Permanent forestry requiring improved forest management – a North Canterbury example

Adam S. Forbes

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

Abstract

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

Native forests of the PQF project area

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

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

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

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

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

Permanent native forestry issues in the PQF project area

Dispersal limitation

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

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

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

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

Enrichment planting in the PQF project area

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

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

Herbivory

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

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

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

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

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

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

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

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

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

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

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

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

The important social dimension

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

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

Herbivore management in PQF project area

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

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

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

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

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

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

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

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

Technical and financial support

Management of existing forests to ensure their permanence

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

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

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

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

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

Establishing additional permanent forest area

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

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

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

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

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

Access to expert advice and adequate funding

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

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

Recommendations

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

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