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Upscaling restoration of native biodiversity: A New Zealand perspective

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Efforts are being made to upscale restoration of New Zealand's native ecosystems. Success depends, however, on consideration of several key issues that need to be built into restoration planning, implementation and monitoring. This study makes eight recommendations to improve the prospect of obtaining the hoped-for biodiversity conservation outcomes.

Key words: *community involvement, eco-sourcing, landscape scale, nursery production, restoration.*

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Figure 1. Restoration in New Zealand involves approaches ranging from allowing nature to reclaim the land (through natural succession) to active restoration plantings, such as in this case at Port Hills, Canterbury. (Photo David Norton).

Introduction

Public conservation lands (national parks, reserves, etc.) are critical to conserving and sustaining native biodiversity as they represent areas that have been least impacted by human activities; but such areas account for only a small amount of the total land area of most countries and often are not representative of the full range of ecosystems. This is certainly the case for New Zealand where public conservation areas are biased towards inland and upland regions, excluding areas with higher productive value that were converted to other land uses with human settlement (Leathwick *et al.* 2003; Norton & Reid 2013). If we are to sustain the full range of native biodiversity, then we also need to prioritise biodiversity conservation on nonconservation (private) lands that are used for pastoral farming, cropping, plantation forestry and horticulture, and urban areas.

Various approaches are used to sustain and enhance native biodiversity on private land. These usually involve either working with surviving remnants of the original ecosystems, such as forest patches (especially through protecting them), or through encouraging more sympathetic management of the matrix to reduce impacts on the native biodiversity that remains. These different approaches have been referred to as land sparing and land sharing (Fischer *et al.* 2014) and the relative merits of both have generated much discussion, although it seems

Figure 2. Allowing natural regeneration, often termed minimum interference management, is an important component of restoration in New Zealand. Pictured here is Tiromoana Bush, Canterbury. (Photo David Norton).

clear that both can be important depending on the local context and spatial scale.

A further approach to enhancing native biodiversity on private land involves facilitating the re-establishment of natural ecosystems in degraded areas, usually after removal of pastoral farming. This restoration can either involve allowing nature to reclaim the land through largely natural successional processes or promoting recovery through active restoration planting and seeding (Fig. 1,2). The particular approach depends on a range of factors including the degree of degradation at the restoration site, residual vegetation, availability of seed sources, project scale, resources available and restoration goals (Hobbs & Norton 1996). Restoration activities can both improve the values of remnants through buffering and enhancing connectivity and increase the overall extent of native habitat. Restoration can also address a range of other environmental outcomes including enhanced water quality, reduced soil erosion and increased carbon sequestration.

Recognising the magnitude of human impacts on natural ecosystems, the extent of both biodiversity loss and the need for realistic carbon sequestration efforts, many global programmes have been initiated to significantly upscale restoration efforts. For example, the Bonn Challenge (www.bonnchallenge.org) aims to restore 150 million ha of the world's deforested and degraded land by 2020 and 350 million ha by 2030, while The Nature Conservancy has a global programme that aims to plant one billion trees by 2025 (www.plantabillion.org).

In New Zealand, a diverse range of groups including community, iwi (Māori tribal group), council, government and business are involved in private land restoration (Peters *et al.* 2015; Norton *et al.* 2016). While there are several new regional-scale initiatives (e.g. Reconnecting Northland, www.reconnectingnorthland.org.nz, and Banks Peninsula Conservation Trust, www.bpct.org.nz), there is still relatively little large-scale coordination for most of the excellent restoration projects being undertaken. However, this is set to change through the Trees That Count initiative (www.treesthatcount.co.nz), a nongovernment programme which aims to encourage New Zealanders to plant millions of native trees for multiple benefits including biodiversity conservation, carbon sequestration and soil erosion control. The initial target for additional native trees planted for 2017 is one tree for every New Zealander (4.7 million), increasing by 15% per year to reach 200 million trees by 2030. To count, trees must be native, be capable of growing to a minimum of 5 m height and be planted with the intention of being maintained and protected until maturity. This initiative has the potential to result in an unprecedented increase in the amount of restoration undertaken in New Zealand, with almost all of it occurring on private land previously used for pastoral farming. The New Zealand government has recently (February 2018) announced an ambitious new programme to plant one billion trees in the next decade, with a substantial number of these being native. Although the exact details of how this will be done have yet to be confirmed, this will further increase the number of native trees planted in New Zealand.

These initiatives to upscale restoration efforts have the potential to make significant contributions to both reversing biodiversity declines and addressing issues such as greenhouse gas emissions. However, to obtain maximum biodiversity benefits, it is not just a matter of planting trees in the ground as has been the case in China where large monocultures of exotic tree species have done little for biodiversity conservation (Hua *et al.* 2016). Rather, the new plantings need to be undertaken in a way that results in positive outcomes for biodiversity as well as meeting goals such as carbon sequestration.

In this article, we ask what are the issues that need to be addressed if we are to substantially upscale restoration efforts in New Zealand? By upscaling, we mean substantially increasing the area of New Zealand that is subject to restorative activities involving tens to hundreds of thousands of hectares of new restoration. We focus specifically on areas that have been used for pastoral farming as these are the landscapes on which there is the most opportunity for substantial biodiversity gains through upscaling restoration efforts (and comprise some 40% of the New Zealand land area; Dr Jennifer Pannell & Prof David Norton, unpublished data, 2017). While our focus is on New Zealand, the issues we discuss are likely to be relevant in many parts of the world. As a framework for this article, we make eight recommendations that we believe will assist upscaling restoration efforts:

1. Retain what is left and manage it properly.
2. Before starting restoration, address the factors that limit natural regeneration and hence will also limit any planting.
3. Consider how large-scale plantings can increase strategic linkages and habitat area, and enhance all-year-round food supplies for local fauna
4. Eco-source an ecologically appropriate range of plant species and mycorrhizae.
5. Establish certification for seed and seedling supply.
6. Invest in new technologies for revegetation.
7. Adopt best-practice planting and early management, including appropriate monitoring, to ensure the long-term success of restoration.
8. Integrate all for an optimum result.

Recommendations

1. Retain What is Left and Manage it Properly

Remnants of the original natural ecosystems

Remnants that occur through farmland – including some older regrowth that often has similar attributes to remnants – are of vital importance. These areas, which are collectively referred to as 'remnants' here, are all that persist of the pre-agricultural development ecosystems and are both legacies of the past and propagule sources for the future. Protection and management of remnant native habitat on private land is critical as it provides key habitat in those parts of New Zealand with the least public conservation land. In many parts of New Zealand, there is more remnant habitat on private land than there is in the public conservation estate, and private land remnants often represent ecosystem types that are under-represented on public land (Dr Jennifer Pannell & Prof David Norton, unpublished data, 2017).

Some form of protection of remnant habitat is essential to ensure remnants are retained. In New Zealand, this is often achieved through the district planning process where development activities such as clearance of habitat deemed as ecologically 'significant' are prohibited (Brown *et al.* 2015). In some instances, government agencies provide funding for purchase and legal protection of remnants, although non-government approaches are more common and more widely accepted in rural communities (Norton & Reid 2013). In New Zealand, the Queen Elizabeth Second (QEII) National Trust is the primary nongovernment organisation that is legislated to covenant remnant habitat on private land (www.openspace.org.nz). The QEII National Trust has been remarkably successful with nearly 5000 covenants covering some 200,000 ha of private land (Fig. 3). While government-funded, the QEII National Trust operates independently of government and is widely respected through rural New Zealand (Norton & Reid 2013). Covenants remain under private ownership, and the perpetual protection they provide has withstood legal challenges through the New Zealand court system (Brown *et al.* 2015).

While legal protection through public ownership, district planning rules, covenants and other protective mechanisms is essential to ensure remnants are retained (Brown *et al.* 2015), legal protection does not guarantee the long-term sustainability of remnants (Norton & Reid 2013). In particular, remnant habitats, irrespective of land tenure, are being degraded by the effects of fragmentation (small size, edge effects, isolation, etc.) and the ongoing impacts of plant and animal pest species. In addition, small remnants are also vulnerable to the impacts of changing climatic conditions (e.g. increasing incidence of droughts). In essence, legal protection of any form while important should be seen as the start of the conservation effort rather than the endpoint (Norton 1988).

Active regrowth of native woody vegetation

For a variety of reasons, including removal of government subsidies to clear regenerating vegetation, large areas of lowland New Zealand are actively reverting to native shrubland and forest. Many successions are through native seral species such as Kānuka (*Kunzea* spp.) and Tōtara (*Podocarpus totara*; Smale *et al.* 1997; Bergin & Kimberley 2014), although successions through exotic species towards native dominance are also widespread (Wilson 1994; Sullivan *et al.* 2007). While much of the focus in conservation is on protecting remnants of original ecosystems, regenerating vegetation also has important values and its protection should be a priority, both legal protection and protection of the successional processes. In fact, in many parts of New Zealand, the area of regenerating native vegetation greatly exceeds that of remnant natural habitats (Wilson 1998). Such vegetation types are the future native forests that have the potential to play a major role in landscape-level biodiversity conservation by both increasing the total area of natural habitats, especially of under-represented ecosystems, and through improving connectivity (Dr Jennifer Pannell & Prof David Norton, unpublished data, 2017).

The New Zealand biota evolved in the absence of mammalian species with the exception of three bat species, and introduced mammalian herbivores and predators are having unparalleled impacts on native biodiversity (Allen & Lee 2006). In farmland, exclusion of domestic livestock is an important first step in remnant management (Fig. 4), but control of feral and wild mammals (e.g. deer, goats, possums, pigs, rats, cats and stoats) is also essential to protect biodiversity values in remnants (Dodd *et al.* 2011) and regenerating vegetation. The New Zealand flora has more naturalised exotic species than native species and many of these exotic species pose serious threats to remnant native biodiversity through smothering (e.g. vines) and competition (Timmins & Williams 1991); many exotic plants also have the ability to redirect successional processes (McQueen *et al.* 2006). Many of these pressures are exacerbated by the location of remnants within the agricultural matrix. Remnants and regenerating vegetation therefore require ongoing management if their values are to be sustained. Without this management, legal protection alone is insufficient to ensure the sustainability of native biodiversity in remnants.

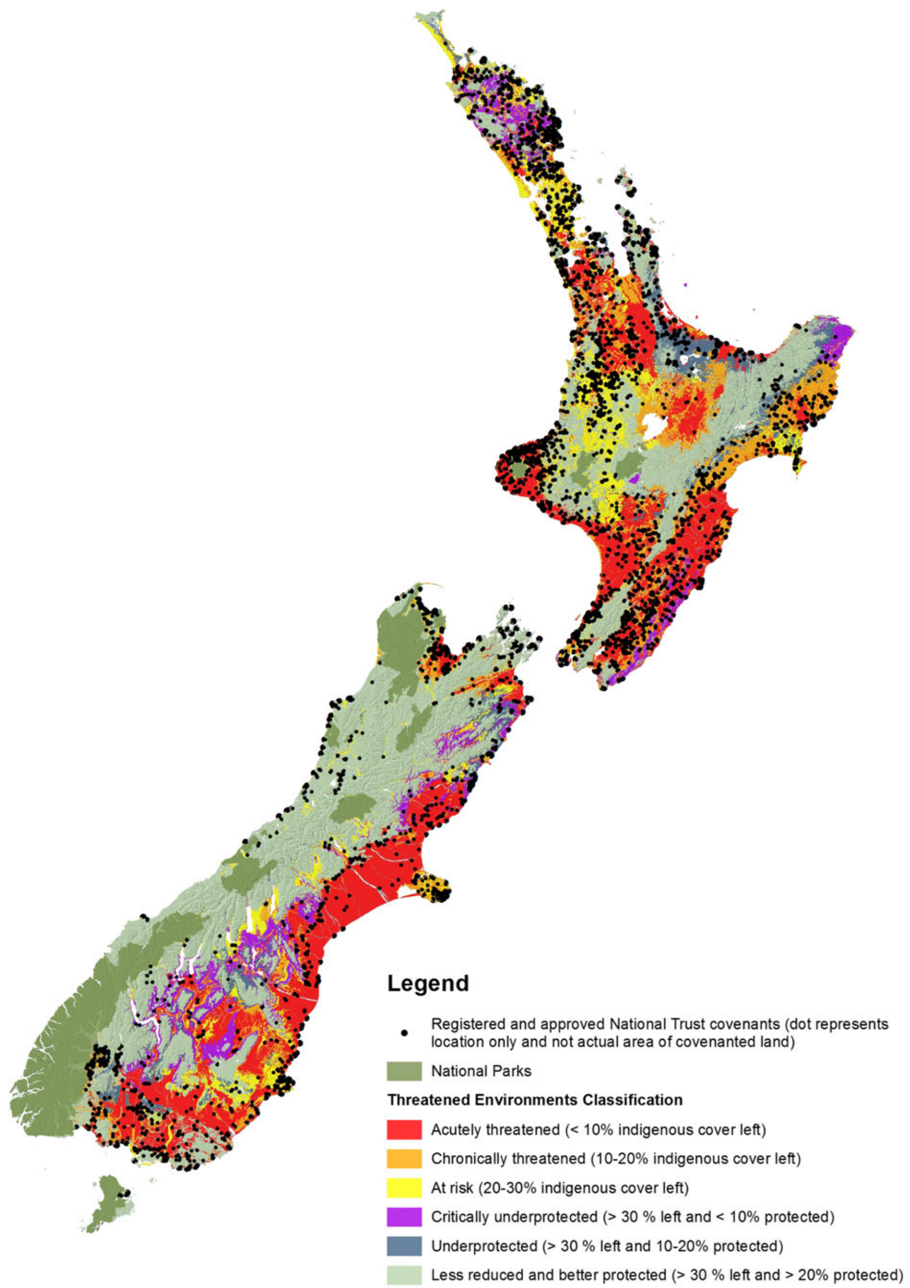

Figure 3. Distribution of QEII National Trust covenants across New Zealand, superimposed on to a map of the amount of remaining native vegetation (image provided by QEII National Trust).

2. Before Starting Restoration, Address the Factors That Limit Natural Regeneration and Hence Will Also Limit Any Planting

The first step before implementing any restorative management at a site is to identify the factors that have led to degradation (Hobbs & Norton 1996). Degrading processes (stressors) can result in a variety of ecosystem responses, depending on the intensity, duration and scale of the impact, and can be both abiotic and biotic. Abiotic stressors (e.g. changes in hydrology or soil loss) usually require more effort to remove or control than biotic stressors (grazing or loss of propagule sources). In many systems, abiotic and biotic stressors collectively cause degradation. While it might be possible to remove one stressor that affects, for example, the biotic part of the system (e.g. grazing animals), this may not result in

Figure 4. Exclusion of domestic livestock (Sheep *Ovis aries* and Cattle *Bos tarus*, left of fence) is essential to sustain native biodiversity in forest remnants, East Cape (David Norton).

ecosystem recovery if strong abiotic stressors are also operating (e.g. elevated nutrient levels or altered hydrology) or some parts of the system are missing (mutualists or seed sources). Ecosystems like this may have crossed ecological thresholds and now exist in alternative stable states (Suding & Hobbs 2009). It is important to recognise when restoration can be achieved by simple removal of stressors and when this alone is insufficient, and further actions are required (Hobbs & Norton 1996). Understanding stressors and implementing appropriate management are essential for restoration success.

In sites that have been subjected to a long history of pastoral farming, which is the most common type of site available for restoration in New Zealand (Norton & Miller 2000), a series of stressors have the ability to limit both natural regeneration and restoration. Increased soil P levels as a result of fertiliser application promote the dominance of an exotic grass sward that can limit the success of both natural regeneration and plantings unless controlled (Fig. 5). Soils have often been eroded and lost their original biota including mycorrhizae. Microclimates of open pasture sites are very different to those experienced in the temperate rainforests that would have dominated prefarming (Davies-Colley *et al.* 2000), and through competition, pasture grasses limit the plant species that can be established. Natural seed sources are often distant and, in the most extensively cleared areas, can be effectively unavailable. In addition, a range of introduced herbivores and carnivores are present that can limit the success of any restoration effort (Dodd *et al.* 2011). Herbivores such as European Rabbit (*Oryctolagus c. cuniculus*), Feral Goat (*Capra hircus*), Deer (*Cervus* spp.) and Brushtail Possum (*Trichosurus vulpecula*) can severely constrain plant growth; omnivores such as House Mouse (*Mus musculus*) consume seed, while Feral Pig (*Sus scofa*) alters soil structure, and carnivores such as rats (*Rattus* spp.), Stoat (*Mustela ermine*) and Cat (*Felis catus*) impact native bird populations that are important for dispersing later successional tree species to restoration sites.

3. Consider how large-scale plantings can increase strategic linkages and habitat area, and enhance all-year-round food supplies for local fauna

Restoration activities invariably focus on the site, but it is important to consider landscape-scale processes such as species interactions and dispersal if we are to sustain biodiversity

Figure 5. Restoration plantings struggle to compete with a thick exotic grass on previously farmed sites, Tiromoana Bush, Canterbury (David Norton).

(Hobbs & Norton 1996; Norton & Miller 2000). In particular, for many mobile species such as Tūī (*Prosthemadera novaeseelandiae*), a honeyeater, and Kererū (*Hemiphaga novaeseelandiae*), a pigeon, viable populations require substantial areas of habitat including a full range of seasonal food resources (MacLeod *et al.* 2008). The importance of spatial scale is relevant both in terms of where we do restoration and the attributes of restoration plantings (species choice, spatial layout, etc.). Most restoration plantings are patch-focussed and, except for those that result in the restoration of large areas, will face the same issues that remnant patches face – small in area, edge effects, isolation, outside influences (e.g. fertiliser), exotic plant and animal pest pressure, etc. (Fraser *et al.* 2015). Connectivity at landscape scale is critical, and individual restoration sites should be developed with consideration to how they can complement other restoration sites and remnant areas in order to enhance connectivity, including under future climate change.

A good New Zealand example of the importance of connectivity comes from a 3-year radio-tracking study of 23 North Island Brown Kiwi (*Apteryx mantelli*) in Northland (Potter 1990). North Island Brown Kiwi regularly cross up to 80 m of pasture between forest remnants, with the maximum distance of pasture crossed being 330 m. However, this species can move between forest patches up to 1.2 km apart so long as forest remnants are available for use as stepping stones. Targeted restoration is clearly going to be important to allow North Island Brown Kiwi to persist in these agricultural landscapes when the distance between remnants is >330 m. Another example involves the native birds Tūī and Kererū, both of which use large areas of native and exotic habitat (farmland and urban areas; Campbell *et al.* 2008). To sustain these species outside of protected natural areas, landscape considerations are essential in terms of the provision of seasonal food resources, including exotic plant species (Fig. 6), and 'safe' sites for nesting (MacLeod *et al.* 2008).

The importance of connectivity cannot be overemphasised, and both the location and composition of local restoration plantings should be cognisant of ecological processes that occur across larger spatial scales. But landscape-scale processes can also be facilitated by other landscape elements such as plantation forests, which can substitute for native forest, improving connectivity between remnants (Norton 1998). Recent large-scale New Zealand conservation initiatives such as the Banks Peninsula Conservation Trust's Wildside Project (Canterbury; www.bpct.org.nz/our-projects?id=30) focus on improving ecological linkages at the catchment or larger spatial scale through remnant protection, restoration plantings, facilitating natural regeneration, and plant and animal pest control.

4. Eco-source an Ecologically Appropriate Range of Plant Species and Mycorrhizae

Upscaling the restoration effort is going to require an 'order-of-magnitude' increase in the provision of plant material. The current capacity of plant nurseries is insufficient to meet the projected future demand, and it is essential that the necessary increase in nursery production does not trade quantity for quality of plant material.

Ensuring vegetation quality is critical, both in terms of the genetics of the source material and in the production of plants that are going to be able to perform well when planted out (especially with regard to the development of mycorrhizal relations and successional diversity). For plants, ecosourcing propagation material is critical because it involves a consideration of genetic integrity (i.e. ensuring that plantings represent sufficient individuals adapted to local environmental conditions) and avoids risks

Figure 6. Sustaining Kererū requires landscape-scale restoration of food resources (including exotic species such as Tree Lucerne *Chamaecytisus palmensis*, in this image) and safe nesting sites (David Norton).

associated with outbreeding depression, while also ensuring that sufficient diversity is represented to avoid inbreeding depression and enable plants within fragmented ecosystems to adapt to a changing climate. Eco-sourcing typically involves collecting seed (preferably) from a range of habitats within the same ecological district, as long as source population sizes are sufficiently large to represent the high levels of genetic diversity needed for adaptation (Broadhurst *et al.* 2008).

There has been recent discussion around the importance of considering a greater degree of genetic variation to buffer restoration plantings against future climate change (Broadhurst *et al.* 2008; Vander Mijnsbrugge *et al.* 2010; Hancock *et al.* 2013). However, the benefits of more remote genetic material for climate change adaptation need to be weighed up against the potential negative consequences for both the survival of plantings under local conditions and the implications of this genetic material for co-adapted species such as mistletoes (Fig. 7) and insect herbivores. It therefore seems prudent to restrict plantings to material sourced from the local area or ecological district, but ensuring that genetic diversity is high by collecting seed across a large number of individuals occurring in as large populations as available and across a range of habitats. Nurseries need to be able to provide guarantees to restoration practitioners about the genetic origins of their restoration plants, perhaps provided in accordance with a much-needed nationally agreed standard for eco-sourcing.

Mycorrhizal inoculation for restoration is also important to ensuring vegetation quality (Harris 2009). For some species, there is no need for inoculation prior to planting as mycorrhizal infection occurs readily in the field. However, for other species and especially at sites where there has been a long history of agricultural land use, the mycorrhizal fungal community composition tends to shift towards dominance by the Glomeraceae at the expense of forest mycorrhiza families (Oehl *et al.* 2003). In these situations, native mycorrhizal species can be absent and inoculation is then used in nurseries to enhance plant growth after establishment in the field. While many nurseries make use of commercial mycorrhizal inoculants, for some species, the best growth occurs when native mycorrhiza are used (Williams *et al.* 2010). Again, the application and nature of mycorrhizal inoculation is something that nurseries should be able to provide assurance on to restoration practitioners.

Figure 7. The New Zealand mistletoe, *Ileostylus micranthus*, exhibits local-scale variation in host preference (Norton & de Lange 1999) and introduction of novel genetic material even of the same host species could reduce the mistletoe's ability to colonise and persist in restoration plantings (David Norton).

A third vegetation quality issue relates to the successional phase of species that are propagated for restoration. Most restoration projects utilise short-lived fast-growing woody species (early successional species) to suppress pasture grasses and create microclimatic conditions that are suitable for the establishment and growth of late-successional species (Smale *et al.* 2001). Early successional species are also generally easier to source seed from and propagate in the nursery, but do not necessarily contribute to long-term forest development. There is clearly a trade-off between species that are cheap, easy to propagate and grow quickly, suppressing pasture grasses and other undesirable plants, but might not live very long, with those that are longer-lived in the field and contribute towards the development of a mature forest canopy, but are harder and more expensive to propagate. However, many of the late-successional tree species require the shelter of early successional species to establish and grow, especially on exposed sites. When dispersal of later canopy dominants is constrained, consideration should be given to either establishing these species with the initial plantings or undertaking subsequent enrichment plantings (Tulod *et al.* 2018).

Planting more diverse assemblages of early successional species might provide more resilience against disease (e.g. myrtle rust) and climatic variations, although many New

Zealand early successional species are also vulnerable to mammalian herbivory and this needs to be considered. Because natural regeneration of species like Kānuka result in virtual monocultures for several decades, careful attention to restoration composition will assist in speeding up the process of ecosystem recovery. In particular, restoration should aim to plant species that are adapted to the site and that will facilitate subsequent recruitment. A proportion of late-successional species could also be included either with the initial planting or established later through enrichment plantings if seed dispersal is lacking.

5. Establish Certification for Seed and Seedling Supply

With nurseries looking to upscale their native plant production, nursery certification focusing on appropriate restoration seed sourcing and propagation techniques, including mycorrhizal use, is one tool that can be used to provide assurance to restoration practitioners about the quality and source of the material being provided. Just as restoration practitioners are certified through the Society for Ecological Restoration (ser.org/page/certification), it seems appropriate that the nurseries providing plant material for restoration projects should also be certified. Such a system could be introduced voluntarily by nurseries, but would require oversight from an organisation such as the Royal New Zealand Institute of Horticulture.

6. Invest in New Technologies for Revegetation

One of the biggest challenges for upscaling restoration is the cost of seedlings, on which most native revegetation in New Zealand is based. While nurseries are able to produce plant material for horticulture or exotic plantation forestry at low cost, the cost of providing plants for restoration is substantially higher. For example, the average cost of producing a 1-year-old Radiata Pine (*Pinus radiata*) seedling for commercial forestry in New Zealand can be <$0.40 per plant, while the cost of a comparable seedling for a restoration project can range from $2 to $5 per plant (Bergin & Gea 2007). This difference occurs because of the techniques used in propagation and scale of the different operations (production of Radiata Pine seedlings is highly mechanised), slower growth rates of native plants and the need for nurseries to raise many different species, some of which take at least 2 years in the nursery. As demand increases, it should be possible to reduce the cost of plants for restoration for some native species. However, it is possible that cost reductions could also occur through the development of direct-seeding technologies.

There is considerable potential for the use of direct seeding as a way to reduce costs associated with nursery-propagated plant material. Direct seeding has been used successfully in many countries (Ceccon *et al.* 2016) but so far has had limited application in New Zealand (Dodd & Power 2007; Ledgard *et al.* 2008). A number of challenges occur with direct seeding in abandoned New Zealand farmland, especially in facilitating seeds to germinate in the dense grass sward that dominates many restoration sites. In addition, issues to do with seed collection, seed storage and development of technology that can be used to deliver seed in the rugged pastoral hill country that dominates much of lowland New Zealand (e.g. by helicopter) need to be addressed before direct seeding can be used operationally. There is, however, scope to learn from the natural reversion that is occurring in many pastoral hill country sites, where native species such as Mānuka (*Leptospermum scoparium*), Kānuka and Tōtara are successfully regenerating, even in the presence of grazing (Smale *et al.* 1997; Bergin & Kimberley 2014). The success of this regeneration suggests that direct seeding has considerable potential. For direct seeding to be a solution at scale, the supply of native seed would need to be increased by orders of magnitude. Whether seed is field-collected or raised at specific seed production sites needs to be considered and will obviously vary with species.

7. Adopt Best-practice Planting and Early Management, Including Appropriate Monitoring, to Ensure the Long-term Success of Restoration

Best-practice planting includes matching species to the site (e.g. wetter lower sites vs. drier ridge sites, sheltered vs. exposed sites), good site preparation (e.g. herbicide control of the grass sward) and planting, timely weed control pre- and postplanting, pest animal control including fencing of stock, and replanting of gaps. Best practice also includes planning how long before canopy coverage reduces the need for maintenance of weed growth. There is a trade-off between dense initial plantings, which are expensive but result in rapid control of grasses and other weeds, compared to cheaper lower density plantings with a longer time to canopy coverage, ongoing weed control costs and greater risk that plantings will be 'forgotten' (Bergin & Gea 2007).

Best-practice restoration requires monitoring to provide information on whether the predetermined goals have been reached. Complete and large-scale restoration of the natural system in some prehuman sense is an unachievable goal (Hobbs & Norton 1996), and it is important to measure success against realistic goals. Restoration success can be defined in terms of a range of ecosystem attributes including composition, structure, pattern, heterogeneity, function and resilience (Hobbs & Norton 1996; SER 2004). Depending on the project, a clear set of carefully defined objectives and goals for particular time periods need to be developed and the success of the project assessed against them (McDonald *et al.* 2016). Monitoring the success or otherwise of plantings is especially important when it assesses the management interventions being used and can provide feedback on their efficacy. With upscaling of the restoration effort and the commitment of substantial amounts of resources, obtaining the best outcomes for these investments is essential.

Providing an easy-to-use yet robust monitoring and mapping system is a major objective for Trees That Count. Monitoring needs to be undertaken by those undertaking the restoration and should be kept simple but scientifically robust. It is essential for all those planting to know what is not working, and why it is not working, and the only way to do this is robust systems of mapping and monitoring so that the lessons learnt can be used to improve future planting.

8. Integrate All for an Optimum Result

If we are to upscale restoration activities and achieve substantial improvement in the condition and sustainability of native biodiversity, then all restoration activities need to be integrated. It is important to consider how remnants of the original ecosystems, natural regeneration and restoration plantings can complement each other across all spatial and temporal scales, and across both private and public land. Integrating private land conservation with public conservation land is paramount to provide connectivity of native biodiversity, particularly across working productive landscapes.

The regulatory environment is critical to fostering large-scale ecological restoration. Regulation needs to facilitate restoration through grants, tax rebates and carbon credits and allow for appropriate economic use while not degrading genetic diversity, rather than restricting innovation and flexibility. Native forests established after 1990 can earn carbon credits under the New Zealand Emissions Trading Scheme (NZETS; Anonymous 2010) and provide some economic return to land that is being restored.

It is equally important to ensure that the long-term integrity of all restoration projects (plantings and natural regeneration) is guaranteed. With current restoration efforts, and even more so with the upscaling envisioned by initiatives such as Trees that Count, huge amounts of resources (capital and volunteers' time) is being expended. It is imperative that the biodiversity outputs from these projects are protected in perpetuity or the resources spent will be wasted. At present, organisations such as the QEII National Trust primarily covenant remnant native habitat and are unlikely to have the capacity to covenant large areas under restoration. It may be that new tools are required to provide guarantees on the future security of restoration projects, and this needs to be urgently sought to provide both funders (government, philanthropy, business, community groups, iwi, etc.) and volunteers with confidence to be involved in these projects. Provisions under the NZETS and various other carbon initiatives such as the Permanent Forest Sink Initiative (Anonymous 2015) provide some protection, while Safe Harbour Agreements (Brown 2016) might be another tool for doing this.

Finally, restoration needs to be strongly driven from the bottom-up through local communities who are the foundation of many restoration efforts (Peters *et al.* 2015; Norton *et al.* 2016). But equally, with the majority of the million or more hectares of pastoral hill country that would benefit from restoration in private or iwi ownership, upscaling of restoration will also require commitment and resources from large landowners and iwi, including incentives and support from regional and central governments. This includes engaging with the corporate sector particularly in their increasing interest in offsetting carbon emissions. New models of regional biodiversity management provide exciting opportunities for enhanced landscape-level outcomes, and these are all driven from the bottom-up (e.g. Reconnecting Northland and the Banks Peninsula Conservation Trust). The key is for all parties to work together from government agencies and research institutes through land owners and iwi to local community groups. All bring together relevant expertise and experience, and the outcomes for national biodiversity conservation will be much stronger than if these groups work in isolation (Norton *et al.* 2016).

Conclusions

Upscaling restoration efforts in New Zealand and globally poses many challenges, but the potential gains for biodiversity conservation far outweigh the costs of tackling these challenges. In this study, we have reviewed what we see as some of the challenges facing upscaling restoration activities in New Zealand and have made eight recommendations that we believe will assist in meeting this outcome. Addressing these recommendations will benefit from the development of robust national guidance on these issues to assist nurseries, restoration practitioners and stakeholders (from community groups to government and nongovernment organisations) to ensure that we obtain the best outcome from proposed future investments in upscaling restoration.

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