. Without recruitment to the forest canopy, as the existing trees senesce and die, these forests will gradually thin and disintegrate.

These data demonstrate that fencing domestic ungulates from native forests is essential for diverse and permanent forest cover and this conclusion has previously been reached in other areas of New Zealand. The data also show that in the PQF project area, even when forest is fenced from stock, feral herbivores are still impacting forest health. In places this effect is severe (with bark stripping, ring barking and only a moderate cover of palatable tree species), and together these factors provide strong indications of detrimental levels of feral ungulates in the PQF project area.

This means that feral herbivores require control across the PQF project area if it is to support diverse, permanent native forest in the long term. In particular, there are anecdotal accounts and evidence from our surveys that feral deer populations are well above population sizes where native forest can regenerate adequately. Where control does not occur, or where feral herbivores are fostered for economic or recreational/cultural reasons, a profound trade-off occurs and native forest health and longevity is significantly compromised. Unless forest management addresses feral herbivores, the native forest estate is limited in its ability to support a diversity of biological life. Factors such as biomass (carbon), biodiversity and ecosystem services will therefore continue to be severely limited.

Achieving a healthy and permanent native forest at a landscape scale will require an ecosystem management approach. This is where animal control is coupled with enrichment planting and mimicked forest disturbance to address local extinction of seed sources (Forbes et al., 2020), and control of other pests to attain conditions where regeneration and succession can proceed (Norton et al., 2018; Coomes et al., 2002). This will in turn require access to information and material support, which is discussed in subsequent sections.

Technical and financial support

Management of existing forests to ensure their permanence

The large area of existing native forests in Aotearoa means native forest is central to our ability to tackle the ongoing biodiversity crisis and also assist with addressing the emerging climate crisis. Despite this, there is currently a profound lack of financial and technical support to assist owners' management of existing forest. Existing forests have to be included in funding mechanisms if we are to secure the services forests provide, such as storing carbon, providing habitats and supporting biota, regulating soil and water quality and quantity, and providing seed sources for natural diversification. The essential and critical physical management actions that need to be supported following an ecosystem management approach are:

- Fencing to exclude domestic stock
- Management of feral herbivories implemented at a community scale
- Management of other pests (e.g. invasive vines and shade-tolerant weeds)
- Enrichment planting to address stalled successions and local species extinctions.

Table 2: Importance values (IVs) of woody species in retired and non-retired forests of the PQF study area

Retired			Non-retired		
Palatability class	Species	IV	Palatability class	Species	IV
Preferred	PSEARB	98	Avoided	KUNROB	64
Avoided	LEUFAS	62	Not selected	LEPJUN	22
Preferred	MELRAM	51	Avoided	COPRHA	21
Avoided	COPRHA	47	Avoided	LEUFAS	16
Avoided	LEPSCO	32	Preferred	PSEARB	14
Avoided	PITTEN	26			
Preferred	COPLUC	14			

Note: Palatability classes follow Forsyth et al., 2002 and A. Forbes' personal observation for *Kunzea*. IVs are the summed cover class scores across all forest tiers as measured in the vegetation survey plots. IV therefore represents a measure of cover with greater weighting given to vegetation occurring in higher elevation tiers. Species IVs in retired (orange columns) and grazed (blue columns) forest of the PQF project area. Species codes are: COPRHA = *Coprosma rhamnoides*, KUNROB = *Kunzea robusta*, LEPJUN = *Leptecophylla juniperina*, LEPSCO = *Leptospermum scoparium*, LEUFAS = *Leucopogon fasciculatus*, MELRAM = *Melicytus ramiflorus*, PITTEN = *Pittosporum tenuifolium* and PSEARB = *Pseudopanax arboreus*

Establishing additional permanent forest area

Stemming the continued decline in the national extent of native forest cover is also essential. Across Aotearoa, 71% (14 million ha) of native forest cover had been lost (Ewers et al., 2006). During 1996–2012, a net

Figure 6: Forest protected from domestic herbivores but still accessible by feral ungulates

loss of 40,000 ha of native shrub and forest occurred (Ministry for the Environment & Statistics NZ, 2018), signalling ongoing declines in native forest cover.

There are several possible approaches to restoring native forest cover. In locations and circumstances where forest species can regenerate, land areas can be reverted from the existing landcover type. Normally these sites are retired exotic grassland with regenerating native scrub, but also woody species such as gorse (Sullivan et al., 2007) or radiata pine (Forbes et al., 2019) can facilitate native forest regeneration, and in this case management focuses on threats to regeneration and limitations on achieving a long-term succession. This style of restoration is less resource intensive (more passive) than planting to establish a native forest canopy. Critically, this method of forest establishment presents options to restore forest cover at scale, which is essential if we are to address our biodiversity and climate crises.

At the other end of the spectrum, active planting can be used at sites where natural regeneration is inadequate to form a forest canopy. This active approach is more resource intensive and costly. In most cases, the area that can be planted is limited by resources or logistics so planting native forests is currently unlikely to be of a meaningful scale for addressing our most pressing environmental concerns. Addressing these concerns at scale requires emphasis on the management of regeneration, following an ecosystem approach and passive restoration principles.

Access to expert advice and adequate funding

Having differentiated active from passive approaches to native forest establishment, there is a need for ready access to free/affordable, expert, independent advice about methods of forest establishment at a given site. One example of this exists, as Te Uru Rākau have for 24 months funded a Restoration Ambassador role to support their One Billion Trees (1BT) programme. This has proven to be an extremely successful extension service throughout mainland New Zealand and the Chatham Islands. The model is now proven and should be scaled-up nationally.

Establishing native forest through planting is currently a relatively expensive exercise. Costs vary depending on a range of factors (e.g. composition, spacing, accessibility, preparation and maintenance requirements). The published cost estimates for planting and five years of maintenance range from $15,250 ha^{-1} (The Aotearoa Circle, 2020) to $25,000–$30,000 ha^{-1} (Douglas et al., 2007). Cost is a barrier for many people who wish to proceed with native forest establishment. The active-to-passive theory goes a long way to address this issue. However, at sites and in circumstances where native forest restoration planting is required, funding a greater proportion of the actual cost (of both planting and fencing) by programmes such as 1BT would enable greater levels of forest establishment.

Recommendations

- In areas of the PQF project area (and nationally) where a forest canopy can establish itself, enrichment planting should be conducted at scale to direct successional development towards diverse, permanent and high-biomass forests representative of pre-human composition and structure
- Feral herbivore populations require greater management to enable the regeneration and succession of native forest species across the PQF project area (and nationally). Community collaborations will be important to achieve forest outcomes at scale, especially given the home range sizes of feral deer. A balanced approach will be required to address the social values ascribed by many to feral herbivores, while still reducing population sizes to levels where native forest species can regenerate
- Overall, improved forest management is needed and this would comprise a bundle of complementary management approaches to enhance forest ecologies such as: mimicking forest disturbance to optimise competitive interactions; reintroducing lost propagules through enrichment planting; or managing pests such as feral herbivores, invasive vines, or shade-tolerant weeds that might inhibit forest regeneration
- Native afforestation grant programmes (such as the 1BT) should be structured to: (1) provide greater support for the improved management of existing forests and forest land; (2) follow a structure that incorporates accepted ecological priorities when allocating grants; (3) give greater support for passive restoration approaches so that restoration can be upscaled; and (4) provide adequate levels of funding and ready access to expert restoration advice.

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Adam Forbes is Managing Director of Forbes Ecology Limited. Email: adam@forbesecology.co.nz

Map of the small-scale forest estate of New Zealand

Bruce Manley, Justin Morgenroth and Cong Xu

Abstract

From 2015 to 2021, final-year Bachelor of Forestry Science (BForSc) students at the University of Canterbury have developed, region by region, a map of the small-scale forest estate in New Zealand. Forest boundaries were mapped in a geographic information system (GIS), based on visual interpretation of aerial photography and satellite imagery. It was found that the mapped area is less than the National Exotic Forest Description (NEFD) estimate of area in eight wood supply regions and exceeds the NEFD area in the other four regions. The total nationwide mapped area is over 90,000 ha less than the NEFD area. The level of NEFD over-estimation is substantial for Central North Island, Canterbury, East Coast, Hawke's Bay and Southland.

The map of the small-scale estate allows the distribution of small-scale forest attributes to be explored, including site productivity (site index and 300 index) and attributes that affect delivered wood cost (slope, distance to public road, distance to port). If combined with LiDAR data, where available, it is also possible to estimate age and forest structure for the small-scale estate.

The study confirms the urgent need for an accurate and up-to-date spatial database of New Zealand's plantation forests. Not only would this provide accurate estimates of plantation area for wood availability forecasting, it would also enable detailed transportation and logistics planning, as well as quantification of the potential wood supply within specified distances from current and potential wood processing sites.

Introduction

New Zealand's small-scale plantation forest estate has become increasingly important for wood production as the large areas of land afforested in the 1990s matures. The Ministry for Primary Industries' Wood Availability Forecasts (WAFs) indicate that, 'For radiata pine, the large-scale owners' forests are able to supply an annual volume of around 19 to 22 million m^3 of logs. … From 2020, the potential wood available from the small-scale owners' forests increases to around 15 million m^3 per annum through to 2035' (MPI, 2016).

However, there is uncertainty about the actual area of the small-scale estate. The 2020 National Exotic Forest Description (NEFD) survey was sent out to all known forest owners with at least 40 ha of plantation forest (NEFD, 2020). This survey accounts for 1,380,000 ha. There is an additional 12,000 ha of previously surveyed resource that is less than 40 ha, plus 67,000 ha derived from a survey of small-scale forest growers carried out in 2004. The final 203,000 ha of area in the NEFD is imputation of new planting in 1992 to 2006. For these years additional areas, not directly captured in the NEFD surveys, were estimated based on annual nursery surveys that measured the sales of planting stock. Imputation was stopped after 2006 because of the low new land planting rate.

For 1992 to 2006, the total number of seedlings sold was used to estimate the total area of planting each year and, by subtracting the area of replanting, the area of new planting was estimated. The national new planting adjustment was calculated by subtracting the new planting area captured in the NEFD survey from this estimate of the total area of new planting. The national new planting adjustment for each year was distributed into territorial authorities (TAs) using the proportions indicated from the new planting collected in the NEFD survey (MPI, 2020). Consequently, there are questions about the estimated total area of the small-scale estate in New Zealand and its distribution by TA.

Since 2015, Management Case Study, the capstone course taken by all BForSc students at the University of Canterbury, has focused on improving our knowledge of the small-scale forest estate. Each year the small-scale estate in one or a number of wood supply regions has been mapped:

- 2015 Canterbury
- 2016 Otago and Southland
- 2017 Southern North Island
- 2018 Hawke's Bay and East Coast
- 2019 Marlborough, Nelson and West Coast
- 2020 Central North Island
- 2021 Northland (initial mapping done in 2020).

Results for the earlier years have been published. Manley et al. (2017) summarises results for Canterbury, Otago and Southland, while Manley et al. (2020) covers East Coast, Hawke's Bay and Southern North Island. The purpose here is to provide a summary of results for all regions, in particular:

- What is the area of the small-scale estate in each wood supply region?
- How do estimates of area compare to those of the NEFD?
- What are key attributes of the small-scale estate?

Methods

The definition of large-scale owners used here is the same as used in the 2014 MPI WAFs, i.e. large-scale owners are those owners that provided harvest intentions for the WAFs. Consequently, there was no defined size cut-off – rather a set of large-scale owners was defined for each wood supply region. All other owners in each region were deemed to be small-scale owners. The same set of large-scale owners has been used for mapping the small-scale estate and for determining the NEFD estimates for each region.

The general approach was that the small-scale estate was mapped and the area calculated and compared with NEFD estimates. The small-scale estate was characterised by slope, Euclidean distance to public road and network distance to nearest port. Finally, productivity estimates were obtained.

Small-scale forest area mapping

Orthorectified aerial photography (resolution 30–50 cm) was primarily used for forest boundary mapping. All aerial photos were downloaded or ordered from the Land Information New Zealand Data Service. Sentinel imagery acquired in summer 2018–2019 (CNI and Northland) or 2016–2017 (all other regions) were provided by the Ministry for the Environment and used to update the status of forests, i.e. whether they were still stocked or were harvested.

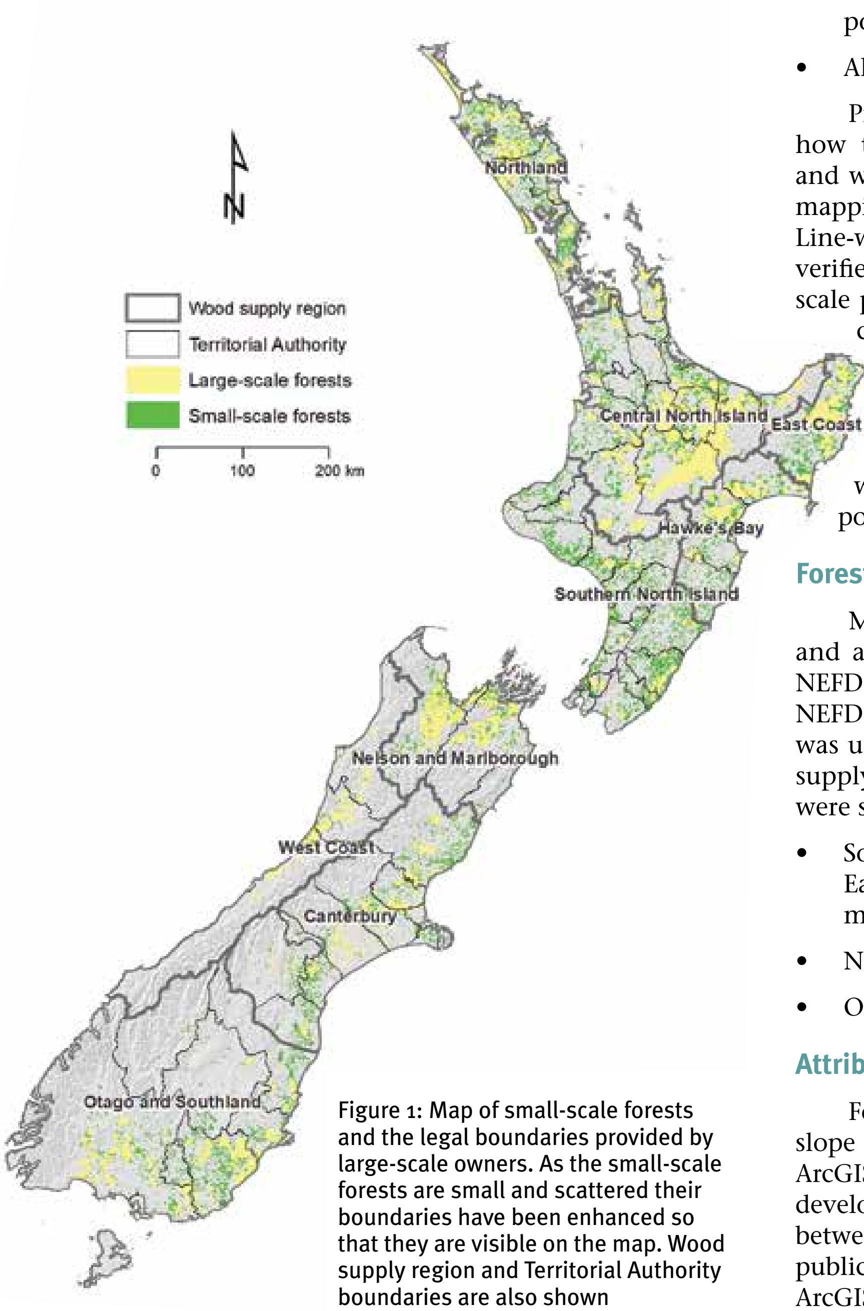

Figure 1: Map of small-scale forests and the legal boundaries provided by large-scale owners. As the small-scale forests are small and scattered their boundaries have been enhanced so that they are visible on the map. Wood supply region and Territorial Authority boundaries are also shown

A mask was applied to the study areas to exclude large-scale plantation forests (with boundaries provided by forest owners – the same set of large-scale owners was used as for the MPI WAFs). Small-scale forests on all land outside this mask, including harvested area awaiting restocking, were systematically mapped in ArcGIS using the following rules:

- The area had to be over 1 ha and greater than 30 m wide, but the 1 ha rule was relaxed when there were contiguous small blocks that added to over 1 ha
- Gaps over 0.1 ha were excluded from the forest area polygons
- All mapping was done at a scale of 1:4,000 or greater.

Prior to mapping, students received training on how to identify plantation forests in aerial imagery, and were also taught best practices for forest boundary mapping. Quality control of mapping was undertaken. Line-work for all polygons mapped by students was verified, and checks were made to ensure that all small-scale plantations had been included and no other land covers had been inadvertently included as small-scale plantations. These steps ensured forest boundary mapping was accurate and minimised omission and commission errors. Every polygon mapped by the students as well as its classification was independently checked by experienced postgraduate students.

Forest area comparisons

Mapped forest areas, including both stocked area and area awaiting restocking, were compared against NEFD estimates. For the comparison, the total of the NEFD stocked area and area awaiting restocking classes was used. Comparison was done on the basis of wood supply region or sub-region. Three wood supply regions were split into sub-regions:

- Southern North Island into SNI-West and SNI-East based on the Ruahine, Tararua and Remutaka mountain ranges
- Nelson/Marlborough into Nelson and Marlborough
- Otago/Southland into Otago and Southland.

Attributes

For each mapped small-scale forest, the average slope was derived using the 'Zonal Statistics' tool in ArcGIS, with the input of a 25-m Digital Elevation Model developed by Landcare Research. The Euclidean distance between the forest polygon centroid and the nearest public road was calculated using the 'Near' function in ArcGIS. On-road network distance to log export port was estimated for each mapped forest using the 'Network Analyst' in ArcGIS. The distance between each forest and port was calculated as the sum of the distance to nearest public road and on-road distance. Site productivity for each forest was obtained using the Kimberley et al. (2017) surfaces for site index and 300 index.

Results

Small-scale forest area

Mapped area of the small-scale estate is shown in Figure 1, together with the legal boundaries provided by large-scale owners. Mapped areas are compared with the NEFD area for each wood supply region (or sub-region) in Table 1. The NEFD area is for the latest year available at the time mapping was done. Although there is a lag of up to two years, it is unlikely this made much difference to the reported NEFD area for the small-scale estate.

Given that the mapping has been done over a six-year period the focus should be on the differences for each region (or sub-region) rather than the national totals. The mapped area is less than the NEFD area in eight wood supply regions and exceeds the NEFD area in the other four regions. The level of NEFD over-estimation is substantial for Central North Island, Canterbury, East Coast, Hawke's Bay and Southland. The total mapped area is over 90,000 ha less than the NEFD area.

Table 1: Area of small-scale estate in each wood supply region or sub-region. Mapped areas are compared with NEFD estimates. The Northland area is provisional and awaiting final confirmation

Wood supply region	Year mapped	NEFD as at	Mapped area (ha)	NEFD area (ha)	Difference (ha)
Canterbury	2015	2014	39,864	70,561	−30,697
Otago	2016	2015	41,665	43,519	−1,854
Southland	2016	2015	24,376	32,665	−8,289
SNI-West	2017	2016	75,051	74,676	375
SNI-East	2017	2016	52,721	51,723	998
Hawke's Bay	2018	2016	58,118	66,778	−8,660
East Coast	2018	2016	62,441	75,056	−12,615
Nelson	2019	2017	23,982	22,687	1,295
Marlborough	2019	2017	33,843	35,813	−1,971
West Coast	2019	2017	5,256	6,313	−1,057
CNI	2020	2019	117,446	154,198	−36,751
Northland	2020	2019	82,263[p]	74,878	7,385
Total			**617,026**	**708,867**	−91,841

Attributes

Site productivity

There is a general north-to-south pattern of reducing site productivity (Table 2). East Coast has the highest average site productivity and Canterbury the lowest. Within all regions there is a wide range of site quality (Figures 2 and 3).

Table 2: Average values for key attributes of the small-scale estate in each wood supply region or sub-region. Averages are calculated on an area-weighted basis

Wood supply region	Site index (m)	300 index (m^3/ha/year)	Slope (degrees)	Distance to public road (km)	Distance to port (km)
Northland	31.7	29.3	17	0.20	115
CNI	33.3	31.6	20	0.27	129
East Coast	32.3	35.3	26	0.35	75
Hawke's Bay	32.2	32.9	24	0.14	74
SNI East	30.5	32.2	23	0.44	137
SNI West	31.2	32.2	24	0.24	129
Marlborough	28.6	27.2	31	0.62	61
Nelson	29.8	27.1	27	0.24	67
West Coast	28.4	25.2	7	0.19	239
Canterbury	24.1	24.1	18	0.38	79
Otago	24.6	26.0	17	0.22	100
Southland	24.4	27.0	14	0.41	110
NZ	30.2	30.3	21	0.29	106

Attributes affecting delivered wood cost

Key attributes that affect delivered wood cost and hence harvest viability are:

- Slope (Figure 4), which influences harvesting and roading costs
- Distance to nearest public road (Figure 5), which influences roading cost
- Distance to nearest port (Figure 6), which influences transport cost.

Some patterns are evident in the distribution of these attributes by region:

- The West Coast stands out as having a high proportion of small-scale forest on flat sites, while Marlborough and Nelson have a high proportion on steep sites (Figure 4)
- All regions have a similar distribution for distance to public road. The distributions are skewed with the majority of small-scale forests being less than 0.1 km from a public road but with a small proportion over 1 km from a public road (Figure 5)
- East Coast, Marlborough and Nelson have the majority of small-scale forests within 60 km of a port. Most of the West Coast small-scale forest is at least 240 km from an export log port (Figure 6).

Discussion

The results presented here confirm those of Manley et al. (2017) and Manley et al. (2020). The small-scale estate is an increasingly important component of the New Zealand estate, yet this country's Tier 1 database (the NEFD) does not accurately estimate the total area of the small-scale estate and, by extension, the total New Zealand plantation area.

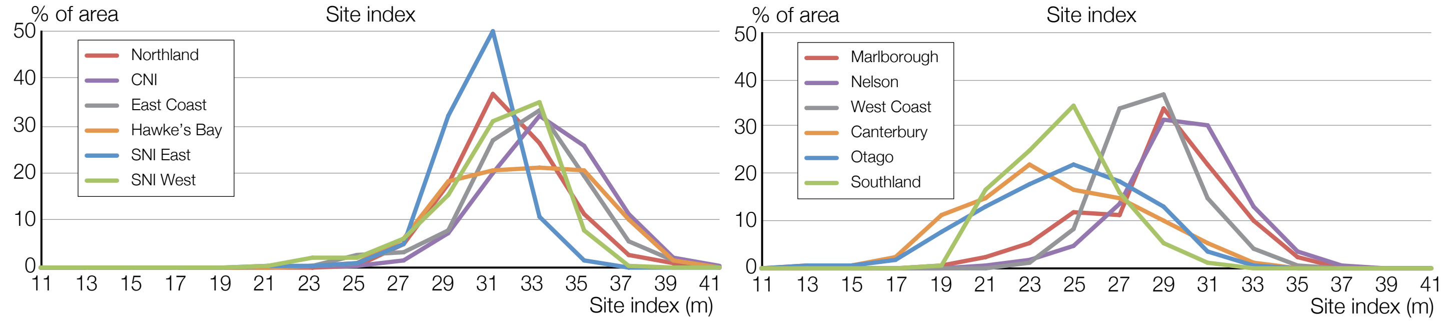

Figure 2: Distribution of site index by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 2 m classes with the site index shown being the mid-point of the class

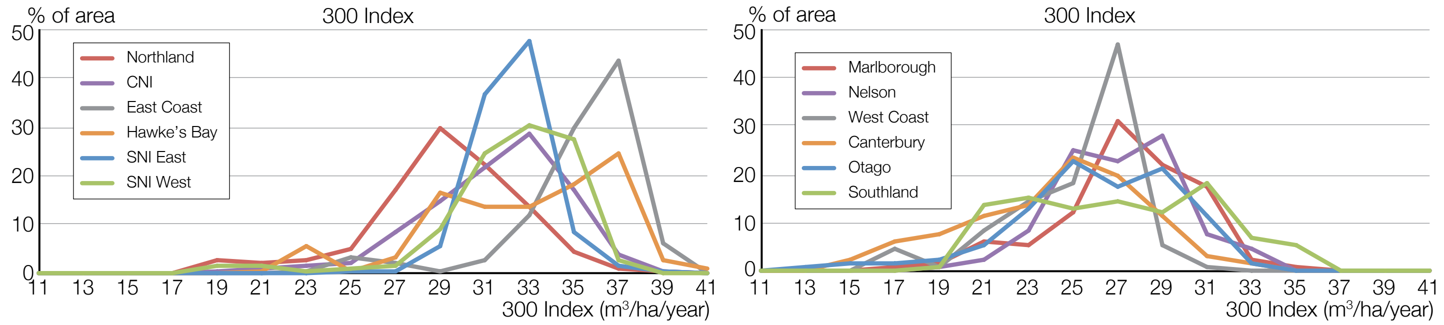

Figure 3: Distribution of 300 index by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 2 m³/ha/year classes with the 300 index shown being the mid-point of the class

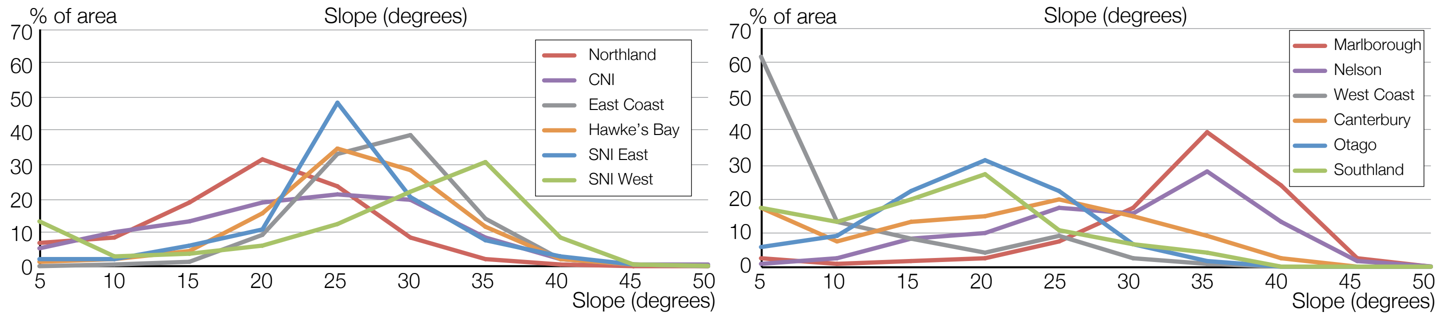

Figure 4: Distribution of slope by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 5 degree classes with the slope shown being the maximum of the class

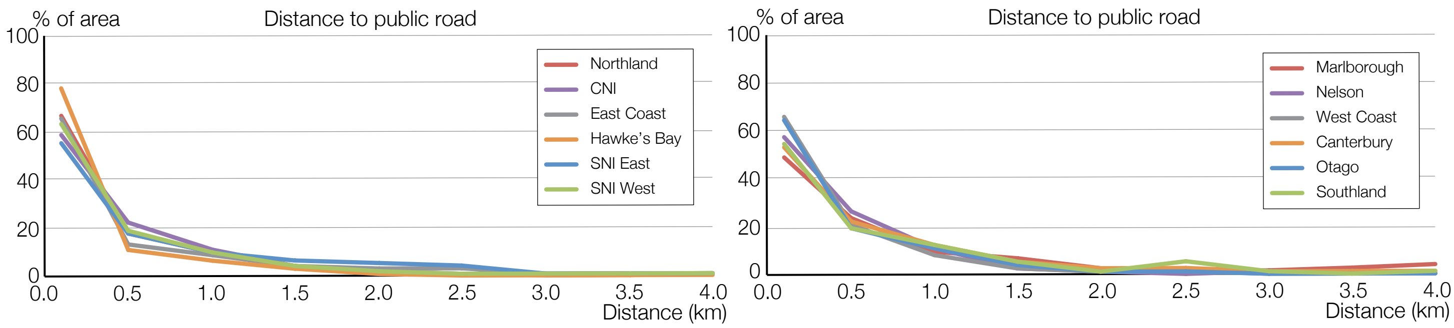

Figure 5: Distribution of distance to public road by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 0.5 km classes (apart from the first class being for distances of 0 to 0.1 km and the second class for 0.1 to 0.5 km) with the distance shown being the maximum of the class

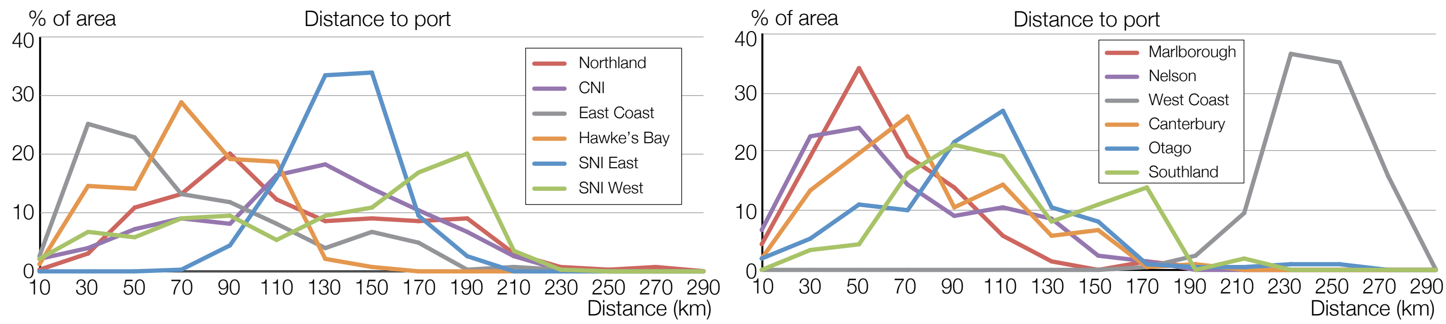

Figure 6: Distribution of distance to port by wood supply region in New Zealand's North (left) and South (right) Islands. Area is graphed by 20 km classes with the distance shown being the mid-point of the class

It is evident that, overall, the NEFD over-estimates the area of the small-scale estate, which has implications for a range of applications including wood availability forecasting. Since 2007, the small-scale owner's estate had generally been reduced by 15% for the purpose of wood availability forecasting. This reduction has been applied because small-scale area is often reported on a gross rather than a net stocked area basis. In hindsight, it is apparent that this reduction has been too great for some regions, but too low for others.

The results confirm the need for an accurate spatial database of New Zealand plantations. The case studies undertaken by BForSc students have shown that it is possible to develop an accurate base map of small-scale plantations. Now that this is achieved it is possible to use satellite imagery to update the status of the area, i.e. when it is harvested. With the availability of LiDAR coverage comes the opportunity to estimate stand height.

In Management Case Study in 2021, students are using the canopy height model derived from LiDAR in Northland, in conjunction with the Kimberley et al. (2017) site index layer, to estimate stand age and hence planting year. Using both LiDAR and satellite imagery there is the potential to estimate standing volume (Xu et al., 2018), thus making it possible to forecast the annual wood volumes available from small-scale forests.

Acknowledgements

The basic work reported here was undertaken by final year BForSc students from 2015 to 2021. Their substantial effort and the support of MPI is gratefully acknowledged.

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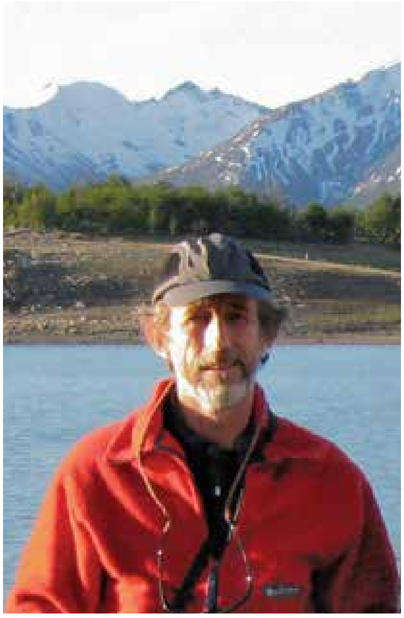
Bruce Manley is Head of School and Professor of Forest Management at the School of Forestry at the University of Canterbury in Christchurch. Justin Morgenroth is Associate Professor in Geospatial Technologies and Cong (Vega) Xu is WIDE Trust Lecturer in Geospatial Technologies. Corresponding author: bruce.manley@canterbury.ac.nz

John Bolton Novis
22 September 1954 – 7 January 2021

Prepared by Paul Lane, Rob Miller, Alan Reid, Kay Shapland and Parnell Trost

John epitomised the values that many of us seek to achieve, but can never fully attain – with his strong professional and personal ethics, his desire to get to the heart of a problem, and ensuring that family comes first. Anyone who worked with him for any length of time recognised his dedication to the forestry sector and to supporting the industry through sound and reasoned policy and planning. John was not afraid to take a contradictory position if he thought the evidence did not support a particular approach, but he also agreed with Einstein that imagination is needed to make the big leaps.



University, NZFS and Ministry work

John Bolton Novis (B. For. Sc., M. Appl. Sc.) was born in 1954 and spent most of his early life in North Canterbury, gaining an appreciation for the outdoors, and building his lifelong interests in fishing, swimming and running. Rugby was another passion, although his active participation was interrupted by injury while still at secondary school. His major frustration over the past six years was how his health prevented him from actively pursuing these activities, in particular pitting his wits against trout and salmon at his favourite fishing spots in the Canterbury high country and in the Waiau and Hurunui Rivers.

His early life experiences shaped his career path, and in his final year at high school he was offered a forester trainee position in the NZ Forest Service, which he took up in 1972. This decision started an almost 50-year involvement in forestry. After his initial induction course in Rotorua, John settled into four years at the University of Canterbury, where his dissertation was on the epidemiology of poplar rust in Canterbury. He lamented on more than one occasion the loss of this pathway into training and the industry.

John's initial training and Forest Service experience will be familiar to many of those reading this. For example, stints of up to six weeks in the bush undertaking survey work in some of New Zealand's remoter regions, including western Fiordland. This experience equipped him for his subsequent work on indigenous forestry and high country management at the Forest and Range Experimental Station. This was followed by stints at Ashley Forest and Westport, and a year of travel in North and South America.

Having worked through his accumulated savings, John returned to New Zealand in 1980 to complete a Master of Applied Science (with First Class Honours) at Lincoln College, where he examined the energy requirements of exotic production forestry.

The leap from forest management to forest policy occurred in 1982 when John moved to Wellington, initially with the Forest Service and then the Ministry of Forestry. His detailed analysis of issues and ability to strategically assess the implications of proposals was soon recognised, and he was drawn into many of the planning, environmental and research issues of the day. He was also actively involved in the work of the New Zealand Institute of Forestry, serving as both a national councillor and secretary, over two terms from the mid-1980s through to the early 1990s.

During this period John authored (or co-authored) publications on the National Exotic Forest Description (NEFD) system, predicted wood supply and the use of land resource inventory material in rural planning. Two of the highlights that remained with him from the 1980s and 1990s was his time as secretary to the Forest Industries Council, where he worked with the key decision-makers of the day, and being called on to support the Office of the Parliamentary Commissioner for the Environment on a major research project.

John returned to Canterbury in the early 1990s, and over the next 15 years he was heavily involved in the first generation of district and regional plans in Canterbury and on the West Coast, initially for the Ministry of Forestry and subsequently for the Ministry

'If you apply common sense, you won't go wrong.'

of Agriculture and Forestry (MAF). His considered views on land use planning and assessment were taken up by his colleagues across New Zealand in their own work (and submissions) on district and regional plans.

John would say that the 1990s was a time of 'personal restructuring' for him, following his marriage to Lisa and the birth of Sarah and Anna. He reduced his hours to be fully involved in bringing up the family and in supporting Lisa.

Benchmark projects

With the creation of MAF in 1998, he brought his skills to that Ministry and later the Ministry for Primary Industry's regional policy team. His experience in resource planning was readily welcomed and he created a niche for himself in leading a number of substantial project areas. His focus remained on forest policy, as was illustrated in the 2002 publication he co-authored with David Rhodes on *The Impact of Incentives on the Development of Plantation Forest Resources in New Zealand*.

During the 2000s and 2010s John led, or made major contributions to, a number of benchmark projects which have helped to build broader community understanding of the forest industry, and of the strides that the sector has made in sustainable resource use. These included the 2009 Forestry Sector Study and the five-yearly Montréal Process country reports on sustainable forest management. As part of this work he participated in several international fora, including the New Zealand delegation to the 13th World Forestry Congress held in Buenos Aires in 2009.

Through each of these projects he sought to raise the image of the industry, demonstrate the connectedness of the sector and better inform the wider public on key areas of forestry activity. His work on the Montréal Process has ensured that New Zealand's progress on sustainable forest management was well documented and benchmarked against key indicators. In these five-yearly reports he ably brought together the issues and information relevant to sustainable forestry and how they are applied to forest management in New Zealand.

Forest resource statistics

An enduring issue for John was the need to improve the quality and value of New Zealand's forest resource statistics. He had a close association with the design and delivery of the NEFD for over 35 years, and in more recent years he managed the annual commercial nursery survey and the preparation of the 2014–16 national wood availability forecasts. The notes he left for his colleagues on his retirement included recommendations for further improving the data collection system.

Integrity and commitment

John will be remembered for his personal integrity and commitment to an industry he devoted almost 50 years to. For his friends and colleagues, it will be his dry sense of humour, tenacity and loyalty that we will recall over the coming years. We all wish that his health had not robbed him of the retirement he richly deserved and of the years he should have shared with Lisa, their daughters and his wider family.

Domestication of Radiata Pine

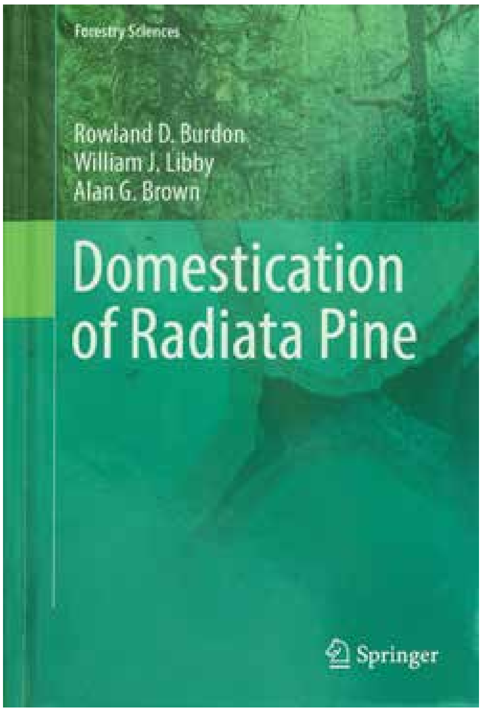
Reviewed by Brian Swale

Authors: Rowland D. Burdon, William J. Libby and Alan G. Brown
Year: 2017
Pages: 480
ISBN: 978-3-319-65017-3
Publisher: Springer Nature (Forestry Sciences, Vol 83)

First impressions – it's heavy, it's expensive and at $400 hard copy it is nearly a dollar a page. The quality is excellent; it has been superbly printed and bound. It has been said of Beethoven that none of his music had too many notes, or too few. Similar could be said of this book. The English is concise and taut. With a broad audience in mind it is written throughout in plain English. It is a great pity the price is so high; as a result the wide readership that lead author Rowland Burdon hopes for may well never materialise.

Rowland and I are of an age – we joined the New Zealand Forest Service as so-called Technical Trainees in the 1956 intake and met at the Forestry Training Centre at Whakarewarewa, Rotorua. He had genetics as a career focus from an early date, which was different from the rest of us trainees, and has maintained that focus.

The *Introduction* covers the processes of domestication and a historical preview of the radiata pine story. The *Early History: 7,000,000 Years Ago to 1901 C.E.* chapter describes five small native forests – three in California and two on Mexican islands. It delves into their probable and known history at the hands of indigenous Americans and later colonisers, also covering the expected effects of the utilisation of these small forests on residual tree genetics. This is very good historical research.



The *Early Plantation Period: 1902–1951* chapter covers early strategic planning for major plantations and the use of indigenous forests, as well as the choice of radiata, especially in New Zealand. Detailed information is given about radiata pine forestry in Chile, Australia and elsewhere.

The Beginnings of Genetic Improvement: 1952–1968 outlines genetics theory, covering concepts and principles that are vital for quantitative genetics and breeding, and then discusses their application to radiata pine. It also contains detail on intensive breeding, including choice of traits, seed orchards, genetic trials and mating designs.

In *Development of the Management Concept While Tree Improvement Shifts Gears: 1969–1983*, it is noted that in order to take advantage of improvements in radiata pine genetics it was soon evident that many forest management processes needed to be altered. This took time, and trial and error. This period was one of intensive learning, and the development and application of new techniques, and it was an exciting time for those involved.

Towards More Precise Genetic Control: 1984–1997 is perhaps the most complex chapter. The author has written about a bewildering collection of changes to forest ownership, which predictably interacted with experiments and functions such as seed orchards on land and in forests with altering ownership or custody. The advent of many private companies, where formerly there were mostly just three main players (including the NZFS), led to significant loss of information sharing. Nevertheless, major advances on several genetic fronts were achieved. This included propagation technology, systems for guaranteeing genetic quality, more focus on the genetic improvement of wood properties, and the commencement of molecular genetics programmes with radiata pine. Computer models were also developed to assist growers make better decisions on silvicultural strategies.

A Wild Ride; 1998 Onwards commences with reference to the December 1997 IUFRO conference 'Genetics of Radiata Pine', which may have been the last such conference untrammelled by the proprietary prohibition of the use of company research findings. In addition, forest ownership was very fluid, beginning with the axing of the state's NZFS. Much the same applied to forestry research organisations and their funding models. Organisations investing in forestry (to primarily finance areas such as superannuation funds) became more common. The existence of coordinated forestry objectives for the benefit of the nation largely vanished, except for research using plots located in ex-state forests where their existence was protected by covenant. This chapter covers a wide range of topics including LIDAR, but most of the focus is on a range of genetic experimentation processes.

The *In Retrospect* chapter details the amenity of radiata pine to domestication, commercial forestry as a business model, the role of radiata in the development of plantation forestry, forest management systems (including the tending regime conundrum), and the modelling of growth and outturns. The final chapter – *The Future* – looks at most aspects of forestry, with radiata as the prime concern. Sections include: Domestication gaps and their implications; Main issues and drivers of the future (why will the species be grown, where, and how will it be grown, what will be the course of continuing genetic improvement, and what will be the impacts of institutional and political factors); and the Clonal forestry goal.

One aspect of this book, which sets it apart from many other books in this field, is that the professionals who did the work are actually named. Since many readers will not have easy access to much of the literature, this is a due recognition of achievement. Compare this aspect of authorship with one where significant developments in forest management processes are noted in passing, but the professionals who created them (and who mostly did not record the events in published papers) go unrecognised. I personally knew very many of the scientists named in this book and find this aspect very satisfying.

This book had a very long gestation period, starting with Ib Thulin in the 1970s. After Thulin's death William Libby had a major role in assembling the material, but eventually (due to other work constraints) this fell to Rowland. All three authors are to be highly commended, but this book will remain a fitting, lasting monument to his lifetime of expert research, insight and leadership in this most important facet of exotic forestry in New Zealand.

At this point it is important to digress from purely reviewing this book. To remind the current readership about the history of involvement of a major state organisation – the NZFS – in both exotic and indigenous forestry in New Zealand, and the huge changes wrought by political upheaval in the 1980s, it is worth mentioning other significant books which cover this background. *Domestication of Radiata Pine* is an important member of this cohort. A list of these publications is given below in the 'Further reading' section and this book is an important member of this cohort.

Alex Entrican (b. 28 January 1898; d. 21 April 1965), father of Elizabeth Orr who is one of the authors in this list, was Director of the Forest Service from 1939 to December 1961 and a university-trained engineer. He understood the value of such training and persuaded T.T.C. Birch, then Director of Training and of Research, to initiate a process of selecting candidates for university-level degree training, first in New Zealand and then to complete a degree overseas in forestry management. The reason was there was at that the time there was no such faculty in New Zealand because both schools had been closed due to the 1930s economic depression. He wanted our government-owned forests to be managed in a science-based professional manner. Hence, the NZFS developed a cadre of such staff who adopted the group title of 'Forester'. The NZFS was a team of 3,000 and benefited from widespread cooperation and sharing, and sites and effort were willingly made available in support of the common goal of progress for the sake of New Zealand.

In conclusion, the depth of research into historical and political matters is excellent (in addition to general forestry and genetics), and the authorship is meticulous. For these facts alone this book will endure.

Note that this book is print on demand (my volume was printed in Australia). For those who cannot afford the hard copy price mentioned above, Amazon have been selling very low numbers at give-away prices and also have an e-version at lower cost.

Further reading

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Brian Swale retired from active participation in forest management 34 years ago. He obtained his Masters in Forestry from the University of Oxford. As a professional forester he worked for the NZFS at Balmoral Forest, Ashley Forest ad Kaingaroa Forest. He was based at the Canterbury Conservancy as an NZFS Senior Forester, after which he worked at MAF Fisheries. Email: bj@caverock.net.nz

A Path Through the Trees

Reviewed by Julie Collins

Author: Vivien Edwards
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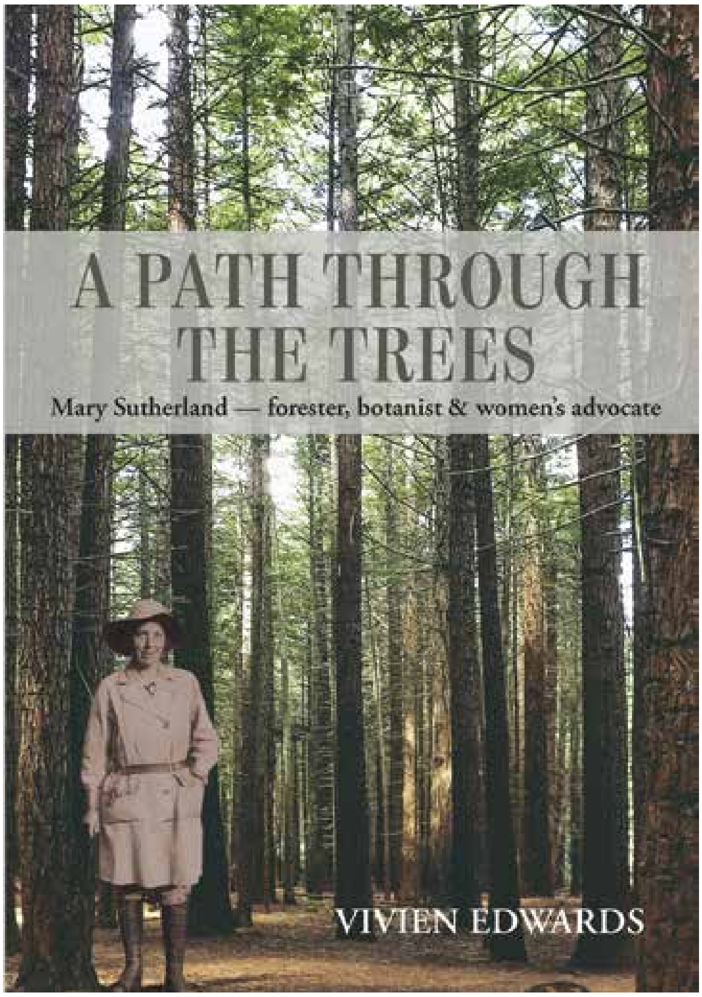
New Zealand history is going through a renaissance of sorts. As a country we have matured enough that we can now celebrate our own history and tell the stories of our own remarkable people. Vivien Edwards has written about one of these remarkable people – Mary Sutherland (1893–1955) – the first woman forestry graduate in the world and a pioneer of tertiary education in New Zealand for women.



Forestry graduate and career

Edwards was inspired to write the story of Mary Sutherland after discovering a plaque dedicated to the forester in the Redwood Grove at Whakarewarewa Forest in Rotorua.

Her research discovered a woman who was dedicated to promoting tertiary education to women, as well as afforestation, and who had a passion for living life the way she wanted to.

Born in the late 1800s in Wales, forestry wasn't a natural career path for women. However, having a mother who valued educating girls, the First World War and the opportunity to move to New Zealand all played defining roles in Mary's life.

For author Vivien Edwards, it is clear through her research she has come to admire and be inspired by Mary. Her writing allows the reader to almost feel as though they are with her as she led teams of women through the forests of Britain trying to secure the timber supply chain while the men who traditionally held these roles went off to war. Unfortunately for Mary, once the men began returning they were given roles in forestry despite her being vastly more experienced and qualified.

So in 1923, unemployed and 30 years old, she decided to join her sister in New Zealand. Here she was intrigued by the State Forest Service and landed a clerical role. This experience gave her the time to learn about New Zealand's native trees and the landscape they thrived in.

Finally, in 1924, she was able to secure a role as a forest assistant and was back among forests. Here she worked closely with forestry rangers, impressing them with her knowledge and work ethic. Mary carried out major pieces of research and in 1934 published a paper on the *Pinus* genus. Eventually, while working in the forests, she became known simply as the 'Lady Ranger' to her colleagues.

Sadly, when the forest service downsized Mary was once again out of work, but this led to a new interest – botany. While her first role in this field was at the Wellington Dominion Museum with an initial job title of clerk, she was eventually formally acknowledged as a botanist. In 1946, she became a farm forestry specialist for the Department of Agriculture and wrote about farms and forestry, an area that continues to be increasingly relevant today.

Vivien Edwards has not only delivered the story of New Zealand and the world's first woman forestry graduate, she has also told the story of how the forest service in this country has grown from strength to strength.

Tertiary education advocate

The legacy of Mary Sutherland is not only the work she did in forestry, but in her advocacy for tertiary education for women, having come from a family who advocated for this. Mary clearly understood how lucky she was to be educated because she went on to work against barriers to the tertiary education of women. In 1932, she joined the New Zealand Federation of University Women and was also elected to the New Zealand Foresters Council.

However, it was not until 1974 that the first woman in New Zealand graduated from the recently re-opened School of Forestry in Canterbury. This was nearly 60 years after Mary began her forestry journey that took her from Wales to what must have seemed like a whole new world in New Zealand. But she never seemed to lose her sense of loss of her home country and for the outdoors, and on her death she left a bequest to the Pearson Fresh Air Fund. This Fund provided opportunities for British children living in urban centres to experience the countryside.

She is also remembered by Bangor University in Wales because 100 years after she first graduated they established the Mary Sutherland award for the best female graduate. Here the scholarship is available to students at a New Zealand polytechnic and is offered by the NZIF Foundation.

As this country continues to work hard to attract women to the primary sector, her story and life serve as an inspiration. Vivien Edwards' book is not only about Mary Sutherland, but is an acknowledgement that the history of strong women in this country is one we should celebrate.

Julie Collins is Deputy Director General Policy and Trade at MPI and was NZIF Forester of the Year in 2020. Email: julie.collins@mpi.govt.nz

Politics in the Year of the Rat

David Rhodes

Mix two parts COVID with one part election year and garnish with global protectionism and climate change. Aside from being a recipe for a full plate, this past Year of the Rat tested the industry like few before. So, what did we learn?

Well, we discovered just how quickly and extensively the Government can assume near wartime powers. Under the unchallengeable banner of saving both lives and jobs the Government passed, literally overnight, legislation governing taxation, social security, immigration, capital expenditure, official information, tenancies and public health.

A short extract from the Imprest Supply Act sums it up – 'Capital expenditure may, during the 2019/20 year, be incurred in advance of appropriation in relation to any Vote.' Capped of course. Let's say no more than $10 billion.

Invoking these powers gave our industry some of the protection it vitally needed. Many of our contractors peered into the abyss and would have gone there were it not for government measures. However, it will be equally reassuring to see those powers put back in the bottle once we have COVID under control.

We rediscovered in the crisis, when the discretionary is stripped away from the essential, that you are left looking at the bedrock of the economy and that largely comprises the primary sector. Early in the emergence of the virus we had collective Ministers stressing to us their reliance on primary production businesses to restore the economy and indeed take a more prominent role beyond COVID. We also learnt how quickly and effectively the industry can cooperate when it needs to. The short-order development of COVID forestry safety protocols, spearheaded by FISC and FICA, is testimony to that.

We observed also how exciting life can be when a minor party needs a pre-election boost to its profile. Slow walking, but not so slow talking, Jones and his self-titled Log Mongers' Bill left us only five working days for submissions and a couple more for a hand-picked select committee. The Bill was both good and bad. Rose-smelling elements of the Bill dealing with increased professionalism and protection were wrapped up in an omnibus, uncosted, package that felt like something the cat had left behind.

What followed had to follow, but was divisive for the industry and could have been avoided. We had a reminder that haste and policy setting are not good companions. In *Unbridled Power? An Interpretation of New Zealand's Constitution and Government*, Geoffrey Palmer included a chapter entitled 'The Fastest Law in the West'. This was not a compliment, and we should have moved on from those days.

With the COVID crisis and an election campaign in lock-step, there was only media room for the party making the calls. Both James Shaw and Shane Jones talked to me about the challenge to gain any sunlight when living under the media halo of the PM. Minister Jones was a champion for the sector and deserves to be recorded as such. He passionately believed in increased benefit for New Zealand, communicated strongly with the sector at all levels, defended and promoted forestry, reinvigorated forest policy within government and invested some putea.

And this was another lesson. Under MMP politics the influence of a minor coalition partner is inversely proportional to its size. The One Billion Trees programme was such an illustration.

One Cabinet Minister who wanted the forestry portfolio was followed by another who desired it and had forestry credentials. But the new Labour Government's increased support meant it had fresh rural friends it didn't want to alienate. This encouraged Ministerial suggestions that we may need to look at new controls on forest planting. Ironically, rules that dictate what can be grown on private property have almost zero support by anyone truly representing the primary sector.

Classically, the Government has many agendas running at the same time. It wants to remain on-side with the rural sector, but it wants to meet climate change goals as well. It plans to reduce agriculture emissions and have more native planting, but it also intends to employ more people and generate higher returns from the primary sector.

As the Year of the Rat came to an end, the Climate Change Commission delivered its 180-page blueprint for resolving these tensions. Exotic plantation forestry is its key to filling carbon gaps until at least 2035. The Commission is budgeting on 380,000 ha of new forestry to remove a huge volume of emissions by 2050 – more than a quarter of New Zealand's current total. It was yet another reminder that no matter how much you play around with the variables of the emissions reduction equation it cannot be solved without the forestry and the wood products industries playing a key role.

Maybe it's fitting we are now in the Year of the Ox.

Email: david.rhodes@nzfoa.org.nz

NZIF FOUNDATION

Appeal for Funds



Please help us to help NZ Forestry?

The NZIF Foundation was established in 2011 to support forestry education, research and training through the provision of grants, scholarships and prizes, promoting the acquisition, development and dissemination of forestry-related knowledge and information, and other activities.

The Foundation's capital has come from donations by the NZ Institute of Forestry and NZIF members. With this, the Board has been able to offer three student scholarships and a travel award each year. It has also offered prizes for student poster competitions at NZIF conferences.

To make a real difference to New Zealand forestry, including being able to offer more and bigger scholarships and grants, the Board needs to grow the Foundation's funds. Consequently it is appealing for donations, large and small, from individuals, companies and organisations.

The Board will consider donations tagged for a specific purpose that meets the charitable requirements of the trust deed. A recent example has seen funds raised to create an award in memory of Jon Dey who was known to many in New Zealand forestry. Donations for that award are still being sought.

The Foundation is a registered charity (CC47691) and donations to it are eligible for tax credits.

To make a donation, to discuss proposals for a targeted award or for further information, please email foundation@nzif.org.nz or phone +64 4 974 8421.

Make a donation today.