Ministry for Primary Industries
Manatū Ahu Matua

Transitioning exotic plantations to native forest

Practical guidance for landowners

November 2021

Te Kāwanatanga o Aotearoa
New Zealand Government

Publisher

Ministry for Primary Industries
Charles Fergusson Building, 34-38 Bowen Street
PO Box 2526, Wellington 6140,New Zealand
Tel: 0800 00 83 33

This publication is available on the Ministry for Primary Industries website at **www.mpi.govt.nz**

Prepared for Te Uru Rākau – New Zealand Forest Service

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MPI Information Paper No: 2021/07

ISBN No: 978-1-99-101974-5 (online)

ISSN No: 2253-394X (online)

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Author's acknowledgements

We thank the Ministry of Primary Industries (MPI) for commissioning this report. We also wish to acknowledge the many researchers, organisations, and landowners for their contributions to the existing state of knowledge on this topic. Case studies draw from experiments and surveys funded and organised by third parties, as outlined here.

Case study one is based on a survey conducted under a collaboration between Forbes Ecology limited (FE Ltd) and Manaaki Whenua - Landcare Research (MWLCR) with funding contributed by Te Uru Rākau – New Zealand Forest Service One Billion Trees Programme (1BT). Special thanks are due to the Milnthorpe Park Reserve Trust for allowing access for the survey and for their generosity hosting the survey and imparting their knowledge of their forest.

Case study two was based on data collected by summer students funded by Gisborne District Council (GDC) in relation to an Envirolink funded project (2125-GSDC163) relating to the Waingake forest restoration project. Data were used with the permission of GDC, and we are very grateful for their support in this regard.

Case study three data were collected by FE Ltd with assistance from James Lambie under contract to (MWLCR) with funding contributed by 1BT. The experiment was established by FE Ltd and Riverside Nurseries with funding from the Post Quake Farming Project. Special thanks are due to the landowners (the Avery family) for their willingness to provide the experimental site and to collaborate on this experiment.

Climate data were sourced from the Cliflo database.

We are grateful for the willingness of all parties to share information and thank MPI for commissioning this work for the benefit of public use.

Cover photograph

Native pigeonwood seedlings naturally established within an exotic Eucalyptus plantation in Golden Bay, Tasman, northern South Island.

Contents

Introduction

Background

This guidance was commissioned by Te Uru Rākau Forestry New Zealand and aims to provide forest owners and investors with practical guidance on transitioning exotic plantations to native (transitional forestry) based on three different sites where this could potentially occur. The guidance is based on the current state of knowledge which is detailed in a companion report (Forbes & Norton, 2021)[1] and the two reports should be read together.

Scope and Structure

This guidance has the following scope and structure:

- **Section 1:** Main practical considerations for landowners when transitioning exotic plantations to native forest.
- **Section 2:** Case studies of Pinus, Eucalyptus and Tagasaste plantations in the context of permanent forestry where a transition to native dominance is a major objective.
- **Section 3:** Conclusion.

Limitations

The guidance presents the main known considerations for transitions to occur and applies these to three case studies of different canopy types across a range of contexts. The purpose of this work is to illustrate applications of the main factors that need to be considered when transitioning a plantation to natives. Where transitional forestry is to be attempted, we recommend specialist ecological advice be sought.

1 Forbes and Norton (2021). *Transitioning Exotic Plantations to Native Forest: A Report on the State of Knowledge.* A consultant report prepared for the Ministry of Primary Industries by Forbes Ecology Limited.

Main Practical considerations

Based on our current state of knowledge (Forbes & Norton 2021), the main practical considerations that forest owners and funders should consider when planning to transition exotic plantation to native forest are set out in Table 1, below:

Table 1: main practical considerations when planning to transition exotic plantation to native forest

Objectives	Set clear objectives defining what management seeks to achieve. Examples include conserve soil, sequester carbon, increase biodiversity, restore cultural values. These are critical as they will help shape and define the management approaches that are implemented.

Specific Considerations

(these are in essence the factors that will either limit or enable the ability to transition an exotic plantation to natives and some or all will require management interventions)

Macroclimate	Locate records for soil moisture/rainfall and air temperature. How amenable is the climate to regeneration? This will be a key factor in (1) determining if a transition is even possible and (2) the level of intervention (especially through enrichment planting) that is required.
Pests	Identify the plant and animal pests threatening regeneration. Remember to consider plant and animal pests both within the site and in the larger landscape as the latter will require a different management approach. What is the level of wilding risk within and beyond the stand? In your management plan you will need to include a plan to address each of these threats
Seed sources & dispersers	Assess the amount and proximity of native seed sources to the forest. Which species are present (seral species or canopy species?) and how important will managing a source of propagules (e.g. enrichment planting) be? How abundant are seed dispersing birds?
Site factors	How might site factors (e.g. aspect, soils) influence regeneration and how does management need to anticipate and respond to these influences?
Stand structure & composition	What is the stand identity, stocking, age, management history? What is the level of understorey regeneration? By which species? What interventions would regeneration benefit from (e.g. canopy gaps, enrichment planting)?
Tree stability	What is the likelihood of instability in the stand? Can this issue be managed (and if so how)?
Scale	Over what scale can a transition be reasonably managed? Consider things such as the level of regeneration occurring, the need for interventions, the nature of pest issues, resourcing, and long-term budgets.

Forest Management

Management plan **Stand interventions** **Monitoring & protection** **Adaptive management**	Develop a management plan to detail how the forest will be transitioned, how progress will be monitored, and which factors will trigger types of management. A management plan should at a minimum include: The overall objectives for the site. The key factors that might constrain the ability to achieve these objectives. 10-year goals (stepping-stones) that will need to be reached if the long-term objectives are to be achieved. The management actions that will be implemented to start transitioning the stand, including a 5-year work programme with a fully-costed budget. The monitoring that will be established to assess the success of the management interventions and inform management. The process that will be used to review progress and adapt the management approach based on monitoring results.

Case Studies

Three case studies are presented here to represent transitional forestry examples in different climate zones and using different planted species. Not all of the case study forests from which data were collected are intended to be transitioned to native forest, however, they all illustrate the range of the issues surrounding transitional forestry and they are valuable case study sites, in particular due to the data available for each.

Summary of Case Studies

Case Study One: Milnthorpe Park Reserve

Case study one is from Milnthorpe Park Reserve located in Golden Bay, Tasman Region. This site represents conditions where rainfall and soil moisture are relatively plentiful and where seed sources are available in the wider landscape. The site has a fifty year history of exotic plantation establishment and a native understorey has been naturally formed beneath differing exotic canopy types. In more recent times, native tree species have been planted in the form of enrichment planting. Although the soils are poor (i.e. strongly acidic podzols), Milnthorpe Park Reserve provides a good example of transitional forestry in favourable climate and landscape contexts.

Study site locations around Aotearoa New Zealand

Case Study Two: Waingake Ngahere Restoration Project

Case study two is based on data collected from a plot survey in mature rotational radiata pine plantations in Tairawhiti and the data are applied to an example stand located in a sensitive water catchment with good seed sources and a favourable climate. Gisborne District Council want to transition this stand to native forest and a detailed plan has been developed to do this. Intensive pest control has commenced, and the understorey regeneration is in the early stages of benefiting from this.

Case Study Three: Tagasaste Nurse Native Restoration

Case study three represents a relatively unfavourable context in terms of climate and seed sources. Partly due to the lack of woody cover in the wider landscape at Grassmere (Marlborough), introduced ungulates and other feral browsing pests (except for rabbits and hares) are, however, not a concern. The tagasaste (tree lucerne) stand used in this case study is part of an experiment comparing native seedling growth rates in open pasture and in tree lucerne which will be reported separately.

Case Study One: Milnthorpe Park Reserve

Context

Table 2: Case Study One: Milnthorpe Park Reserve – context

Location	40°42'S 172°40'E
Elevation	10-40 m a.s.l
Macroclimate	Mild and sub-humid
Climate statistics	Mean annual rainfall = 3,339±571(SD) mm Average deficit of soil moisture = 33±33 mm (days of deficit 8±8) Mean annual air temperature = 12.8±0.37℃
Native seed source context (radius)	100 m = little to none 1,000 m = c. 70 ha of secondary forest inc old-growth individual trees 5,000 m = c. 300 ha of secondary forest inc old-growth individual trees
Landforms	Faces
Soils	Perch-gley podzols, strongly acidic with near surface waterlogging on lower slopes. Patches of orthic brown and sandy brown soils with better drainage
Relevant threats to regeneration	Competition from exotic trees Generally pest issues are well managed

Stand Details

Table 3: Case Study One: Milnthorpe Park Reserve – stand details

Former land use	Pastoral grazing. History of fire prior to plantation establishment
Composition	Three stands of *Eucalyptus* plantation of approx. 41 years of age
Eucalyptus stems ha^{-1}	367±113
Canopy height (m)	40±3
Plantation canopy cover (%)	83±3
Understorey regeneration	Mean sapling density (stems ha^{-1}): Native = 2,527±842 (2,525±845 excluding planted natives) Exotic = 567±792 Mean native sapling and tree density combined (stems ha^{-1}): 3,783±1,451 Understorey cover summed % cover across <0.3, 0.3-2, 2-5 m tiers: Native = 78.3±10% Exotic = 27±13%
Tree composition (basal area)	Mean basal area: Native = 3.8±3 m^2 ha^{-1} Planted native = 0 m^2 ha^{-1} Exotic = 70.6±23 m^2 ha^{-1} Dead standing = 1.5±1.3 m^2 ha^{-1} Total = 75.9±22 m^2 ha^{-1}

		Mean	SD	%
Tree composition by species (basal area, m^2 ha^{-1}; excluding dead standing wood & tree ferns)	Eucalyptus	68.140	24.084	91.6
	Mahoe	2.303	2.724	3.1
	Acacia	2.138	1.394	2.9
	Kanuka	0.878	1.520	1.2
	Hoheria populnea	0.397	0.363	0.5
	Other exotic	0.280	0.272	0.4
	Red mapou	0.096	0.086	0.1
	Pigeonwood	0.063	0.057	0.1
	Totara	0.038	0.066	0.1
	Five finger	0.026	0.045	< 0.0
	Rimu	0.019	0.032	< 0.0
	Kohuhu	0.016	0.027	< 0.0
	Lemonwood	0.004	0.008	< 0.0
Presence of long-lived canopy dominant species	Species = rimu, kahikatea, and totara Stem density = 155±100 stems ha^{-1}			

Stand Photographs (April 2021)

Forestry Objectives

Table 4: Case Study One: Milnthorpe Park Reserve – forestry objectives

To establish a permanent and self-sustaining native forest
To use exotic trees to facilitate the subsequent establishment of native species

Management Approach to Transition

The mild and sub-humid climate at Milnthorpe is well suited to forest regeneration. Mean annual rainfall is plentiful (c. 3,300 mm year–1), although summer droughts have been reported in recent years which are exacerbated by shallow soils that limit rooting depths. Animal pest issues are well managed. There are no immediate plant pest issues noted within the *Eucalyptus* stands. While forest remnants are not embedded within the plantation, the wider landscape contains good amounts of native cover. However, these forests are mainly secondary (i.e. re-established following primary forest clearance) and are missing some representative canopy dominants (e.g. northern rata, native conifers).

Landform is similar among the *Eucalyptus* stands. Soils are relatively poor (i.e. strongly acidic podzols) which is a site factor needing consideration when selecting species for enrichment planting.

Over forty years, the *Eucalyptus* plantation has shown height growth of over 1 metre year–1. While occasional windthrow has occurred, at a stand level the trees appear to be stable. The *Eucalyptus* form c. 83 percent canopy cover. By basal area, the stand is 5.4 percent native. The understorey is native dominated. Native saplings are present at around 2,500 stem ha–1, and with native trees combined around 3,800 stems ha–1 which is equivalent to 1.6 × 1.6 m to 2 × 2 m spacing, respectively, which are a spacings sometimes selected in native forest restoration plantings to establish forest canopy. Mahoe is the most dominant native species, followed by kanuka, and *Hoheria populnea*. While understorey cover is predominantly native (i.e. in forest tiers from <0.3, 0.3-2, 2-5 m), native cover in any one tier is only around 20-40 percent, which is insufficient to form a stand-alone native forest.

Reducing competition from the exotic canopy would likely stimulate the growth of the existing native understorey and may promote further native establishment. This could be done through selective removal of the exotic canopy (e.g. drill and fill poisoning of trees to leave them dead standing). Removing acacia from the *Eucalyptus* stands should be a priority for interventions as acacia appears to replace itself at this site (and will therefore be persistent and potentially generate undesirable levels of competition in the future). Any canopy interventions should be planned on a site-specific basis.

Further enrichment planting is needed to boost native tree biomass and to reintroduce species that are currently missing or underrepresented in the existing forest composition (e.g. native conifers). While potential old growth canopy trees (i.e. rimu, kahikatea, & totara) are present, their density is low, and they are spatially variable through the forest (155±100 stems ha^{-1}). A particular focus should be on planting long-lived tree species that help form a native forest canopy and those that support ecological functionality in the forest (e.g. year-round feeding resources for native birds, tree architecture to support perching, and as insect habitats).

Case Study Two: Waingake Ngahere Restoration Project

Context

Table 5: Case Study Two: Waingake Ngahere Restoration Project – context

Location	38°50'S 177°46'E
Elevation	340-580 m a.s.l
Macroclimate	Mild, semi-arid to sub-humid
Climate statistics	Mean annual rainfall = 1,490±319 mm Average deficit of soil moisture = 51±11 mm (days of deficit 73±21) Mean annual air temperature = 14±0.5°C (at Manutuke: 21 kilometres NE at 10 m a.s.l)
Native seed source context (radius)	100 m = secondary forest surrounds the stand 1,000 m = c. 150 ha of secondary forest inc old-growth individual trees 5,000 m = c. 380 ha of secondary forest and 230 ha of old-growth forest
Landforms	Various
Soils	Moderately deep, well-drained loam, from rhyolitic tephra
Relevant threats to regeneration	Browsing pests (deer, goats, pigs, possums) Plant pests (e.g. blackberry, cotoneaster)

Stand Details

Table 6: Case Study Two: Waingake Ngahere Restoration Project – stand details

Former land use	The original forest was cleared for pastoral grazing prior to plantation establishment. Plantations are 28-32 years of age
Composition	Stand of monocultural radiata pine plantation (9.3 ha)
Radiata stems ha^{-1}	241±100
Canopy height (m)	24.3±4.8
Canopy cover (%)	85±20
Understorey regeneration	Mean native woody seedling density (stems ha^{-1}): 19,300±10,170 (range = 3,000-423,000) Mean native sapling and tree density (stems ha^{-1}): 1,600±1,830 (0-7,300) Understorey cover summed % cover across <0.3, 0.3-2, 2-5, 5-12 m tiers: Native = 85.2±36% (0->80% cover occurred in any one tier)

Composition	Species	IV[2]	Species	IV	Species	IV
	Radiata pine	14.9	Tall mingimingi	1.7	Kanuka	0.5
	Coprosma rhamnoides	5.4	Five finger	1.7	Inkweed	0.5
	Rough tree fern	3.9	Rangiora	1.7	Kawakawa	0.4
	Kohuhu	3.4	Smiths tree fern	1.6	Red mapou	0.4
	Mahoe	3.1	*Hoheria sexstylosa*	1.6	Seven finger	0.4
	Sliver fern	2.7	Karamu	1.1	Tawa	0.3
	Hangehange	2.4	Kotukutuku	0.9	Mānuka	0.3
	Mamaku	2.3	Pigeonwood	0.9	*H. populnea*	0.3
	Lancewood	2.1	*Helichrysum lanceolatum*	0.8	Titoki	0.3
	Makomako	2	Rewarewa	0.8	Poataniwha	0.3
	Marbleleaf	2	Wheki-ponga	0.5	Poroporo	0.1
Presence of long-lived canopy dominant species	Species = rewarewa, tawa and titoki					

2 IV = Species importance values which represent the summed cover by species in forest tiers averaged across 15 radiata pine vegetation plots. Higher values indicate greater levels of cover by that species on average across plots.

Stand Photographs (2020/21)

Above: (Top) Case study example stand and (bottom) understorey regeneration (thriving following recent goat eradication) within the Waingake Restoration Area.

Forestry Objectives

Table 7: Case Study Two: Waingake Ngahere Restoration Project – forestry objectives

To establish a permanent native forest while avoiding clear-fell of the exotic plantation in an environmentally sensitive catchment

Management Approach to Transition

The macroclimate (rainfall and temperature) at Waingake is suitable to support native forest regeneration. Seed sources are immediately adjacent and surround the stand to be transitioned, although the closest native forests are secondary and are missing key canopy dominants with old-growth native forests 1.2 kilometres away. Adequate populations of native birds are present for dispersal of fleshy tree species including kereru, tui and korimako.

The forest has a history of high goat numbers and deer, possums and pigs are present. In the last 24 months intensive goat control (conducted by professional cullers quarterly) has commenced and the plantation understories are showing signs of improved regeneration because of this. Future plans are to expand the types of control to address other animal pests.

The plantation is largely free of plant pests that might threaten regeneration, although this should be a subject of monitoring.

The site holds good landform variability. Drier ridge and upper northern slopes can be expected to regenerate more slowly compared to southern faces.

The radiata pine stand is of a commercial stocking and density (e.g. pine canopy cover of 85 percent) and will be creating adverse levels of competition for light for the native understorey. Native woody cover in the understorey is of a high stem density but this cover is spatially variable. In understorey areas where native cover is high (native species are shading the ground independently from the pine cover), liberal opening of the pine canopy can be executed at the outset. This is because the shading by the extant native cover should maintain the current resilience from invasion by light demanding exotic weeds (e.g. radiata pine wildings, old man's beard, gorse).

Where required, canopy opening should be by drill-and-fill method, so as to retain both a more complex light environment and overhead perches until the standing trees rot down. Site management will need to recognise the resulting dead standing trees as a health and safety issue and set site protocols accordingly. From a regeneration perspective, it would be less risky to start with smaller openings and judge over proceeding years the adequacy of the understorey response. This intervening time also allows an opportunity to gauge what level of old-growth species establishment will occur in gaps without enrichment planting. Tawa, rewarewa and titoki are already present in low cover scores, although native conifers are absent.

Where localised gaps are required to gradually build native understorey cover, circular gaps should be created by drilling-and-filling all pine trees within 24 metres diameter (a diameter equal to canopy height). Larger gaps run the risk of creating too light an environment resulting in light demanding weeds establishing. The lower risk option is to create small gaps and expand them in subsequent years once the effect of gap creation is apparent. Gap treatments would be spaced throughout the stand excepting the edge zone (24 metres from the forest edge) and gaps would be no closer (edge to edge) than 24 metres. These measures are to preserve forest microclimate. Gaps will be ideal sites for enrichment planting of old-growth species should this be deemed necessary.

The plan for transitioning through manipulation is to have treated 80 percent of the 9.3 hectares stand over a 10-year period. This will be achieved as follows:

- Identify understorey areas where native cover already shades the ground and plan for initial treatment of these areas as described above. These are likely to be gullies and lower slopes/southern slopes where regeneration is naturally more advanced.

For the balance of the plantation, the plan is as follows:

- Current pine spacing is 6.5 × 6.5 metres.
- 24 metre diameter gaps result in 0.045 hectares treated per gap (c. 11 pine trees require poison per gap)
- 6 gaps per hectare results in 27 percent of each hectare treated per wave of treatments.
- Waves of treatments occur in years 1, 5 and 10 at which point 81 percent of the plantation would have been treated with gaps.

A management plan would guide forest management over this time including monitoring and specifying thresholds for interventions (enrichment planting). Browser control would be maintained on an ongoing basis.

Case Study Three: Tagasaste Nurse Native Restoration

Context

Table 8: Case Study Three: Tagasaste Nurse Native Restoration – context

Location	41°45'S 174°07'E
Elevation	20-60 m a.s.l
Macroclimate	Mild semi arid
Climate statistics	Mean annual rainfall = 556±121 mm Average deficit of soil moisture = 91±15 mm (days of deficit 147±30 days) Mean annual air temperature = 13.5±0.87°C
Native seed source context (radius)	100 m = little to none 1,000 m = little to none 5,000 m = c. 45 ha of secondary forest/scrub
Landforms	Faces
Soils	Shallow well-drained silts
Relevant threats to regeneration	Droughts Herbivory by rabbits and hares

Stand Details

Table 9: Case Study Three: Tagasaste Nurse Native Restoration – stand details

Former land use	Pastoral grazing planted in tagasaste 5 years earlier
Climate conds. During experiment	Monthly rainfall (mm): 30.7±27(8-79) Mean soil moisture deficit (mm): 124.8±23(89.3-142.5)
Composition	A stand of tagasaste with planted golden akeake, black beech, and ngaio
Tagasaste stems ha^{-1}	1140±450 (c. 3x3 m spacing)
Canopy height (m)	2±0.5
Plantation canopy cover (%)	October 2020 = 23±31; March 2021 = 10±20
Understorey regeneration	No natural native understorey regeneration
Planted native composition, survival and growth rates	Golden Akeake: Composition = 54% Growth = 48.5±41 mm (over six months Oct-March) Unlikely to survive/dead = 0% Black beech: Composition = 36% Growth = -8.7±43 mm (over six months Oct-March) Unlikely to survive/dead = 3% Ngaio: Composition = 10% Growth = 51.8±39 mm (over six months Oct-March) Unlikely to survive/dead = 0%
Presence of long-lived canopy dominant species	Species = Ngaio and black beech

Stand Photographs (October 2020)

Above: Tagasaste stand enrichment planted with native tree species

Forestry Objectives

Table 10: Case Study Three: Tagasaste Nurse Native Restoration – forestry objectives

To establish permanent native forest in a very dry climate
To use exotic trees to facilitate the subsequent establishment of native species

Management Approach to Transition

The climate at Grassmere is mild but very dry. Around half the year the soils are in moisture deficit and the annual average deficit is 91 mm. Experience at the site has shown that depending on the species, establishing trees requires an active approach of planting and subsequent tending, including watering during sustained dry periods. There is very little forest cover in the wider landscape and ungulate numbers are reported to be very low. Overall, plant and animal pest issues are well managed. Exotic grassland dominates the landscape and without shading, these grasses have the potential to supress planted natives. The dry nature of the landscape led to early clearance of the original native forest cover by Polynesian fires and little native cover remains in the landscape. The nearest native remnant comprises a canopy predominantly of mānuka, ngaio, golden akeake, and kōhūhū (three out four of these species are wind dispersed). Important dispersers of fleshy fruited native species (kererū, tui and bellbird) are scarce or absent. The combination of dry climate and absence of seed sources means native forest establishment at this site will require active inputs starting with planting of native species.

Being a sloping site (22 degrees average) and having a southwestern aspect means the site receives some reprieve from sustained sunshine. Soils are eroding and relatively poor which is a site factor needing consideration when selecting species for enrichment planting. It is likely to have been several centuries since the soil received regular organic matter inputs from forest cover.

The wider landscape is grazed by domestic stock and the apparent risk of wilding tagasaste spread is low.

Over five years, the tagasaste plantation has grown to 2 metres in height and has attained a canopy cover of 10-23 percent (varying with slope position and season). Tree stability is not an issue for this small-statured and light-canopied stand. Shading by the tagasaste canopy has thinned the cover of exotic grasses in places to levels where bare soil is exposed (and a duff layer is sometimes present). This is an important function being served by the exotic plantation, addressing excessive competition from exotic grass and opening up establishment sites for native seedlings. No natural establishment of native trees had occurred, indicating at this site even with an exotic plantation an active approach to tree establishment will be necessary for the foreseeable future.

Growth rates among the planted native species were variable, showing the importance of species selection when enrichment planting. Even despite having been recently planted and suffering a mean soil moisture deficit of 124 mm over the measurement period, both ngaio and golden akeake showed height growth rates of c. 50 mm over the 6-month summer/autumn growth period. At this rate it would require several decades before the planted native seedlings over-topped the tree lucerne. However, once the seedlings are established it is reasonable to expect faster growth rates and also tree lucerne is a relative short-lived species so it is likely the tree lucerne will senesce reducing competition for the planted native seedlings. Black beech showed poor performance (negative height growth on average) and the reasons for this are yet to be examined.

Given the survival and growth rates of ngaio and golden akeake at this site, further enrichment planting is warranted to ensure the native seedlings densities are sufficient to form an independent forest canopy as the tree lucerne senesces in future decades. Native planting should be expanded to include other locally adapted native species especially those that add structural and functional diversity to the stand.

Conclusion

The guidance presented here represents advice based on the current state of knowledge and this document should be read in conjunction with Forbes and Norton (2021).

Successful forest transitions will require clear objectives defining what management seeks to achieve. We provide a set of specific considerations that are factors which will either limit or enable a transition from exotic to native forest. Forest management will then need to develop this information into a management plan which details how the forest will be transitioned, how progress will be monitored, and which factors will trigger specific management interventions. The transitional forestry approach needs to be an adaptive one with ongoing management responses informed by monitoring and with ongoing financial support.

Our three case studies illustrate examples of different exotic plantation types in different environmental contexts and how our considerations can be applied at a site-specific scale in the form of management approaches.