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Science, policy, and sustainable indigenous forestry in New Zealand

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Abstract

Background: Over 80% of New Zealand's indigenous forests are in public ownership with logging prohibited, and logging of private indigenous forests is restricted to sustainable harvesting only. Such limitations are highly unusual globally and were imposed only in the last few decades of the 20th century. Previously, the national goal had been indigenous wood production in perpetuity. Here we review the role of forestry science in this outcome, and in particular in relation to the policies and practices adopted by the New Zealand Forest Service.

Methods: Literature review.

Results: As early as 1900, it was recognised that economically viable management of indigenous forests for timber production was marginal at best. Nevertheless, the Forest Service, from its formation in 1919 to its abolition in 1987, advocated sustainable commercial management of indigenous forests. However, it failed to bring any significant areas under such management nor prevented conversion of substantial tracts of old-growth forest to exotic plantations or agriculture. Indigenous forest logging would have continued until commercial exhaustion of tall conifer species if a confluence of factors (urbanization, political upheaval, rise of an assertive conservation movement, and declining economic contribution) had not weakened the influence of provincial logging advocacy. Forestry research played a minor role in this saga as it focused on the technical issues of indigenous silviculture (e.g., coupe vs group vs single-tree harvesting methods) while the main drivers of change were economic, social, and cultural.

Conclusions: Commercially valuable indigenous forests were protected only when the political cost of continuing logging was greater than that of halting it. However, it is an open question if the current policy settings will remain. Changes in governance (including increased Māori participation), land use change, planted indigenous forests and formation of exotic-indigenous forest communities will affect public attitudes as regards their use. If indigenous forestry science is to be of more consequence than in the past, New Zealand will need clear forestry goals and policies to deal with these changed circumstances, and the will to implement them.

Keywords: indigenous forest; logging; sustainability; conservation; silviculture

Introduction

> *'No issue in forestry evokes such strong emotions as logging…'* (Singh 2001).

The present day indigenous forests of New Zealand cover 30% (8.0 million ha) of its land area but yield only 0.08% of its timber products (Ministry for Primary Industries 2015). Exotic forest plantations (7.9% of the land area) account for virtually all the wood production. Indigenous forestry is prohibited on state-owned land (Allen et al. 2013), aside from occasional salvage logging (Watson 2017), and strictly regulated on private land. For a well-wooded country, New Zealand thus has an unusual, perhaps unique, forestry industry (Benecke 1996). This is a recent development. For most of the period between 1850 and 1960, indigenous timbers supplied most or a large proportion of local demand and, in the earlier years, were an export mainstay (Roche 1990). From the 1870s onwards, forestry professionals consistently argued for management of the indigenous forests to ensure sustained production (Star 2002) and progressively larger areas - eventually amounting to over 80% of the total - were brought under state control. From the 1920s onwards, areas suitable for sustained harvest were designated as State Forests, inventories of the indigenous forest resource conducted, and its silviculture and protection from pests and weeds researched. Nevertheless, by the early years of the 21st century, the last state-administered forests were withdrawn from timber production and strict controls imposed on logging in privately-owned tracts (Allen 2004, Allen et al. 2013).

This outcome of near-total reservation of indigenous forest is often presented as a triumphalist narrative of conservationists prevailing in the face of the machinations of a Forest Service bent on destruction of the native forests (Bensemann 2018). It is more complex than that, however, with economics, state restructuring, changing electoral politics and urbanisation also playing key roles. However, the failure of the hundred-year effort made by generations of scientists, foresters, managers, and policy makers to achieve large-scale and sustainable production of affordable timber from indigenous forests is arguably the critical element. It is this effort that we review here, as it has important lessons about the limitations of science in resolving dilemmas in which biology, economics, and public opinion collide.

There is an extensive literature on the history of New Zealand forestry, and we found the following particularly informative. Michael Roche included detailed and insightful chapters on the history of indigenous forest utilisation and the conservation debates in his book on this topic (Roche 1990). We have also relied on Alan Reid's comprehensive coverage of the history and impact of logging restrictions in New Zealand's indigenous forests (Reid 2001). For insights into the policies and activities of the State Forest Service (1919–1949) and its successor, the New Zealand Forest Service (1949–1987), the annual reports of these organisations to Parliament are invaluable[1]. Until the retirement of the Director-General, Pat Entrican, these remarkable documents gave frank, outspoken assessments of the progress of forestry and did not hesitate to warn and admonish successive government administrations, even to the extent of outright opposition to Government policy. They also launched uninhibited critiques of sawmillers, the timber industry as a whole, local and visiting experts and, in particular, conservationists ('preservationists' in their language). We refer to the State Forest Service Annual Reports to Parliament as SFSAR and the New Zealand Forest Service Annual Reports as NZFSAR.

There were intense internal debates over indigenous forestry within the Forest Service, with a wide range of opinions expressed, and some staff did their utmost to restrict the area logged and to minimise the damage done during logging. However, as our focus is on the policies as promulgated and their consequences, we leave an account of these internal debates to others. Two recent books provide such accounts. Elizabeth Orr (2017) gives an insider's view (she was the daughter of Pat Entrican, the Director-General of Forests, 1939–1961) of the controversies surrounding state forestry. *The Drama of Conservation: The history of Pureora Forest, New Zealand* (King et al. 2015) provides a scientific and social history of a forest pivotal in the late 20th century debate on indigenous logging and presents the views and reminiscences of scientists involved.

In this review we examine the issues surrounding exploitation of indigenous forests but not those concerning indigenous plantation forestry, a related but separate matter (see Bergin & Kimberley 2003, Steward et al. 2014). We first summarise the ecology of the indigenous forests in relation to the commercial timber species before summarising the history of their exploitation, the attempts to achieve sustainable harvesting and its ultimate abandonment. We then examine the role of scientific investigation in this history and then pose the question as to whether sustainable indigenous forestry was ever an economically, ecologically, or socially credible goal for New Zealand. Finally, we discuss whether the imposition of a forest policy that restricts the exploitation of indigenous forests will persist, given changes in governance and the expansion of planned and naturalising hybrid exotic–indigenous forest mixtures.

Ecology of New Zealand indigenous forests

Composition and structure

New Zealand was almost entirely forest covered below tree line before human settlement in the thirteenth century. Although growing under an oceanic climate similar to that of north-western North America or western Europe, New Zealand forests are markedly different to either (McGlone et al. 2016) and observers have often commented on their 'tropical' appearance (Dawson & Sneddon 1969). The forests are nearly entirely evergreen and, in the lowlands and many montane locations, structurally complex, with abundant tall lianas and monopodial trees (palms, tree ferns), epiphytic trees and shrubs, strangler lianas, fern-rich ground layers and few understory forbs (McGlone et al. 2016). Most lowland - and some northern montane - forests are characterised by emergent conifers (Araucariaceae, Podocarpaceae and Cupressaceae) over a canopy layer of broad-leaved angiosperms. These forests in general are species-rich for their latitude and the New Zealand flora as a whole has over 250 almost entirely endemic species of trees and lianas (McGlone et al. 2010). Cooler uplands in the north and the lowlands of the far south have extensive nanophyll Nothofagaceae (collectively referred to as "southern

[1] *Annual reports of the Director of Forestry (State Forest Service) (1921-1949) were presented to Parliament from 1921 to 1949 as Appendices to the Journals of the House of Representatives, Section C (Crown lands) 03. Annual reports of the Director of Forestry (from 1961 Director-General of Forests) to Parliament were continued under the New Zealand Forest Service until its dissolution in 1987. The State Forest Service reports are digitally available in the National Library collection (https://paperspast.natlib.govt.nz/parliamentary/AJHR). The New Zealand Forest Service annual reports are held as physical copies in larger libraries.*

beech" and consisting of two genera, *Lophozonia* and *Fuscospora*) forests, which are sometimes monodominant (Wardle 1984). Deciduous tree species are few, and tend to occupy niches characterised by cool winters and fertile soils (McGlone et al. 2004). Ectomycorrhizal trees include only five genera, *Leptospermum* and *Kunzea* (Myrtaceae), *Pomaderris* (Rhamnaceae), and *Fuscospora* and *Lophozonia* (Nothofagaceae) (Orlovich & Cairney 2004).

New Zealand trees are, for the most part, slow-growing (Bee et al. 2007) especially in comparison with the introduced plantation trees (mainly ectomycorrhizal Pinaceae – chiefly from Europe and North America – but including ectomycorrhizal *Eucalyptus* spp.) and a number of species (e.g., *Acer pseudoplatanus*, *Ligustrum* spp., *Salix* spp.) some of which are plantation wildings (*Pinus* spp., *Pseudotsuga menziesii*) (Table 1). Why they

TABLE 1: Representative mean annual diameter growth rates for New Zealand native timber tree species and exotic tree species used in commercial plantations.

Species	Mean growth rate (range), cm yr^{-1}	References
Native conifers		
Kauri (*Agathis australis*)	0.23 (0.11–0.61)	Palmer & Ogden (1983), mean across all natural populations cited in Steward & Beveridge (2010)
Rimu (*Dacrydium cupressinum*)	0.25 (0.08–1.00)	Katz (1980), Smale & Kimberley (1986), Stewart & White (1995) and references therein, mean across all natural populations cited in Norton et al. (1988)
Tōtara (*Podocarpus totara*)	0.51 (0.29–1.05)	Katz (1980), Ebbett (1998), Willems (1999), Bergin & Kimberley (2003)
Kahikatea (*Dacrycarpus dacrydioides*)	0.62 (0.19–0.96)	Katz (1980), Burns et al. (1999), Duncan (1991), Smale (1984)
Exotic conifers		
Radiata pine (*Pinus radiata*)	2.9 (2.8–3.0)	Richardson et al. (1999), Watt et al. (2004)
Douglas-fir (*Pseudotsuga menziesii*)	1.2 (1.1–1.5)	Lausberg et al. (1995)
Native angiosperms		
Tawhai raunui/Red beech (*Fuscospora fusca*)	0.28 (0.08–1.49)	June & Ogden (1978), Ogden (1978), Wardle (1984), Runkle et al. (1997), Wiser et al. (2005), Richardson et al. (2011)
Tawhai/Silver beech (*Lophozonia menziesii*)	0.23 (0.08–1.14)	Wardle (1980), Wardle (1984), Runkle et al. (1997), Wiser et al. (2005), Richardson et al. (2011)
Tawa (*Beilschmiedia tawa*)	0.22 (0.04–0.55)	Ogden & West (1981), Smale & Kimberley (1986), Smale et al. (2014)
Exotic angiosperms		
Sugar maple (*Acer saccharum*)	0.38	Godman (1957)
Red maple (*Acer rubrum*)	0.43 (0.26–0.57)	Walters & Yawney (1990), Zhang et al. (2015)
White oak (*Quercus alba*)	0.47	Rogers (1990)
Red oak (*Quercus rubra*)	0.65 (0.5–1.0)	Sander (1990)
Tulip tree (*Liriodendron tulipifera*)	0.75 (0.5–1.0)	McDonald & Urban (2004)

are so slow growing is not clear as New Zealand climates are mild and, while New Zealand soils in general are not particularly fertile (Hewitt et al. 2021), introduced weed and plantation tree species often grow at several times the rate of their indigenous competitors. There are apparent functional gaps as well (Lee 1998). The New Zealand tree flora lacks a fast-growing stress-tolerant pioneer equivalent to the Northern Hemisphere firs and pines. Indigenous trees on droughty, frost-prone sites grow much more slowly and achieve lower heights than invasive Northern Hemisphere conifers. There are no close local equivalents to the clonal, rapidly spreading *Salix* spp. that invade New Zealand's riparian zones and wetlands (Dansereau 1964). Fire-resistant or fire-promoting canopy trees are notably absent and fire-adapted seral trees, shrubs and ferns are few in species but now abundant in the fire-prone landscapes created by human settlement (e.g., *Leptospermum scoparium*, *Kunzea ericoides*, *Pittosporum tenuifolium*, *Cordyline australis*, *Discaria toumatou*, *Pteridium esculentum*; Perry et al. 2014).

Regeneration

Slow growth rates (Table 1) and the multi-layered structure of conifer–broadleaved forests mitigate against a rapid replacement of the overstorey dominants after disturbance. To simplify a complex and spatially highly variable situation, tall emergents, which are often conifers (*Agathis australis*, *Dacrycarpus dacrydioides*, *Dacrydium cupressinum*, *Podocarpus* spp., *Prumnopitys* spp.) but sometimes angiosperms (*Metrosideros robusta*, *Laurelia novae-zelandiae*, *Knightia excelsa*), form a usually discontinuous layer above a canopy of tall broad-leaved angiosperms, under which or in canopy gaps are smaller understory trees and tree ferns, and beneath that shrubs and small trees and a fern-rich ground layer. While disturbance often results in most of the components of this forest re-establishing within a relatively short period, shade cast by thickets of shrubs, small trees and tree ferns may completely exclude recruitment of canopy and emergent species for long periods, or severely reduce the growth rates of their seedlings and saplings (Lusk et al. 2015).

Heavily stocked conifer forest tends to prevail either on deep, recent soils after disturbance, or on waterlogged, podzolised soils or drought-prone ridges where broadleaved trees cannot thrive. These dense conifer stands tend to have little or no conifer regeneration. In conifer–angiosperm stands, conifers tend to occupy more stressed (waterlogged or dry) sites than most angiosperm trees (Coomes & Bellingham 2011), and often occur as isolated individuals or small clusters (Ogden & Stewart 1995, McGlone et al. 2017). A key insight from Ogden & Stewart (1995) is that conifer–angiosperm forests in New Zealand are essentially two-component forests in which one component, the long-lived conifers, occupies a superior, often emergent stratum, while the other component, angiosperms and tree ferns, although capable of outcompeting conifers in the juvenile and sapling stages, are eventually overtopped or open up through senescence, permitting a conifer cohort to re-establish. It is typical for 50 years or more to pass before substantial regeneration of the previous dominants is apparent. Kauri (*Agathis australis*), treasured for its extraordinarily versatile timber, may take 25 years to attain 1.4 m in height, even on optimal sites, and reach full productivity only after 200 years (Steward et al. 2014). On stressed sites such as ridges or frost- and drought-prone valley floors, tall pioneers such as kānuka (*Kunzea ericoides*) may dominate for 80 or more years, with recruitment of the previous dominants occurring only after significant dieback and opening up of the dense kānuka canopy (Bellingham et al. 2010, Richardson et al. 2014). Long-lived tree fern glades have a similar effect (Coomes et al. 2005).

Oscillations in dominance between conifers and angiosperms can differ markedly according to location and history. Examples are the postulated 2000-year linear sequence from dense podocarps to scattered podocarps over a broadleaved canopy sparked by the devastation and bared landscape created by the massive Taupō volcanic eruption c. AD 230 in the central North Island (McKelvey 1963); the 'catastrophe' cycle of 700 to 1000 years caused by widespread fire or cyclonic damage and resulting in succession through a prolonged kānuka stand phase, followed by dense podocarps (Cameron 1954); and the regeneration cycle lasting 500–700 years when large conifer trees or small groups fall and the small gap made follows a tree fern–broadleaved–podocarp succession (Beveridge 1973).

Beech forests are quite different and have much simpler regeneration patterns, which have been well described and quantified (Wardle 1984, Ogden et al. 1996). These ectomycorrhizal trees often grow in species-poor, sometimes monodominant, stands, often with sparse understories. Episodic seeding events provide large numbers of slow-growing but long-lived seedlings which act as a permanent store of advance regeneration. Stand-clearing events (aside from fire) are therefore usually followed by rapid regeneration (Stewart et al. 1991, Coomes & Allen 2007). However, a major limitation for the southern beeches is their poorly dispersed, small but heavy wind-blown seeds and requirement for ectomycorrhizal infection (Baylis 1980, Dickie et al. 2012, Forsyth et al. 2015). Beech forests therefore often have sharp boundaries with competing forest types or fail to spread into cleared adjacent ground. On more climatically stressed sites in mountainous areas, beech regenerate freely on bared ground, though taking some years to suppress a dense fern or herb ground cover should the latter colonise the site first. In the case of blow-down where the soil remains intact, advanced seedling banks of long-lived stunted individuals quickly respond to increased light and reduction of root competition to recapture the gap. Under progressively more benign climatic regimes, the nearly monospecific stands that characterise harsher sites share canopy dominance with podocarps and a range of broadleaved trees, and the understories have a greater proportion of ferns and tree ferns. Under these circumstances, beech regeneration is suppressed by broader-leaved angiosperm trees such as kāmahi

(*Pterophylla racemosa,* until recently *Weinmannia racemosa*) and *Quintinia acutifolia* and tree ferns (Lusk & Smith 1998).

The course of indigenous forest exploitation

In 1840, when New Zealand became a British colony, much of the forest had been cleared through burning by Māori, and the eastern half of the South Island and around a third of the North Island was largely in grassland, fernland or shrubland. Exploitation of the timber in kauri forests had been in progress since the 1820s as well as clearance for agriculture (Cameron 1961, Roche 1990). Even though Māori rights to forests were guaranteed by the Treaty of Waitangi (1840), colonial settlement saw a rapid shift towards state ownership and private freehold which accelerated after the New Zealand Wars of the 1860s and subsequent confiscations and dubiously legal alienation of Māori land. Freehold or leased indigenous forest tracts during the peak periods of milling provided two-thirds of the timber output, although making up less than one-third of the forested area (Roche 1990).

Forestry exports were important during the early colonial era, mainly highly-valued kauri timber, but rapid depletion of the most accessible coastal stands and expansion of wool and gold receipts led to them falling below 3% of total export value until 1880, after which they increased as improved transport enabled greater access, peaking in the 1890s. Exhaustion of the most sought-after timbers through over-cutting and the global depression of the 1930s reduced forestry exports to a new low but they increased in the 1950s as exotic plantations came on stream (Fig.1). However, compared with the overwhelming dominance of pastoral agricultural exports after the 1850s, forestry export earnings always took a distant second place. This, plus the administrative arrangement whereby forested Crown lands were managed by the Lands Department whose chief concern was farm development, accounts for the scant regard for protecting forests. Kauri was severely depleted by the early 1920s (Orwin 2019), and kahikatea (*Dacrycarpus dacrydioides*), favoured for construction of boxes for dairy products both in New Zealand and Australia and often growing on first-rate agricultural soils, was reduced to remnants by 1950. Rimu (*Dacrydium cupressinum*) became the mainstay of the local timber industry but had no particular merits to attract much international interest.

From the earliest days of the colony, New Zealand imported timber from North America, Australia and the Baltic states, and later in the 20th century from numerous other sources, including hardwoods from tropical countries. In part, this was for specialist uses not well provided for by indigenous or exotic plantations in New Zealand but also because internationally sourced timber was usually of higher quality and often cheaper than locally sourced offerings. This too tended to devalue indigenous forests.

Mass exotic plantings on agriculturally marginal land during the Great Depression of the late 1920s and early 1930s were designed to head off projected timber shortages resulting from rapid depletion of the indigenous forest. By the 1950s these plantations had begun to mature at the same time as a resurgent post-World War II economy increased the demand for construction timber (Fig. 2). In the course of 10 years, locally grown exotic timber rose from less than 10% of New Zealand production to be approximately equivalent with indigenous timber and the long-predicted 'timber famine' was averted. Many of the early pine plantings had been poorly sited and the forests badly managed,

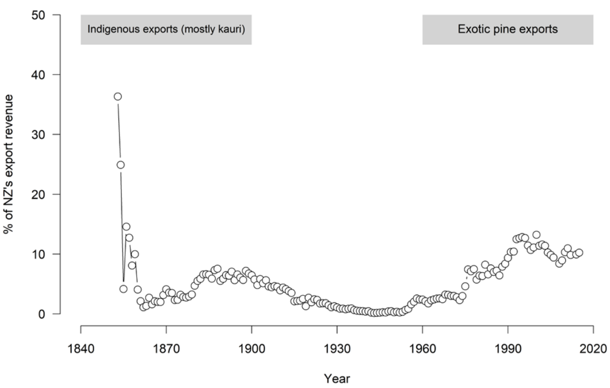


FIGURE 1: Contribution by forestry to New Zealand's merchandise export revenue, 1853 to 2015. Grey boxes and text show two periods during which exports were typically greater than 5% of New Zealand's export revenue, the earlier period being indigenous exports, and the latter being exotic pine exports. Data from Briggs (2003) and New Zealand Forest Owner's Association 2003-2018 (https://www.nzfoa.org.nz/resources/publications/facts-and-figures; accessed March 2020).

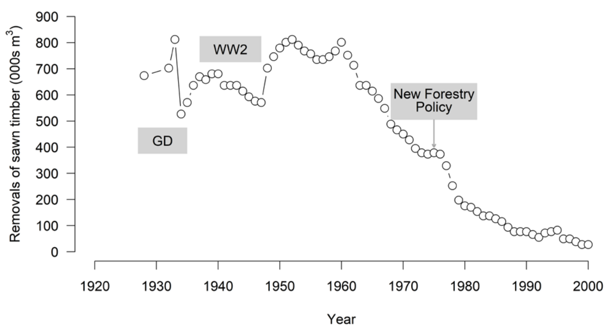


FIGURE 2: Volumes of rough sawn timber extracted from indigenous forests in New Zealand, 1928-2000. Three historical events are marked: GD = Great Depression (1929-1933); WW2 = World War 2 (1939-1945); New Policy for Indigenous State Forests passed in 1975. Data from Roche (1990), Devoe & Olson (2001), Griffiths (2002), and Griffiths (2016).

and what to do with an inferior product became a pressing issue. With the government-sponsored 'Kawerau scheme' and the private Kinleith venture, large pulp and paper mills began to absorb the surplus from the early 1950s on, and commodity log exports surged as radiata pine (*Pinus radiata*) quality improved because of major investment in its genetics, silviculture, and post-harvest treatment (Fig. 3). Meanwhile, production of indigenous timber (now largely rimu) began a steep decline accelerating from 1975, and by the turn of the 21st century, it was no longer a significant contributor to the New Zealand economy (Fig. 3). Factors behind this dramatic shift are discussed in the following section.

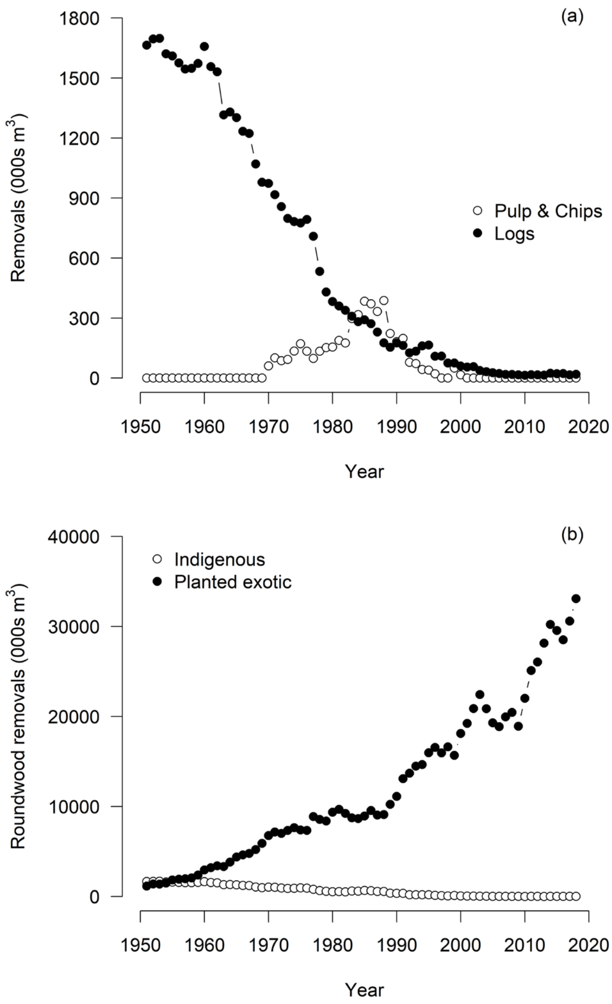


FIGURE 3: Timber harvesting totals from New Zealand, 1951-2018: (a) removals of logs versus pulp and chips from old growth indigenous forests; (b) roundwood removals from old growth indigenous forests and planted exotic forests. Data from NZ Ministry for Primary Industries (https://www.mpi.govt.nz/forestry/new-zealand-forests-forest-industry/forestry/wood-processing/; accessed March 2020).

Acts, policies, controversies, and indigenous forests

'To lock up 40,000 acres, however, as a plant museum or "tree cemetery" would be regarded by the Service and a large body of its supporters as fantastically wasteful of land and natural resources.' Commentary on the Waipoua Forest reserve proposal. (NZFSAR 1948: p22).

In the following sections, we outline the significant acts, policies, controversies and events that determined the use of indigenous forests in New Zealand. Key dates and events are summarised in Table 2.

Pre-1920

The forest flora was well documented by the late 19th century (Kirk 1889) and although little systematic quantification of forest resources had been carried out, the impact of unrestrained logging and clearance of lowland forests was clear. The Government Geologist, James Hector presented estimates for 1873 showing a 40% decline since 1830 in forest cover of which an astonishing 15% had occurred in the previous 5 years (Appendix to the Journals of the House of Representatives, 1874. H-5 Papers relating to state forests, their conservation, planting, management, etc. Part 1: pp 35-36). Dismay at the wasteful clearance (less than 10% of the timber was harvested; NZFSAR 1959: p 17) and inefficient sawmill practices, concern regarding the enormous conflagrations that were an inevitable consequence of contemporary logging and land clearance practices (Arnold 1994), and widespread apprehension that unconstrained and unchecked forest clearance would lead to flooding and local climate change (Beattie 2003) resulted in the passing of the Forests Act 1874. A Chief Forest Conservator, Captain Inches Campbell-Walker, who had considerable forestry experience in India and familiarity with German forestry, was appointed in 1875 and he presented a detailed Parliamentary report on the state of the forests (Campbell-Walker 1877). A strong advocate for scientific State forestry, he was supported by local foresters with continental European experience (Campbell-Walker 1876; Lecoy 1879). His vision, kept alive by government agencies until the beginning of the 21st century, was for reservation under State control of large areas of indigenous forest that could be managed as a sustainable source of timber.

The Forests Act and the formation of the State forestry branch of government was vigorously opposed in Parliament and by sawmillers and rural landholders (Roche 1990). The prevailing opinion was that all suitable forested land should be converted to pasture or crops. The Royal Commission on Forestry (1913) reflected this consensus, stating: "*...as a broad principle that no forest land, except it be required for the special purposes of a climatic or a scenic reserve and which is suitable for farm land, should be permitted to remain under forest if it can be occupied and resided upon in reasonably limited areas. Should the area under consideration contain milling-timber the question will arise whether it be more profitable to mill before settlement or to fell, burn, and*

TABLE 2: Acts and policies influencing the use or conservation of indigenous forests in New Zealand.

Act, Policy, Event	Date	Provisions or consequences
Treaty of Waitangi/Tiriti o Waitangi	1840	New Zealand colony established; accelerated emigration of British settlers; beginning of alienation of Māori forests
Forests Act	1873	Regulated sales of native timber; provision made for State Forest; Minister of the Crown as Commissioner of State Forests
State Forest Act	1885	Chief Conservator of the State Forests (Branch of Crown Lands Department) established. Controls imposed on logging in high elevation forests
Royal Commission on the Timber and Timber-building Industries	1909	Reported that indigenous forests would be depleted within 40 years
Royal Commission on Forestry	1913	Recommended which forests to be retained for soil protection, water conservation, and scenic reserves and which for agriculture or logging. Recommended State Forest Service
Director of Forests and Forests Act	1919-1922	Implementation of Royal Commission: appointment step towards independent service, formation of State Forest Service, and acquisition of forests
Forests Act	1949	The Forest Service to direct forest policy, regulations and commercial operations. Clarified extent and purpose of State Forests but not preservation of indigenous forests.
South Island Beech Scheme	1971	New Zealand Forest Service plans to log for timber and pulp c. 340,000 ha of indigenous forest in the South Island. Only partly implemented; sparked a severe conservation backlash.
New Forest Service native forest policy	1975-1977	Indigenous clear-felling abandoned in favour of selection logging and reservation of large area
Maruia Declaration	1977	Influential Parliamentary petition calling for the end to indigenous logging
West Coast Accord	1986	Agreement between The West Coast United Council, environmental, industry groups, conservation groups, and local communities on South Island West Coast forests strategy. Some indigenous sawmilling permitted.
Disestablishment of New Zealand Forest Service	1987	Conservation forests assigned to the newly created Department of Conservation.
Timberlands West Coast Ltd	1990	A state-owned enterprise created to manage production forestry, including sustainably-managing indigenous West Coast forests.
Resource Management Act	1991	A fundamental reshaping of environmental law to encourage sustainable management of natural and physical resources.
Amendment to Forests Act 1949	1993	Mandated cessation of unsustainable indigenous logging. Certain Māori owned forests excluded.
End of logging West Coast, South Island	2002	Government’s directive to cease all indigenous logging on Crown owned land
Forests Amendment Act	2004	Further amendment of the 1949 Forests Act. Prohibits felling of indigenous timber on state land and export of indigenous forest produce. Requires sustainable forest management plans for felling indigenous forest on private land. No second cut permitted until volume of timber is equivalent to that at commencement of first permit.
West Coast Wind-blown Timber (Conservation Lands) Act 2014	2014	Allows the removal of timber from West Coast South Island conservation forests damaged by Cyclone Ita.

grass. Obviously the answer is purely one of finance, and each case must be dealt with on its merits, the main factors being the enhanced value of the timber if reserved for a stated period, its distance from the centre of demand, and the expense of the milling…" And regarding beech forests: "…*these forests are the only ones amongst those indigenous to New Zealand which may regenerate rapidly enough to warrant their permanent retention*". The Commission gave detailed financial justifications for why planting of podocarps would be "…*an utter absurdity*." Dr Leonard Cockayne, a vocal advocate for forest reserves (Cockayne 1927), was a member of the committee; of the other four, two were farmers, one a builder and one a woodware manufacturer (Goulding 2013).

Supporting this view of forest as an obstacle to agriculture was the assumption that indigenous forest management was a pointless exercise. The rapid retreat of indigenous forest and the spectacular growth of exotic conifers and woody weeds suggested to many that the timber trees of New Zealand were inferior to those of the Northern Hemisphere (Campbell-Walker 1876). Observations of dense forests with old stag-headed podocarp trees lacking pole or seedling cohorts versus vigorous but economically valueless angiosperm regeneration in cutover tracts of 'wasteland' confirmed this opinion.

Campbell-Walker was vilified in the press and his appointment was not renewed. Some progress was made under the Conservators: reports on indigenous forests were made, 800,000 ha set aside as forest reserves and regulations introduced to reduce misuse. However, the long depression of the 1880s, popular opposition and changes in government led to the position of Chief Conservator of Forests being disestablished in 1887. In any case, provisions of the Forests Act had been poorly funded and not enforced. Logging and clearance proceeded as before.

Formation of the State Forest Service and 1945 policy

Among other far-reaching recommendations (Roche 2013), the 1913 Royal Commission suggested establishment of a State Forest Service and, after a delay because of the world war, a Canadian forester, L. MacIntosh Ellis, was appointed Director of Forestry in 1919 and head of the newly formed State Forest Service. He was well suited for the job as he had academic training and practical forestry experience in Canada and had just completed military service in France as a forester. Within a year of taking up his position, he provided a detailed report for Parliament (Ellis 1920) setting out the rapidly depleting state of the indigenous forests of New Zealand, pointing out the failures of the government to regulate logging and presenting a comprehensive vision of a sustainable, multiple-use future for the indigenous forests. He proposed a well-funded Forest Service that would have custody of most of the forested land, both for production and preservation, control logging, manage forests, and carry out scientific investigations into all aspects of silviculture.

Much of his ambitious vision was to come to pass. The State Forest Service (renamed the New Zealand Forest Service in 1949) managed most of the forested land; the logging industry was controlled to some extent; and scientific investigations proceeded. Just as importantly, some of it did not. By as early as 1925 the planting of what were to become immense plantations of exotic conifers had begun and this eventually reduced the need to conserve indigenous forests. The Forest Service was not given control of all State forests; Scenic and Scientific Reserves and National Parks were placed under the residual Department of Lands (later Department of Lands & Survey); and the Department of Internal Affairs given responsibility for indigenous avifauna. This narrowly focussed the Forest Service on timber production and maintenance of landscape protection forests.

The Forest Service's plan was that forests on poorer soils or in suboptimal climates would be reserved for sustainable timber yield or protection forestry while on better soils and under milder climates, clear-felling and conversion to agriculture or plantations would be the norm. Although this plan was widely supported, conservationist assertiveness grew over time. Before 1900, conservation concerns centred on wasteful exploitation of forests and the fear that adverse climate change, flooding and soil erosion would follow their removal (Beattie 2003). By the 1920s, conservationists' concerns had shifted to an emphasis on wildlife, scenery and amenity value (Star, 2002). Early logging excesses were for the most part supported or largely unnoticed by the public and tolerated by the Forest Service. However, public disquiet increased, and the lack of Forest Service investment in research and management of indigenous forest relative to exotic plantation noted. The Forest Service response was that this focus on exotics was the best approach: "… *it has only been interim concentration on exotic forestry which has enabled the Forest Service, since its inception 30 years ago, to save already 150,000 acres of the best indigenous forest from milling."* (NZFSAR 1951: p 5).

1945–1975: State control and continuing exploitation

During World War II, the New Zealand government developed a highly centralised control over the economy that was maintained for four decades (Easton 2020). Successive governments expanded the public service and were willing to sponsor or undertake commercial activities in order to improve the nation's productivity. In 1949, sweeping powers were given the renamed and expanding New Zealand Forest Service. The Forest Service was a major player in the supply of both indigenous and exotic timber, virtually the only provider of forestry research, the enforcer of forestry regulations and the prime source of policy advice. It was thus deeply engaged with politicians, the public, rural interests and private forestry companies.

After 1945, a national priority was to address the shortfall in housing and other construction, a legacy of the 1930s depression and World War II, and the demand for timber surged (Roche 1990). Therefore, even though significant areas of indigenous forest were reserved and all high-elevation forests strictly protected, it was in the context of accelerated logging of the rest of the indigenous forests. The burgeoning supply of exotic conifer timber after 1950 did not reduce the demand for indigenous timber as radiata pine was regarded as unsuitable for many uses and builders preferred the indigenous timbers they were familiar with. With the decline of the kauri industry in the north – although some exploitation continued until the 1980s - and the reservation of the largest remaining kauri forest (Waipoua) in 1952 (a severe blow to the Forest Service's ambitions for sustainable harvest), three large areas of relatively unexploited indigenous forest timber remained: the forests of the central North Island (largely podocarps, in particular rimu); the West Coast of the South Island (podocarps and beech); and the far south of the South Island (mostly beech). Post-war governments encouraged indigenous logging in these areas and low stumpage fees, guaranteed sawmiller profit margins, and price control of sawn timber was maintained until 1979 (Bassett 1987). Indigenous timber was therefore cheap and was used mostly for basic construction rather than for the more specialised uses for which its higher grades were best suited. The government continued to side with the sawmillers, going to the extent of endorsing a committee report in 1953 which stated that "…*the preservation of indigenous timber supplies is of no consequence*.." over the strenuous objections of the Forest Service which was attempting to slow the cutting rate to a sustainable level (Halkett 1991). Government policy remained in essence the 'best land use' policy promoted by the 1913 Royal Commission, which encouraged conversion of indigenous forest to exotic plantation or farmland should this result in higher productivity. Cutover indigenous forest that was not converted was left in a derelict state.

The Forest Service promoted pine, and called for restraint in indigenous logging, raising the spectre of disease or climatic events affecting exotic plantations as a justification for continuing to reserve indigenous forests for future logging (Conway 1977). As regeneration of merchantable timber in cutover tracts was sporadic and sometimes non-existent on any reasonable timescale, a continuing supply of indigenous timber could not be maintained in a given region without strict controls. However, strongly pro-development governments and intense pressure from local sawmillers meant that the Forest Service had difficulty in ensuring adherence to their forest management plans. The over-cutting that went on was indistinguishable from clear-felling in many cases, and damage from logging machinery to the forest environment considerable. Especially in North Island forests, logging often targeted scattered emergent podocarps in a matrix of angiosperm trees, notably tawa (*Beilschmiedia tawa*), resulting in logged forests that were substantially altered in structure and composition. Local sawmillers became adept at circumventing controls. The 1950 Forest Service Annual Report discussed the difficulties in preventing them from circumventing plans for the sustained and equitable allocation of cutting rights. Among the 'innumerable' tactics the Forest Service faced was sawmillers erecting mills alongside unallocated State Forest and then requesting access on compassionate grounds. The Forest Service had eventually to admit its inability to control the cut "*whether on State forest, Māori forest or that owned by any private interest*" and that it would have to rely on exhaustion of the supplies available to the mills (NZFSAR 1960: p 23).

After World War II, national opinion with regard to indigenous forests shifted steadily from a focus on economic benefits and employment to more biocentric issues. In the 1960s there was increasing emphasis on scenery, birdlife and larger reserves (Salmon 1960) and from the 1970s a strongly preservationist agitation began for retaining natural old-growth forest. Protest intensified with continued encroachment of logging into old-growth podocarp forest (Tihoi, Pureora and Whirinaki) in the central North Island and kauri forest in Northland (Warawara) and fuelled the rise of conservation campaigns in the late 1960s and early 1970s (Young 2004, Orwin 2019). As national-level support for indigenous logging weakened, silvicultural techniques – as practised, not as promoted – came under scrutiny and were found wanting. Conservation organisations rightly pointed out that indigenous logging operations were still completely focussed on maximum extraction of merchantable timber, made only token efforts towards ensuring regeneration, and left the forests in an unnatural state.

Meanwhile, the rise of an international market for wood chips made previously neglected indigenous angiosperm species economically viable, in particular North Island tawa and South Island beech. Logging indigenous tawa forests for chipping and pulp began in the North Island in 1970 and a large-scale South Island scheme based on beech was proposed in 1971. By 1989, 1000 ha of indigenous forest was being cleared for chipping every year (Wilson 1994). These wood chip and pulp initiatives inflamed opinion because they were less selective and used much more of the forest biomass. Conservationists by now were well organised, focused and adept at using the media (Young 2004, Bensemann 2018). We can surmise that there was also a moral dimension in play as the chips were almost entirely for export and for paper, demolishing the rhetoric of wise use of indigenous forest for specialist local needs.

1975–present: reduction in indigenous forestry

Economic arguments for continuing exploitation of indigenous forests lost credibility as the availability of exotic timber grew, the indigenous forest cut declined and cheap imports of hardwood timber and products with similar or superior qualities became readily available. As well, indigenous forestry made only a vestigial contribution to the export balance sheet and thus its national importance waned at a time when conservationist protest was intensifying.

The official Forest Service policy was amended in 1975 and a candid admission made that, despite years of promoting sustainable indigenous forestry "…*the practice over the last quarter century throughout much of the country has been to extract all the merchantable trees* *when logging an area. Where they comprised the bulk of the crop this resulted in what is termed clear felling. In mixed forests of hardwoods and softwoods it was the latter which by and large were removed, and while a forest cover of sorts remained it bore little or no resemblance to the original stand*" (NZFSAR 1976). The new policy had as its key elements that: (1) clear-felling should only proceed if a "*clear need*" is evident; (2) indigenous forest should be cleared only when a study of the social, environmental and economic factors show national welfare would be enhanced; (3) a decision on whether timber production is of greater importance than other conflicting values should be deferred until a commitment one way or the other is necessary; (4) logging of indigenous forests is not precluded but should be carried out in a way that leaves "*open the options of maintaining an indigenous forest structure with a wide range of values or clearing for other uses at some unspecified future time*" (Conway 1977).

The new policy slowed exploitation of indigenous State Forests. Cutting in privately-owned forests (which provided ca. 66% of the total) fell at the same rate, even though not directly affected by the policy, probably because the diminishing State Forest supply disrupted the entire indigenous timber infrastructure (Fig. 2). Nevertheless, the Forest Service promotion of multiple use of State Forests became increasingly controversial because of the suspicion that it was a cover for a continuation of forest mining. Oversight of logging was poor and there were apparently no good-faith intentions or resources to manage regeneration. The 1969 Forestry Development Conference recommended a second major expansion of the exotic forestry estate and cutover native State Forest was seen as an obvious land bank for this. Moreover, indigenous conversions continued: from 1970 to the mid-1980s large areas of secondary forest (often rich in regenerating conifers) were destroyed to make way for radiata pine plantations, and even old-growth forests (on the Mamakū Plateau, in Northland, in north Westland) were clear-felled and burnt to make way for plantations (Fleming 1969). While the Forest Service had made progress towards its ideal forest model in that some attempt at best-practice logging techniques was made and scientific reserves set aside, it was now lagging well behind changing public opinion. Leading conservation movements called for a ban on logging in public forests, sustainable management of indigenous forests in private hands, and a ban on indigenous exports (Gillman 2008). A bitter, complex debate ensured (Thompson 1987, Roche 1990, King et al. 2015).

In 1984, in the aftermath of a national financial crisis, a neoliberal government with a focus on efficiency and economic return was elected (Tilling 1992). The new Labour government was less concerned than its predecessors with rural issues and Richard Prebble, a key minister in the administration, pointed out that in 70 years of existence the Forest Service had failed to make a profit from its forestry operations (Prebble 1996). The government was also ideologically antagonistic to the sprawling Forest Service with its multiple, conflicting agendas, opaque decision-making, entanglements with private forestry companies, and propensity to antagonise conservationists. Disestablishment of the Forest Service came in 1987. Protection and conservation forests were allocated to the newly formed Department of Conservation and production forestry privatised or incorporated into State-Owned enterprises.

The end to State-sponsored indigenous forestry came with the demise of Timberlands, a state-owned company set up to manage Crown-owned forest tracts in Westland for timber. With financial support from central Government, Timberlands invested in the development and trialling of small-scale (<0.2 ha) coupe and group harvesting methods in beech forests (Wiser et al. 2005, Wiser et al. 2007), and single-tree harvesting methods for rimu (Richards 1994, James & Norton 2002). These methods were designed to minimise canopy disturbance and thus maintain the character of natural forests. After several decades of monitoring across replicated sites, there was evidence for adequate regeneration by beech in small coupes (Wiser et al. 2005, Wiser et al. 2007, Allen et al. 2012). Comparable studies are not available from rimu forests, but light-demanding rimu seedlings (Norton et al. 1998) are unlikely to regenerate after single-tree harvesting because of rapid canopy closure by adjacent trees (James & Norton 2002, Allen et al. 2013). In spite of promising results from beech forests, there were analyses (Mason 2000) that suggested the beech timber extraction necessary to keep the Timberlands enterprise afloat could not be balanced by the speed with which natural regeneration replaced harvested canopy trees. When it was revealed that the company had been undertaking a secret lobbying campaign to bolster its position, including denigration of the Prime Minister (Hager & Burton 1999), its fate was sealed.

A new policy was announced in the amendment to the Forest Act 1949 in 1993 where Part 3A (section 7) promotes the sustainable management of indigenous forest land defined as: "…*the management of an area of indigenous forest land in a way that maintains the ability of the forest growing on that land to continue to provide a full range of products and amenities in perpetuity while retaining the forest's natural values*." Since the Forests Amendment Act 2004, indigenous forest milling has taken place only on privately-owned land and is subject to a requirement for sustainable forest management. Nevertheless, calls for a new, holistic forest policy in which the distinction between indigenous and plantation forestry is dissolved, and for sustainable management of the Department of Conservation forests for timber, are made from time to time (Levack 2006).

Māori-owned forest lands

Māori were the original owners of New Zealand forests and their rights to forest resources were guaranteed in the Treaty of Waitangi, but subsequent confiscation, seizure under the Public Works act and other legal and illegal stratagems greatly reduced their holdings. Māori were mostly willing participants in the exploitation and conversion of indigenous forests, undertaking major clearances for agriculture on their own behalf in the early 19th century (Cameron 1961), and providers of a considerable amount of forest resource and forestry labour in the 20th century. Peak logging on Māori land came after 1950 when increased prices spurred a dramatic rise in logging from less than 71,000 m^3 in 1947 to about 190,000 m^3 in 1958 (NZFSAR 1959: p29). Māori continue to be a major supplier of indigenous timber in the sustainable logging industry. Currently around 600,000 ha of indigenous forest are owned or under control of Māori (150,000 ha covenanted), that is around 29% of all privately-owned indigenous forest (Wilson & Memon 2005, Holt & Bennett 2014).

The policy history we have presented, which resulted in the ultimate victory of those who viewed continuing exploitation for timber on publicly-owned forest land as impermissible and logging on private land acceptable only on sustainable grounds, is largely a settler-pākehā narrative. It has been argued that the prevailing biocentric view of forests derives from European scientific notions of how indigenous forests should be managed and that for Māori "…*cultural, economic and social factors combine to create forest management pathways that are complex and that may not necessarily be compatible with Western (i.e. Pakeha) notions of 'ideal' biodiversity preservation*" (Wilson & Memon 2010). Geoff Park (2000) went further in suggesting that for Māori '*preservation was also subordination*'.

Research into sustainable indigenous forests

> '*The pure botanist has little if any conception of silviculture, but relies on an academic knowledge of the natural growth of individual plants and plant societies. He has no appreciation of the concept of forestry as an art and as an applied science, and yet has purported to advise the public on the future of Waipoua*' (SFSAR 1948: p23).

Until late in the 20th century, advanced training of New Zealand's foresters and ecologists largely took place in the United States, Britain, and Australia (McKelvey 1999) and the international literature was dominated by management issues specific to Northern Hemisphere conifer and hardwood forests. As well, research carried out by ecologists and botanists was particularly important during the 1920s, in part due to the lack of forestry professionals (Sveding 2019). Each generation of New Zealand forest scientists therefore had to address the issue of the extent to which the ecological concepts and forestry principles taught them applied locally. There had been lively scientific debates regarding the slow growth rates of indigenous timber trees beginning in the 1830s (Roche 1997). The pioneer ecologist Leonard Cockayne noted the widespread lack of regeneration of the conifer overstorey in many undisturbed forests and suggested that the podocarp forests of northern regions were "..*turning by degrees into a climax with the tawa (Beilschmiedia tawa) dominant, and that the podocarps of South Island forest, to the south of lat. 42°, would be eventually replaced by Weinmannia racemosa*." (Cockayne 1928: p. 153). He believed the valuable timber trees of the dense podocarp and kauri stands to be a temporary phase which was destined to give way to a 'climax' forest dominated by angiosperms, supporting his view that the evolutionarily more advanced angiosperms would eventually replace the conifers. This bolstered the widespread popular belief that all indigenous forest was likely to succumb to invading exotics due to some undefined shortfall in their nature, and that valuable conifers were destined to be replaced by angiosperm trees of little value as timber. On the other hand, Cockayne saw a great future for management of the extensive beech forests (Cockayne 1926, 1928).

Systematic scientific investigations into the extent, management and timber potential of indigenous forests began in the 1920s but little progress was made: "*It is difficult to estimate to what extent the botanist's preoccupation with naming and classification, and the forester's interest in the economic possibilities of exotics has been responsible for the lack of experimenting. The fact remains that planned experimentation as the basis of scientific study has been notoriously absent. In the whole of the country's indigenous forest estate there are probably not five sets of even small plots which have been studied and tended continually over a period of the 40 consecutive years of departmental existence, let alone any longer. One is forced to speculate whether the woeful lack of scientific observation is not due to some basic defect in the teaching of research in New Zealand*." (NZFSAR 1960: p. 19). New Zealand was poorly provided with forestry professionals until the late 1940s. The newly formed State Forest Service was supposed to carry out most of the forest science necessary to implement Ellis's original vision. However, few forestry professionals were appointed. Their number was never greater than 8 (including scientists, foresters, and engineers) until after 1945, falling as low as 3 in the 1930s (NZFSAR 1950). The two forestry schools (Auckland and Christchurch) founded in the 1920s were poorly funded, undermined by internal dissent, and defunct by 1934 (McKelvey 1999). The resources and staff later invested in sustainable forestry research by the Forest Service were always minimal, never amounting to more than a few scientists and technicians.

Given the poor understanding of the extent of merchantable timber in the forest estate and growing public pressure for reserves, a National Forest Inventory was carried out (1921–1923). By the 1940s, the limitations of the National Forest Inventory were clear. Between 1946 and 1952, the much more ambitious National Forest Survey was undertaken, based on fieldwork, systematically placed ground-based plots, aerial photograph interpretation, and statistical methods (Masters et al. 1957). It provided estimates of the amount of merchantable indigenous timber in non-protection forests and documented regeneration and damage by introduced herbivores, in particular deer and goats. This project had profound effects on the direction of forestry science in New Zealand, and not least by provision of a cadre of scientists with extensive field experience in indigenous forests. The lack of conifer regeneration in mature stands it revealed was interpreted as evidence that the conifers were ill suited to contemporary climates (Holloway 1954), and this was echoed in later papers (Nicholls 1956, Wardle 1963, McKelvey 1963), a view not supported by later research (Veblen & Stewart 1982, Wardle 1985). However, even though contested at the time (Cumberland 1962), the climatic hypothesis provided further support to popular and industry views that logging indigenous conifers was simply anticipating their inevitable demise. The Forest Service Annual Report of 1949 made this clear: "*….much of our forest is in an unstable condition. Present distribution and composition appear to reflect a warmer and more humid period in the past…the bulk of the podocarp forest displays symptoms of over-maturity and stagnation with the virtual absence of young growth*" (p. 9).

After World War II, the central issue that forestry scientists faced was how to promote the regeneration of valuable, slow-growing conifer timber trees. The problem was exacerbated by the widespread belief among foresters that many indigenous forests - left to their own devices - would lack conifer regeneration and be replaced by commercially valueless hardwood species, so that they doubted the forests were even worth managing. Although some early investigations had given hope of a reasonable yield from well-stocked rimu stands on the west coast of the South Island (Hutchinson 1928, Hutchinson 1931) or kauri in Northland (Sando 1936), these claims proved to be illusory. Even under ideal conditions and optimistic calculations the main timber tree, rimu, would take 85 years to recover to a merchantable state after clear-felling of a stand (Hutchinson 1931). A frank assessment of the situation was given by a Forest Service forester David Kennedy: "*The New Zealand forester has long been the target of criticism for his neglect of indigenous silviculture. He is continually being asked why he does not replant rimu after his stands have been harvested by the sawmiller. It is true that small areas could conceivably be replanted with trees raised in nurseries from the minute, irregular, and predominantly infertile seed crops that are a characteristic of rimu, the main species. Likewise, it would be possible, by oft-repeated and long-continued release cuttings to ensure that such plantings were allowed to develop without undue competition from the ubiquitous second growth that follows logging. The answer is, of course, that such forms of silviculture would be hopelessly uneconomic, and could not possibly be justified as practical forestry.*" (Kennedy 1951).

Technological advances in forestry practices in the second half of the 20th century provided the impetus to have another look at the situation. Increasing mechanization and replacement of bush tramways by a more intensive road network reduced the costs of timber extraction, making feasible more sophisticated alternatives to clear-felling or removal of conifers from mixed forests.

Renewed scientific investigations and experimental trials to support the development of sustainable indigenous forest began in the 1950s and have continued to the present. Key areas for these investigations were the large remaining stands of lowland dense podocarp forest on the west coast of the South Island and on the Volcanic Plateau of the central North Island (Chavasse & Travers 1966, James & Franklin 1977, Six-Dijkstra et al. 1985, Smale et al. 1998, Beveridge et al. 2000, Carswell et al. 2007, Beveridge et al. 2009). There were also investigations into the sustainable management of young kauri stands that had developed after clear-felling of old-growth stands in the 19th century (Halkett 1983, Barton & Madgwick 1987, Steward & Beveridge 2010).

The emphasis in the earlier years was on the optimal logging pattern to ensure regeneration. Strip-felling, in which 80 m wide bands of untouched forest were left, was promoted in Westland terrace rimu forest (Chavasse 1954) but proved to be less successful than anticipated in achieving regeneration and preserving old growth. Conventional methods of extraction by rope hauling and tramways, replaced later by crawler tractors, resulted in unacceptable damage. Many forests were on soils prone to compaction, waterlogging and windthrow resulting in premature deaths and lack of regeneration of the remaining trees. In podocarp forest, regeneration was sparse in the cleared strips and wind damage excessive in the untouched strips, and the technique (first trialled in 1956) was abandoned in 1965 in favour of selection logging and small coupe approaches (Halkett 1991). Under selection logging, large areas of forest were thinned out by removal of trees in a range of age classes. In the 1980s, more environmentally friendly technology in the form of low ground pressure bulldozers, portable bush sawmills and helicopter log extraction increased the range of possibilities for selective logging by taking single or small groups of stems (James & Norton 2002).

With regard to podocarp–angiosperm forests, given the great range of initial conditions of the stands, the percentage of stems removed, damage to the forest and soils during logging operations, and subsequent deaths of remaining timber trees, conclusions varied to how sustainable such initiatives were. Estimates for cutting cycles of selectively logged forest for the most valuable large diameter stems were typically long: for instance, for South Island west coast rimu forests, a suggested cycle was three cuts over 225 years but even on the best sites this might have been optimistic (Six-Dijkstra et al. 1985). In some cases introduced deer browsing caused a complete hiatus of podocarp regeneration on otherwise suitable sites (Richardson et al. 2014). Analysis of a North Island podocarp–tawa forest block, selectively harvested in 1961 for one third of its merchantable conifer and hardwood volume with preferential removal of unthrifty trees, revealed that after 43 years the size class structures of commercial species were maintained after harvesting, regeneration of conifers and tawa was proceeding, and stability of the forest was not affected but that nearly a century would be needed for the forest to recover 80% of its previous basal area (Smale & Beveridge 2007). It was noted that the least marketable timber tree, tawa, was the most suited to selective logging management and that in similar forests elsewhere, conifer regeneration after logging had been poor. The overall conclusion was that the selection system, while often regarded as that most likely to mimic natural processes, produces outcomes that resemble few natural forests, and that careful intervention is needed to maintain it.

Beech stands generally have more prolific and assured regeneration than podocarps and studies of their management yielded more optimistic conclusions (Wardle 1984), but there were provisos. Many harvestable trees had defects which precluded their use as sawlogs which meant that for many stands, selection logging was uneconomic, relative to imported timbers, and was viable only if the timber was used for pulp (Johnston 1972). Woody debris in beech stands is important as a carbon store, moderating energy flow, in the nutrient cycle and as a substrate for invertebrate and fungal biodiversity (Allen et al. 2000). However, it also provides brood material for wood-boring insects that during outbreaks can sometimes damage even healthy trees sufficiently to lead to deterioration or death through fungal pathogens (Ogden et al. 1996). Stand hygiene to reduce outbreaks is necessary, but fundamentally alters the natural functioning of the forest.

Although the results of some of these studies could be seen as supportive of selective logging, this support extended only as far as the issue of effective replacement of the focus timber tree. Two elements were generally missing: the broader forest biodiversity, and the economic or social implications. The philosophy behind sustainable forestry until the 1980s was essentially the 'better-than-natural' ideal (O'Hara 2002) in which indigenous forests were to be managed so as to be even-aged over economic cutting compartments and producing maximum volume increments of merchantable timber. Descriptors for forests in this condition were 'healthy' or 'vigorous'. These were contrasted with uneven-aged, old-growth stands which were described as 'over-mature', 'senescent', 'stagnant', 'moribund', 'unthrifty', or 'decadent'. That such management (even if realistic in New Zealand) would result in forests resembling plantations was mostly unremarked. However, by the 1990s, it was clear that intrinsic biodiversity values also had to be catered for, including all animal and plant life, invertebrates, and fungi. Inclusion of these elements – a large component of which are favoured by undisturbed soils, old, large trees, dense undergrowth, dead standing and fallen wood – completely changed the argument. For maximum biodiversity, a diverse age structure is required and this includes old-growth stands previously characterised as 'stagnant' or 'moribund'. From a forester's point of view, the goalposts had now shifted. The ideal forest was no longer young, vigorous and productive but ancient and steady-state, and they no longer had either the ideological mindset or the research basis to deal with the new dispensation.

While high-quality and sophisticated biophysical work has been carried out since the 1990s on how technically to address sustainable forestry (e.g., Wiser et al. 2005), economic or social analyses are almost always lacking. Even comprehensive accounts rarely make any but a passing reference to the costs relative to outcomes (Reay & Norton 1999, James & Norton 2002, Smale & Beveridge 2007, Forbes et al. 2021). Economic studies tend to show that the net annualised return for biophysically sustainable indigenous forestry generally lies below zero (Evison et al. 2012), a finding that echoes the views of some forest owners (Hawes & Memon 1998).

Could sustainable indigenous forestry have been implemented?

> "*The ultimate objective is to convert the stagnant and over-mature indigenous stands so characteristic of the country's forests today into vigorous growing and highly productive stands. Only if this is achieved will any indigenous forests remain for the enjoyment of prosperity*" NZFSAR 1951: p. 7.

The official forestry policy in New Zealand from 1921 until 2004 encouraged management of indigenous forests in perpetuity. As discussed above, a number of issues prevented this from becoming a reality:

- The often irregular seeding and inherently slow growth of the conifer species with the most desirable wood properties, and thus the extremely long conifer regeneration cycle;
- The poor soils, terrain and climates that characterise most remaining forests;
- Post-logging issues including soil compaction and waterlogging, weed invasion and pest herbivores;
- The lack of a market for timber from associated angiosperm trees and the weak market for beech.

Confronted with this unpromising set of issues – most of which were well understood by 1900 – research focused on silvicultural manipulation during harvesting and observations of the subsequent regrowth. The problems with the recalcitrant biology and the long regeneration cycle of conifers cannot be solved solely by manipulating tree extraction procedures; subsequent silvicultural investment is needed if shorter harvest cycles are required. While the costs of carrying out different harvesting strategies are essentially paid for by the timber extracted, this is not the case for subsequent silviculture. The relative lack of investigation of the effects of further silvicultural interventions (such as planting, release of seedlings, pruning, weed and herbivore control) can be attributed to their high cost and the reluctance of forest managers to invest in them. Moreover, given the very long cycle involved in even the fastest-growing indigenous timber trees, the costs that can be recovered through improved value are minimal. Calculations for Westland rimu in 1951 suggested that the timber produced from a planted and silviculturally tended stand would need to be priced at £127 (= $8000 current) per cubic metre merely to cover the investment, more than 150 times the going rate at the time – an economic outcome referred to as "...*startlingly poor*" (NZFSAR 1951: p. 6). While efforts at creating indigenous plantations were regularly highlighted in successive

Forest Service annual reports, they are estimated to cover only a few thousand hectares at most (Forbes et al. 2021). Recent analyses of the potential for indigenous plantation forestry for rimu in a North Island location showed that on flat terrain it was not profitable, and on steep slopes only profitable with a low discount rate, high stumpage price and with other benefits such as avoided erosion, carbon sequestration, and biodiversity and cultural enhancement factored in (Pizzirani et al. 2019).

The high costs of establishing indigenous conifers in cutover native forest or exotic plantations regions is confirmed by more recent work in the central North Island (Forbes et al. 2021); establishing and tending podocarps until year 5 cost at least $40,000/ha (Rob Allen pers. comm. August 2021). The current One Billion Trees programme for accelerated tree-planting allocates up to $6,000/ha for planting high-quality indigenous forest (https://www.mpi.govt.nz/forestry/funding-tree-planting-research/one-billion-trees-programme/one-billion-tree-fund/; accessed July 2021), a very substantial underestimate of the true costs of a successful project. This underestimation extends to the research needed. As late as 1997, after more than 75 years of re-iteration by the Forest Service on a more-or-less yearly basis of the need for research into indigenous silviculture, when it became apparent that demand for permits to log freehold indigenous forests was escalating, a Ministry of Forestry workshop concluded: "*Although indigenous forest management for timber production remains one of the most contentious land-use issues in New Zealand, there is little research currently funded to ensure the sustainable management of private indigenous forests.*" (Allen & Benecke 1997). The One Billion Tree initiative is currently funding a limited amount of research into indigenous forest planting and natural successions.

Some attempts have been made to improve the market, in particular for indigenous angiosperm timber. In the early days specialist uses were trialled including matches, tool handles, deep sea fishing rods, bowling balls, telephone cross-arms and coach building to supplement the more common use in furniture, interior finishing and veneer for the better grades, and mine props, fencing, boxing and rough construction for the lower grades. While indigenous angiosperm timbers with superior wood qualities have a wide range of uses (Wardle 2011; Nguyen et al. 2021), they are effectively niche products and, in general, do not command sufficiently high prices to justify intensive management of the source forest, especially when it is as slow growing as, for instance, tawa (Smale et al. 1986) (Table 1). A recent appraisal of indigenous timber production in New Zealand concluded that the key element in the sector failing to realise expectations (value of harvest in 2016 was < 40% of 2001) was not the cost of establishing Sustainable Forestry Plans but low demand for the product (Griffiths 2017). Competing imports of furniture from countries with lower costs of production and the subsequent retrenchment of the local indigenous manufacturing industries were thought to be largely responsible and hence there has been agitation from the forest owners for permission to export logs and pulp, rather than just sawn timber and manufactured products. This of course demolishes the argument for continuing logging of these forests because of local, niche manufacturing demand.

While arguably the official policy for over 80 years, sustainable indigenous forestry was never seriously attempted on any substantial scale. Although large areas were set aside as State Forest, much of it cutover, only very limited attempts were made to manage them for timber production. The state of the effectively abandoned cutover forest was well known: "*Everyone is familiar with the depressing areas of logged native forest, abounding in weeds and useless scrub, the refuge of noxious animals and pests […] The best economics is often to raise on the land a crop of exotic trees…*" NZFSAR 1962: p. 15. Today private efforts continue but on a small scale, and mostly confined to owners of forest tracts who, by registering a Sustainable Forest Management (SFM) plan under the Forests Amendment Act 2004, are permitted to take a portion of the annual increment. Thus, with a few exceptions, these SFM plans are a legal means by which owners can recover some short-term value from forest which otherwise provides little income. In practice, sustainable indigenous forestry is effectively almost extinct in New Zealand, with the exception of limited beech operations in the South Island (Allen et al., 2012). Need this have been the outcome?

For sustainable forestry to have been feasible in New Zealand, a number of factors would have had to have aligned. First, silvicultural and forest management techniques would have to have been developed which minimised the slow growth/poor regeneration handicap of nearly all indigenous timber species; secondly, the economic return for the timber produced through utilization of those techniques would, at the very least, have had to cover the silvicultural outgoings; thirdly, local provincial interests would need to be receptive; and fourthly, national public opinion in agreement.

As we have seen, silvicultural techniques were developed that minimised damage and gave a fair chance of adequate regeneration but, although time to a second harvest could be improved, it still remained too long to be economically competitive against imports. Local opinion remained adamantly against 'locking up' (i.e., not clear-felling as expeditiously as possible) their forests and maintained ongoing political pressure to continue the unofficial clear-felling policy. As noted in 1955 (NZFSAR: p16), "*Pressure for the release of State Forest land for agricultural development has continued unabated throughout the year*", and in 1962 the Forest Service admitted that it had to abandon all hope of a reduction in cutting in indigenous forests, whether State or private, despite earlier attempts at regulation (NZFSAR 1962: p23).

If Campbell-Walker's (1877) and Ellis' (1920) vision had been put into practice, that is, a much greater area of lowland indigenous forest on productive soils reserved for sustainable wood production, would such a system be currently economically viable given the contemporary requirement to maintain near-natural states? Central to this issue is the economic value of the timber produced versus the costs incurred through low-impact harvesting to maintain all-aged forest tracts and ensure regeneration and the ongoing costs of suppressing competing vegetation and controlling weeds and pests. The timber price on the local market is linked to those prevailing internationally, and in the absence of tariff protection, the value of indigenous timber is depressed. The biology of the valuable conifer species (kauri, rimu and tōtara *Podocarpus totara*) mitigates against short rotations and, while the beech species apparently can be managed within a commercial framework, their timber does not command as high a premium. The scarcity of private investment in sustainable indigenous forestry, and the fact that state efforts were confined to small experimental treatments and the short-lived Timberlands schemes at the turn of the century, demonstrate the lack of a commercially viable return relative to other opportunities.

We conclude that even extensive lowland forests would not yield competitively priced timber unless mined as it was in the past. Some public good would have to be factored in to make logging acceptable. Some balancing considerations can be suggested: provision of jobs for rural communities; non-timber products (such as honey, sphagnum moss, possum fur); recreational and tourist opportunities (hunting, bushwalking, sightseeing); the environmental value of weed and pest control; carbon sequestration; and finally, the existence value of the managed forest (Yao et al. 2017). However, the problem with using these considerations as counterweights is that all but jobs and weed and pest control are provided simply by leaving the forests as they are. Unless the profit realised by the timber is higher than has been the case to date, the extraction of timber barely pays for the silviculture necessary to ensure a second viable crop within a commercially viable timespan, and there is little left over for weed and pest control. That leaves the sole significant balancing consideration as jobs for rural communities, and that indeed was a major element in the equation until recent years. The implicit assumption for many years was that sustainable forest management was a desirable alternative to much more damaging clear-felling or conversion to pasture or exotic plantations, and that it merely had to show that it was technically feasible. That is why the focus has been on how to avoid damage during logging, how to ensure adequate regeneration and how to maintain a forest structure that bears some resemblance to the natural state (Allen et al. 2013; Wiser et al. 2005). However, with much more strict regulation and a near-total ban on conversion of indigenous forest to other uses, the focus now has to be on the intrinsic value of indigenous forests.

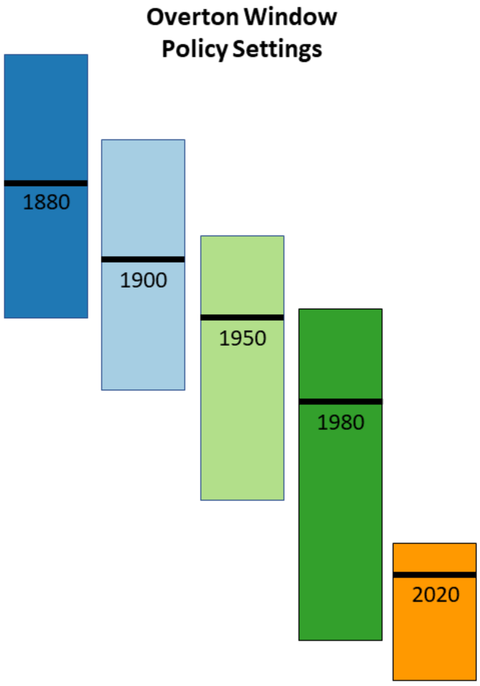
Leaving indigenous forests free of timber extraction is underpinned as a policy by the ease with which timber can be sourced elsewhere at competitive prices. However, a valid case can be made that, by importing hardwood timber products, New Zealand can be supporting unsustainable logging practices elsewhere in the globe (Mayer et al. 2005, Allen et al. 2013). Global product certification may go some way towards rectifying this situation but it seems certain that in the medium term, unless imported furniture and fittings cheaply manufactured from overseas hardwoods are excluded or subject to tariffs, prices for indigenous New Zealand timber will not reflect the true costs of their sustainable production (Griffiths 2017).

Science, policy, and practice

> *"To the rest of the developed world such rights (including access to their native timbers) are integral to their culture and heritage. Perhaps it is time that we as a culture developed a more mature perspective as well, and stopped fighting the phantom, bush-clearing pioneer in every forest management plan"* (Perley 1998).

Applied sciences such as forestry can thrive only when the products of their research are taken up and used. If the economic rationale is weak, and consistent, clear policies, regulation and enforcement are lacking, research struggles to be relevant. Throughout the nearly 70 years of the New Zealand Forest Service's existence, the economic basis for sustainable indigenous forestry was questionable, official policy often did not reflect the actual situation and, although well-intentioned regulations were promulgated, enforcement was slack. As well, the New Zealand Forest Service itself had a dilemma that became only worse through time.

We can best see this through using the concept of an 'Overton Window of Political Possibilities' (Szałek 2013). Politicians have only a limited number of policy options available to them at any one time, and are constrained by societal willingness to support them. Options can be portrayed as a sequence from less government control and regulation to greater regulation, or in the case of New Zealand indigenous forests from policies that prioritise social and economic factors to biocentric ones. The Overton Window depicts the range of acceptable options available at a given time (Fig. 4). Our estimation is that the Overton Window for New Zealand indigenous forestry shifted in the course of 140 years from a range of policy options that favoured destruction of the lowland forests to a policy range that put preservation of the forests first. In the early years, the New Zealand Forest Service was a consistent advocate for reservation of forest for timber production and reduction of waste and at the upper end of the contemporary Overton Window. By 1980, they were well towards the bottom of the Overton Window. However, these positions relate only to the policies that the New Zealand Forest Service was advocating, that is for silvicultural management of indigenous forests, and with multiple-use forests preferred over strict reservation. As we have seen, actual forestry practice was different. Varying felling techniques were mandated but oversight of private loggers was weak and silvicultural management was rarely done. There was thus only a limited amount of data that could be collected to inform best practice and expensive experimental investigations had to be undertaken to provide this. These investigations were necessarily limited. As well, despite the official policies advocated



Policies	Primary purpose	Private & Māori	State	Protected
1	Conversion to agriculture	No controls	Logging & conversion to pasture encouraged	No reserves
2	Timber supplies in perpetuity from land not suitable for agriculture	Clearance/felling with limited timber recovery; exotics/pasture conversion encouraged	Logging primary use but exotic/pasture conversion permitted	Steep lands to prevent erosion; scenic and amenity reserves
3	Preservation of forest as security; full utilisation of cut	Logging & exotic/pasture conversion permitted	Logging primary use and continuous yield aim; exotic/pasture conversion limited	Few National Parks; many scenic reserves
4	Management of healthy productive forests; multiple use	Logging & exotic/pasture conversion permitted	Logging sustainable where possible; no exotic/pasture conversion	Many National Parks, Scientific and Scenic Reserves
5	Management for productive forests with natural values	Logging permitted; exotic/pasture conversion limited	Logging under strict sustainability	Extensive National Parks, Scientific and Scenic Reserves
6	Retention of natural forest	Logging under strict sustainability	Retention of natural forest cover	All state-owned lands
7	Expansion of natural forest	No logging	Reforestation with indigenous cover	All forest lands

FIGURE 4: An Overton Window analysis of New Zealand forestry policy, 1880 to 2020. Forest policy settings (as we have interpreted them from New Zealand Forest Service Annual Reports and Ministry for Primary Industries reports) are listed (top to bottom) from those advocating little regulation (1) to those advocating complete cessation of logging and clearance (7). The boxes to the left are our assessment of the feasible policy settings (= Overton Windows) given the public opinion and economic imperatives at various times in the past. The black lines within each time period indicate the position taken by the New Zealand Forest Service and successor organisations at those times.

regarding perpetuation of vigorous, healthy productive forests, the New Zealand Forest Service remained highly pessimistic about whether economically viable indigenous forestry was possible. As the Annual Report of 1960 (p19) stated: "…*overseas professional visitors have almost invariably described the Forest Service attitude to indigenous forestry as one of "defeatism"* ". This is reflected in the statement some years later that: "…*there is no intention of planning restrictions on the milling of private and Maori-owned timber so that the only method of husbanding our timber resource is to control cutting of State-owned timber*" (NZFSAR 1965: p7). As the Overton Window later shifted inexorably downwards, the focus on timber production and the relative neglect of other aspects of indigenous forests vitiated Forest Service policy recommendations.

Scientific research and forest research scientists have only a limited role in this story. Research into sustainable forest practice was only sporadically carried out in State Forests and largely ignored on private land until legislation early in the 20th century (Halkett 1991). Even then, conservation-minded forest scientists supported pastoral development over retention of forest. As late as the 1970s, the Ecological Society of New Zealand offered only muted criticism of the ill-conceived West Coast Beech Scheme of 1971, focussing largely on provision for reserves and stating: "…*if in the future, the reservations are found to be needlessly generous in ecological, scientific, recreational, tourism and "conservation" grounds, the timber resource will still be available and be of even greater economic value than if it is imprudently cut now*" (New Zealand Ecological Society 1978). The dedicated effort by Forest Service and Department of Scientific and Industrial Research scientists to document and argue the case for ecological reserves (Bassett & Miers 1984) is, more than indigenous silviculture, the enduring scientific success of this period.

Scientific research therefore was operating in an unreal environment. The prevailing pessimistic attitudes towards indigenous forestry meant that take-up of harvest and silvicultural recommendations on State Forest land were likely to be half-hearted and non-existent on private land. The economic basis for sustainable indigenous forestry was lacking and this probably lay behind the failure to document costs and to project future returns. However, whether intended or not, this scientific effort enabled the Forest Service to keep the illusion going until the end that indigenous forestry was viable on a sustainable but economically unquantified basis. Ultimately, rosy visions of a time in the undetermined future when research would deliver the means for sustainable forestry was insufficient. In the early 1970s, the Forest Service could not point to extensive areas of indigenous forest where plans for their sustainable management could be demonstrated, nor to a thriving specialist timber industry, but instead were advocating indigenous log and pulp exports and clear-felling natural forests for their replacement by exotic conifer plantations. The lesson from this history is that if it is to have any hope of making an effective contribution to environmental debates, applied scientific research needs to address realistic policy goals and to partner with broader economic and social analyses (Tilling 1988).

While this is a bleak assessment of the influence of science on indigenous forestry policy and outcomes, the work that the Forest Service and other forestry scientists carried out was and remains of great value. The forest plots they established throughout New Zealand forests have provided a secure basis for later monitoring and research (Wiser et al. 2001; Bellingham et al. 2020). Through their unparalleled knowledge of the forests, Forest Service scientists such as John Nicholls were well placed to ensure that ecologically and scientifically important reserves were created, even in the midst of the post-war indigenous logging frenzy (Bassett & Miers 1984). The research that the Forest Service conducted and the infrastructure of plots they established underpinned physiological work on the fundamentals of tree growth and carbon sequestration (Beets 1980, Benecke & Nordmeyer 1982, Hollinger et al. 1994, Hall et al. 2001), climate-tree relationships (Leathwick, et al. 1996, Leathwick & Whitehead 2001), and forest modelling (Hall & Hollinger 2000), advances now critical to dealing with the issues raised by climate change (Holdaway et al. 2017), pest animal impacts, and novel pathogens (McCarthy et al. 2021).

The future

> "*The resulting 'Natural Forestry' approach represents a paradigm shift that is long overdue in New Zealand and overseas. Unfortunately recent public statements suggest that many conservationists cannot adapt to TWC's challenge, nor divorce their religious fundamentalist beliefs from scientific inference that the proposed forestry represents a commendable compromise between conservation, economics and other societal needs*." (Moller 1998).
>
> "*…it just isn't appropriate to run the sort of campaign against indigenous forest managers that we ran back in the70s and 80s. Indeed, it seems counterproductive…*" (Salmon 1998)
>
> "*The beech scheme has all the makings of an economic as well as ecological fiasco*" (Sage 1998).

The radically divergent positions (quoted above) on the Timberlands beech scheme adopted by prominent conservationists at the height of the controversy show that the issue of sustainable indigenous forestry in New Zealand is not settled. And indeed, it never was for Māori. As Michael Roche points out, the original mandate of the Department of Conservation for preservation is 'no longer beyond question' as authorization by Parliament for salvage logging of windthrown indigenous forest and disestablishment of a national park and its reconstitution under a joint iwi–Crown management shows (Roche 2017). Many Māori, as discussed above, may have a more use-orientated attitude to indigenous forest than the dominant pākehā paradigm of biocentric and non-extractive use conservation (Lyver et al. 2017). This pākehā–urban paradigm has deep roots, and appears to have begun to spread early in the 20th century when the difficulties of sustained management of indigenous forests first became apparent. As Star (2002) states: '*… a curiously fractured society has evolved in New Zealand, which seeks spiritual sustenance through its native forests while being physically remote and gaining no material sustenance from them. Whether this approach was (and is) necessary or, on balance, the most constructive way forward – for New Zealand or any country – should be the subject of continuing debate.*' Roche argues that the current 'New Zealand Forest Model' of strict separation of exotic production forest and indigenous preservation reflects mono-functional tendencies which were inscribed in cadastral patterns and land tenure systems since colonial times.

This mono-functional trend may be reversed, not only by changing legislation and regulation, but also by continuing research and the nature of the forests themselves. As an example of the research, more than 200,000 ha of Northland freehold land include stands of regenerating tōtara. A pioneering species, it often produces dense stands on otherwise unproductive land (Young & Norton 2017), and it has been shown that merchantable timber can be extracted from them with little disturbance to their stand structure (Steward & Quinlan 2019) and that the end product is highly acceptable and favoured by architects and furniture makers as an attractive native timber (Quinlan 2011). Similar research is underway on the abundant beech forests of the South Island that already produce the bulk of indigenous timber milled in the country (Allen et al. 2012), and support the only substantial indigenous timber operation left in the country, that of Lindsay & Dixon in the Longwood Range.

Invasion of exotic trees into indigenous forests and vice versa challenges the New Zealand Forest Model. For instance, regeneration on abandoned pasture or cut-over forest will often include vigorous woody exotics. Exotic successions may lead to indigenous forests quite different from those following indigenous successions (Sullivan et al. 2007) and mixed exotic–indigenous forest types are not uncommon. Underplanting of pine plantations with native trees is another instance where 'not quite natural' indigenous forests will result (Forbes et al. 2019). Exactly where will these novel forest types fall on the current forest model spectrum? Will they be available for commercial exploitation without the restrictions applying to indigenous forests?

Roche (2017) argues that New Zealand does not currently have a comprehensive national forest policy to answer these and similar questions, but instead an assemblage of institutions with governance or oversight responsibility and a range of legislation. Lack of such a policy is negatively impacting the forestry sector (McEwen 2013). As we have seen, in the absence of clear goals responsive to public opinion as well as commercial imperatives, and lack of well-designed policy linked to practical actions, scientific research struggles to deliver.

Potential problems of the lack of a comprehensive national forest policy can be seen in The One Billion Trees programme (Te Uru Rākau). Like the massive exotic plantings of the 1920s and 1930s, it is primarily driven by an economic imperative although, rather than a looming timber shortage, it is a need to sequester carbon in response to the imminent disaster of climate change (Bastin et al. 2019), although tree planting will not solve climate change (Holl & Brancalion 2020). As with the earlier exotic forest programme of the early 20th century, it relies on mass plantings (although in this case 70% indigenous) using rural labour. For indigenous plantings that are centred on establishing podocarps, the economic and ecological problems that saw such efforts fail in the past will be encountered again. Te Uru Rākau is funding scientific research (One Billion Trees Science plan) with the aim of preventing such failure and that intends to reactivate plots established by Forest Service scientists in the 1980s. It is to be hoped that this research will be generously funded, long-term, and supported by clear goals. An essential component of this research must be attention to the costs of the various interventions and provision of high-quality monitoring of progress. What needs to be avoided at all costs is the ‘smart solutions’ approach of short-term technology-driven innovation focussing on establishment. The key issues are not nursery-raising of seedlings or planting techniques, but the more fundamental concerns about what happens after, and that requires a long-term perspective.

Conclusion

Scientific research was far less useful than it might otherwise have been in providing solutions to New Zealand’s sustainable indigenous forestry problems. In the 20th century researchers were assigned a goal of economically viable sustainable indigenous timber production that was known with some certainty to be unobtainable even in the 19th century and which collapsed in the 21st. The New Zealand Forest Service for almost 70 years promoted sustainability policies for multiple-use forests which would be ‘better than natural’, which they never seriously attempted to implement and that would have been blocked by Government and rural interests had they tried. Nevertheless, there is a valuable science legacy consisting of forests protected from exploitation and underpinning research into all aspects of indigenous forests. There are opportunities for future applied research, but policy guidance is needed. We still need a national consensus, vision and plan: that is an understanding of what roles, including provision of timber, indigenous forests will play in New Zealand landscapes, and the pathways to achieve them.

Competing interests

The authors declare that they have no competing interests.

Authors’ contributions

All authors conceived of the study, and participated in its direction and completion. All authors read and approved the final manuscript.

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