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

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

Abstract

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

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

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

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

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

New Zealand Carbon Farming

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

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

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

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

The science behind the NZCF regeneration regime

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Internal organisation capability key

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

Best practice and research

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

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

Foundation blueprint – the forest design process

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

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

Nurse crop species selection

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

Critical role of pest management

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

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

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

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

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

A focus on the local community

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

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

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

Optimising site occupancy and regeneration in establishment phase

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

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

Nurse crop interventions to promote forest health and regeneration

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

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

Tailored carbon leases for other landowners

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

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

Summary

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

Many exotic plantation forests around New Zealand and the world already have significant regenerating native vegetation present within them, given the suitable micro-climatic conditions that these forests create. The existing body of research confirms that rather than harvesting the nurse crop, it can continue to be managed to facilitate and accelerate the regeneration process to a native forest cover. It identifies key factors critical to the success of the regeneration

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

process, including the importance of effective pest management, which has the potential to stop the whole regeneration process if not well executed. The existing research confirms this forest management approach. While successfully demonstrating this approach across its estate, in both new and existing forests, NZCF is constantly working to further enhance and refine the approach to execute this strategy at scale.

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

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

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