Plantation forestry best practice for Northland

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This document is intended to provide land owners with information to help them make best practice decisions on establishing and maintaining tree plantations intended to produce timber.

The opportunity for Northland is to embrace positive land use change, from highly erodible pastoral slopes into productive timber plantations. For this transformational change in land use to take place the land owner requires confidence that they are doing the right thing in terms of environmental outcomes for the region but also their revenue streams.

To be able to achieve this goal, landowners will require adequate knowledge to plant the right trees, in the right place, for the right purpose. This resource provides information on plantation forest establishment best practice.

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Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

Contents

1. Siting and species adaptability

Northland's diverse land forms provide highly variable micro-sites, each suitable for different tree species. For successful outcomes the grower requires some knowledge on siting of different tree species. Siting limitations include:

- soil drainage
- soil structure and fertility
- exposure to wind

These factors influence species productivity, with the worst-case scenario being plantation failure.

The grower must understand that each tree species has different limitations to soil and climate extremes and also that nothing is certain. The mantra for growing trees is "eliminate as much risk as possible to improve the odds of success".

Radiata pine is well known as a resilient species, one that is adaptable to a wide range of sites and conditions. However, even radiata has limitations, for example it does not like wet feet. Better species are available for poorly-drained sites. Another newly emerged siting limitation is red needle cast caused by the foliar pathogen *Phytophthora pluvialis*. This seasonal disease causes death of needles and defoliation in high-elevation, damper sites in Northland. This highlights the need to site trees within their "comfort zone" – which varies according to species and their adaptions to site factors.

Wind exposure and trees

The severity of wind and even how salt laden that wind is, influences species selection for a site. Radiata pine is resilient to both and is a good benchmark to compare other species with.

Wind causes toppling of trees and stem breakages. Productivity of the stand tends to decline as the site gets windier, such as nearer to ridge-tops, especially if general wind-resistance of the species is lower. Wind in coastal sites can burn foliage of many species, depending on level of salt exposure. It is important to carefully match species with site.

Soil and trees

Soil drainage and fertility are important in the context of species selection. Evaluating soils for level of drainage is easier in winter when poorly-drained soils become soggy and stock cause pugging. Another indicator of poor drainage is presence of certain water-loving vegetation types, such as rushes and buttercup. Some tree species such as poplar enjoy wet soils while others such as radiata pine do not thrive at all in poorly-drained soils. Again, radiata is a good benchmark to compare other species with.

Different soil types have different levels of natural fertility. Soil fertility can be measured by either testing the soil or by foliar tests of the existing vegetation (e.g. radiata pine or pasture species). A fertiliser history suggests moderate to good fertility, whereas pastoral farming for decades without addition of fertiliser suggests low soil fertility. Vegetation types present on the site also indicate soil nutrient status, for example if the natural bush in the area is dominated by totara and kahikatea then natural fertility might be low, whereas if broadleaf trees such as puriri, kohekohe and taraire are common then this suggests a good base level of soil fertility. Tanekaha tends to indicate poor soils in elevated drier locations. If there is no clover present in the pasture this suggests low soil fertility, possibly a phosphate deficiency.

Fertility status usually has a direct relationship with tree growth rates. However, there are negative consequences to both excessively high and excessively low fertility. Low fertility stunts growth rates and high fertility can cause excessive growth, resulting in windthrow, stem breakages or deformation.

Species assessment and selection for site

Table 1: Exotic plantation species and their siting

Species*	Resilience to wind exposure	Resilience to salt wind exposure	Soil fertility requirements	Soil drainage requirements
Cedar, Japanese *Cryptomeria japonica*	Very high	Moderate	Medium	High
Mexican cypress *Cupressus lusitanica*	Low	Low	Medium	Very high
Macrocarpa *Cupressus macrocarpa*	High	Very high	Medium	Very high
Oven's cypress *Cupressus 'Ovensii'*	High	Moderate	Medium	Very high
Southern mahogany *Eucalyptus botryoides*	High	Very high	Low-medium	Low
White stringybark *Eucalyptus globoidea*	Moderate	High	Low-medium	High
Tallowwood *Eucalyptus microcorys*	Low	Low	Medium	Medium
Yellow stringybark *Eucalyptus muelleriana*	Moderate	High	Low-medium	High
Blackbutt *Eucalyptus pilularis*	Moderate	High	Low-medium	High
Sydney blue gum *Eucalyptus saligna*	Moderate	High	Low-medium	Low
Blackdown stringybark *Eucalyptus sphaerocarpa*	High	High	Low-medium	High
Pine, radiata *Pinus radiata*	High	High	Low-medium	High
Poplar – Kawa *Populus deltoides x yunnanensis*	Low	Low	Medium	Low
Redwood – Coast *Sequoia sempervirens*	Low	Low	Medium	Medium

*This species list is not comprehensive but is a selection of "best-bet" options.

Table 2: Native plantation species and their siting

Species*	Resilience to wind exposure	Resilience to salt wind exposure	Soil fertility requirements	Soil drainage requirements
Totara *Podocarpus totara*	High	Moderate	Low-medium	Medium
Rata/Pohutukawa hybrid *Metrosideros umbellata x excelsa*	Very high	Very high	Low-medium	Medium
Kahikatea *Dacrycarpus dacrydioides*	High	Moderate	Low-medium	Low
Tanekaha, Celery pine *Phyllocladus trichomanoides*	Very high	High	Low-medium	High
Rewarewa *Knightia excelsa*	Moderate	Moderate	Low-medium	Medium
Kauri *Agathis australis*	Very high	High	Low-medium	High

*This species list is not comprehensive but is a selection of “best-bet” options.

Northland has a solid history of plantation forestry and species trials, with a good knowledge base that growers can tap into. Successes and failures over time have resulted in a shortlist of well proven "core species" that growers can be confident in planting with appropriate siting (tables 1 and 2). Detailed information on each species is presented in Chapter 4. Individual tree descriptions. Growers are not discouraged from experimenting with other species.

Growers should also be aware that for each species a minimum scale is required, so that development of niche markets can take place with a consistent reliable supply of timber. Suppliers and processors have recognised this and are working on market development for several “specialty timber” species in Northland.

2. Production forest planning

Planning a production forest requires decisions on appropriate land use. This requires an evaluation of the environmental sustainability and economics of competing land uses.

Costs involved with establishing plantation forestry on pastoral sites may include:

- fencing to exclude grazing animals
- roading for both planting and harvesting, and
- costs of tree establishment.

Tree planting requires forward planning, specifically securing orders for seed, tree stock, site preparation and arranging labour. Orders should be made well in advance of planting, ideally a year ahead.

Economics and species selection

Exotic tree species tend to grow considerably faster than New Zealand indigenous species, usually by a magnitude of at least two, sometimes up to four. Radiata pine is the predominant plantation forest species grown in Northland, so is a useful benchmark to compare other species with for growth rates, both exotic and native.

Productivity and timber value vary between species and are useful indicators of potential returns. Species that grow slowly but yield high-value timber might be more profitable than lower-value species that are more productive.

Although future timber values are inherently speculative, table 3 offers "best bet" estimates to compare timber utility based on species quality scores, with radiata pine as the benchmark (higher scores are better):

Table 3: Species timber quality scores

Species	Durability	Strength	Hardness	Sapwood depth	Appearance	Timber quality score*
Radiata pine[1]	2	5	4	4	5	**20**
Poplar (kawa)	2	4	3	4	8	**21**
Kahikatea	2	5	4	4	7	**22**
Cedar, Japanese	7	2	2	4	8	**23**
Redwood	7	2	2	4	8	**23**
Cypress	7	4	4	4	8	**27**
Kauri	7	5	4	3	8	**27**
Totara	7	5	4	4	8	**28**
Rewarewa	2	8	8	3	8	**29**
Tanekaha	7	6	6	4	8	**31**
Eucalypt, medium durability (Group 1)[2]	7	7	7	5	8	**34**
Rata/Pohutukawa hybrid	7	8	8	5	8	**36**
Eucalypt, medium durability (Group 2)[2]	7	7	7	8	8	**37**
Eucalypt, high durability (Group 3)[2]	8	8	8	8	8	**40**

*Equal weighting is applied to durability, strength, hardness and sapwood depth. This does not apply to products where specific features are desired (e.g. hardness in flooring).

[1] Radiata pine is a special case whereby its inherently low durability as a result of high wood porosity currently favours the species in the market, because although this property renders the species "treatable" with chemical preservatives, it is also reliant on these. Therefore, depending on societies changing attitudes towards chemical treatment, this feature illustrates what economists describe as Knightian uncertainty, where an imperfect knowledge of future events implies that future economic value of timber cannot be measured in the present.

[2] See the Eucalypt chapter below for grouping of individual species.

Timber and log markets

Export log markets are available for most exotic timber species including radiata pine, eucalypt, cypress, poplar and redwood. However, for minor species to realise their market value potential as export logs, a co-operative effort would be required to generate economies of scale.

Growers planting trees now can only speculate on level of market development and market value into the future for their timber species.

To generate market premiums for timber, a predictable and steady supply of logs and a consistent product quality is required. The grower planting trees now, to be a price setter rather than a price taker, must either become:

- a niche marketer with a unique timber product; or
- part of a marketing network or collective that achieves a scale that captures market share.

The Northland region is well positioned to generate opportunities for high returns from high quality timber. However, to be assured of success growers would need to collectively achieve the scale threshold necessary for their species to generate value premiums. The individual grower must also focus on producing high quality timber by following good management practice.

Combining individual species productivity with timber quality and an estimate of biological risk reveals a "value proposition" score for each species that represents potential economic utility relative to radiata pine (table 4):

Table 4: Species value proposition

Species	Timber quality[2]	Productivity	Biological risk	Score[1]
Kauri	1.35	0.4	0.2	**0.65**
Kahikatea	1.1	0.2	1	**0.77**
Tanekaha	1.55	0.2	1	**0.91**
Rewarewa	1.45	0.3	1	**0.92**
Totara	1.4	0.4	1	**0.93**
Cypress	1.35	0.7	0.9	**0.98**
Radiata pine[1]	1	1	1	**1.0**
Eucalypt, medium durability (Group 1)[3]	1.7	0.8	0.5	**1.0**
Poplar	1.05	1	1	**1.02**
Rata/Pohutukawa hybrid	1.8	0.3	1	**1.03**
Japanese cedar	1.15	0.8	1.2	**1.05**
Redwood	1.15	0.8	1.2	**1.05**
Eucalypt, medium durability (Group 2)[3]	1.85	0.8	1	**1.22**
Eucalypt, high durability (Group 3)[3]	2.0	0.7	1	**1.23**

[1] Scores are relative to radiata pine (as the benchmark). A higher score represents a better value proposition.

[2] Quality scores are from Table 2 *Species timber quality scores* (above), adjusted to be relative to radiata pine (=1)

[3] See the Eucalypt section of Chapter 4, *Individual species descriptions for grouping of individual species*.

Assumptions:

1. The primary purpose of forest plantations is timber production.
2. Market value for timber products is based on timber qualities.
3. Timber value is based on physical properties rather than convention or other subjective market values or product part-worth's.
4. Costs for establishing the plantation are equal between species.
5. Equal weighting is applied to timber quality, productivity and biological risk.

Notification of activities and Resource consent

The National Environmental Standard for plantation forestry (NES-PF) provides rules and regulations for plantation forestry activities. In some cases a resource consent is required from Northland Regional Council.

Written notice is required to Northland Regional Council before a landowner can undertake afforestation activities on more than 1 hectare of land that has not been in plantation forest in the last 5 years (i.e. essentially new land converting to forestry). Such notice must be received 20 days before planting commences and involves a minimum of describing the timing, location, wilding potential of the trees being planted (from the Wilding Tree Risk Calculator) and Erosion Susceptibility Classification (ESC) maps for the land. Notification for afforestation activities is submitted via the online portal on NRC's website:
https://www.nrc.govt.nz/environment/forestry/
Our forestry webpage has all the steps and tools to be able to prepare and submit a Notice and/or a management plan.

If afforestation activities are to be undertaken on 2 hectares or more of red zone (highly erodible) land under the NES-PF (National Environmental Standard for plantation forestry), or within the Poutō Forestry Restriction Area, resource consent is required from Northland Regional Council. Contact your NRC Land Management Advisor about whether your land is red zone, or use the online ESC tool provided by MPI:
https://mpi_nes.cloud.eaglegis.co.nz/NESPF/

For resource consent to plant ESC red-zoned land, the consent application will need to provide written notice, a wilding risk calculation where planting conifers, the setbacks between the forest and adjoining properties, water bodies, dwellings, papakāinga, urban areas, significant natural areas and public roads, along with evidence the land being planted is not a significant natural area, or an outstanding natural feature or landscape. For more information see the NES for Plantation Forestry – User Guide on NRC's forestry page on our website:
https://www.nrc.govt.nz/environment/forestry/

Resource consent is also required to harvest on ESC red-zoned land, unless the harvesting activity is 'low-intensity harvesting' i.e. 75% canopy cover is retained at all times. Where clearfell harvesting is to take place on greater than 2 hectares or Land Use Capability (LUC) class 8e land, harvesting becomes a controlled activity, requiring a harvest plan demonstrating that management practices remedy or mitigate adverse effects on the environment. These include sediment discharge, slash and debris management, ground disturbance and disturbance of water margins, each assessed as conditions in granting the resource consent.

Regimes

Planting density is one of the most important decisions to make for a new forestry plantation. Three important factors must be considered when planning a species regime. These are:

1. initial stocking
2. final stocking, and
3. rotation length.

Planting density is mostly influenced by genetic quality of the planting stock. Radiata pine is usually planted at a density of between 600 and 1200 stems per hectare (sph). Unimproved seedlines usually require higher stockings and some improved clonal lines (e.g. cypress and redwood) can be planted at stockings as low as 600 sph.

High tree stockings require more work later thinning out unwanted trees, but offer a higher selection ratio, meaning better quality (more valuable) trees can be retained as crop trees. The tradeoff is therefore between increased establishment costs and improved returns from greater volumes of better-quality stems. Some species (for example eucalypts) also benefit from high initial stockings by self-pruning, which can negate the high establishment costs by not requiring manual pruning. Stockings of ~2000 sph achieve this.

3. Forest Establishment

Weed competition and browsing animals are the two biggest threats to establishment of trees. These threats should be both detected and dealt with early, sooner rather than later.

Browsing stock and wild animals

Seedlings must be protected from browsing stock and wild animals. Fences must be stock proof and well maintained for several years, or, for some species, permanently. Pukekos are likely to pull out young seedlings and can pull out thousands. Rabbits, hares and possums must be well controlled before planting. Last minute animal control is not likely to be as effective as a dedicated control effort for a period before planting. Repellent should not be relied on but can be made by blending 5 fresh eggs, 150 ml of acrylic white paint and 600 ml of water. This is sprayed on the seedlings in the nursery and allowed to dry before dispatch.

Land preparation

Good weed control produces better growth and survival in young trees, especially in the first year after planting. Weeds compete for moisture, nutrients and light and their presence (especially grasses) delays establishment of trees.

Although fire has been used in the past as a tool for land clearance, modern practice land preparation for establishing trees in pasture and forest cutover is to desiccate existing vegetation with herbicides before planting. This can be achieved either by "spot spraying" of 1m diameter circles at the required spacing, or blanket desiccation of the whole planting site by aerial spraying. Spot application uses considerably less herbicide but can be more expensive than blanket spraying. Woody vegetation is best sprayed a year before planting to allow it to decompose

before planting. A glyphosate/metsulfuron mix is often used for controlling gorse, tobacco weed, blackberry and brushweeds. If metsulfuron is used the site should not be planted for at least 3 months after spraying.

Cultivation or deep ripping is not recommended. Cultivation is likely to cause erosion and sedimentation and deep ripping creates wet zones and water pooling in the rip zones, which can cause toppling of planted trees.

Fertiliser is recommended to be applied to the root zone of newly planted trees, but only if the site doesn't have a recent fertiliser history or base fertility is low from soil tests. Fertiliser tablets planted with the tree provide a slow release of nutrients to the tree rather than feeding the competing weeds. Side dressing of small quantities of DAP fertiliser (di-ammonium phosphate) above the tree is suitable for post-planting application where good subsequent weed control is undertaken.

Planting

Tree seedlings are produced as either bare-rooted or containerised stock. Container-grown trees can be heavier and therefore more expensive to lug around the hills but produce faster initial growth and are more resistant to water stress because the whole root system is intact within the "plug". Bare-rooted stock has much of the root system cut back for planting, which is fine for planting in the middle of winter when soil moisture levels are high, and where desiccation is unlikely to occur.

It is generally recommended that bare-rooted stock be planted through winter until the end of August, whereas containerised stock can be planted through winter and spring. Containerised stock may be less prone to root distortion resulting from poor ("slit and stuff") planting practice. However, if seedlings are pricked out into containers (rather than direct seeded) there may be root distortion present in the core of the plug. Root distortion from careless planting of bare-rooted stock, or from poor pricking out in containerised stock, is implicated in increased toppling of young trees, so the grower should actively minimise this.

Bare-rooted stock should be freshly dug but can be refrigerated for short periods of time. Bags or boxes of trees will begin composting if not kept cool.

If allowed to dry out for more than a day, containerised stock must be soaked in water before planting. This requires full immersion of the plugs in a water bath, trough or bucket until bubbling stops, for up to an hour. Plants should be handled carefully to minimise damage to the root plug.

Containerised stock does not need to be planted as deep as bare-rooted stock, but the plug must not be exposed to the air. If the top of the plug is exposed, this will act as a wick and the plant may dry out.

Planting costs are usually about $0.50 per tree for small containerised trees and bare-rooted radiata seedling stock. Containerised stock is usually more expensive, starting from $0.60 but sometimes more than $1.00 per tree for some species. Native species may be planted as larger grades which are significantly more expensive to both buy and plant. For slower-growing species these larger trees offer less risk in terms of being smothered by weeds, but higher risks in terms of susceptibility to drought during the first summer after planting.

Contract grown plants are usually cheaper than those grown “on spec”, but require more forward planning on the part of the grower.

Releasing

Herbicides are used to facilitate establishment of trees after planting. This is called "releasing", because the young trees are released from the weed competition. Manual suppression of weeds can also be practiced, whereby the weed growth is checked using physical means so that the young trees have room to grow and do not become smothered by competing weeds. Manual releasing is more time consuming than chemical releasing and needs to be repeated at a higher frequency, usually 2-3 times in the first summer, compared to 1-2 times for chemical releasing. However, provided manual releasing is executed in a timely manner and slower initial growth is accepted, this method can be successful for landowners who do not want to use herbicides. Releasing is required until the tree is sufficiently robust to not be overtopped by weeds. This will depend on tree growth rate and type of weed competition.

A range of herbicides are available and used for releasing different tree species. Some are selective, which means they might kill some weeds but not others, or some tree species but not others. Selective herbicides are a powerful tool for controlling weeds in tree plantations, provided the practitioner has knowledge about what species each herbicide kills and doesn't kill.

Costs for spot spraying and spray releasing can be as low as $0.50 per tree per application. Manual releasing may cost $1 or more per tree, depending on timing and size of weeds. Small trees easily get lost among the rank grass and weeds, so timing of control operations is important.

Residual herbicides

Residual herbicides control weeds for an extended period, but the residual action in the soil can also kill young trees. When applying residual herbicides with a knapsack, care must be taken to avoid over-application and spraying the same ground more than once. Spray dye is recommended as an additive for all knapsack spray-releasing operations.

Terbuthylazine is the most widely used residual herbicide used in tree plantations. It has some knockdown ability and is usually applied once, shortly after planting and prior to the spring flush of growth. Terbuthylazine should not be applied if rain is expected within 3 hours, but approximately 10mm of rain is required within a week for the chemical to be washed into the soil and become effective.

Terbuthylazine should not be used on sandy soils as it will leach into the roots of young trees and kill them. It is effective on most weed species provided they are no taller than 10 cm. Terbuthylazine can be mixed with haloxyfop or clopyralid for a dual knockdown and residual effect on weeds over 10 cm tall.

Rates used for pine, redwood, cypress and other conifer species are 2 ml active per square metre. Rimu has shown good tolerance.

For *Eucalyptus* and other sensitive species no more than 1.5 ml per square metre should be used; and contact with foliage avoided where possible. Terbuthylazine should only be used around poplars after the first year and at half the rate used for conifers. Terbuthylazine should not be used near acacia species. For knapsack spray releasing the average user might release 20 trees per litre of spray (1 square metre each). At this rate 40 ml active per litre of water will deliver 2 ml terbuthylazine per square metre. Calibrating the sprayer for the user is essential so that the dose per square metre is accurate. It is recommended to spray rectangular sites sweeping one side of the tree then the other, making sure to not double-spray the centre where the tree is. Terbuthylazine should not be used over actively growing trees.

Knockdown herbicides

Glyphosate and glufosinate-ammonium (buster) are two non-selective knockdown herbicides.

Glyphosate can be used around any tree species for weed control, provided it does not contact the leaves and green bark. This is because it is translocated through the plant and small doses can be lethal. Only skilled practitioners should use glyphosate for releasing trees and then very carefully with a spray guard, so that spray does not drift on to the foliage of the crop tree. Glyphosate has no residual effects.

Glufosinate-ammonium (buster) is a non-selective herbicide with no residual effect that does not translocate through the plant. However, although safer than glyphosate, being a non-selective contact herbicide, the practitioner should still be careful to not get it on the tree foliage.

Haloxyfop-P can be used over tree species and only controls grasses. Average knapsack application rate is 3 ml (haloxyfop 100g/litre) per litre of water to treat 20 trees. Penetrant should not be added. Compatible with clopyralid and terbuthylazine. Can cause some tree scorching if applied over trees that are flushing. Can affect the growth of young kahikatea.

Clopyralid is a selective herbicide used for controlling annual broadleaved weeds and legumes. Clopyralid is classed as a hazardous substance and only available to certified approved handlers. Average knapsack application rate is 3 ml per litre of water to treat 20 trees. Compatible with haloxyfop-P and terbuthylazine and is suitable for carefully spray releasing most species when not in active growth (avoiding leaf contact where possible), but not alders, acacias, or kahikatea. Totara seedlings can also be negatively impacted.

Triclopyr (grazon) can be used as a selective herbicide for spot spraying blackberry, gorse, broom or Himalayan honeysuckle in plantations, but direct contact with trees must be avoided because triclopyr translocates and is toxic to trees. Rimu and totara have shown some tolerance.

Sequence of events for good weed control

Removing weed competition by release spraying improves the growth rate of establishing trees and this can be continued into the second and third years. However, there can be a downside to the lush tree growth resulting from a "bare earth policy", because by removing competition for nutrients and moisture, the roots become “lazy” and the tree produces fast height growth with little root growth, thereby increasing the risk for toppling.

There is a tradeoff between the (sometimes dramatically) increased growth rates resulting from complete weed suppression and the (sometimes vastly) increased risk of toppling resulting from such high growth rates, should a storm event occur involving wind and rain.

The practitioner can manage this tradeoff by, for example, only supressing weeds sufficiently to ensure they do not out-compete the trees, and by accepting moderate initial growth rates. Experience helps with such judgment calls and implementing practices that achieve the "right" level of weed control for the site. It should also be noted that in erodible hill country, minimising areas of bare earth reduces risk for erosion and resulting sedimentation to occur. The more vegetation there is on the slope, the less risk for loss of soil during a storm event. Erosion results in lower productivity for any land use and mitigating this risk is good land management practice.

Pruning

Pruning is practiced for production of clearwood. For naturally durable species where the aim is production of clear heartwood, large stem diameters are required because smaller trees will produce low volumes of clear heartwood. Where production of clearwood that includes sapwood is the goal, recoveries can be high even for small diameter trees. The rule of thumb for pruning is that as frequency of pruning is increased (this can be as often as annually), the length of the pruning lift decreases (i.e. more pruning lifts are required) but the grower can minimise DOS (diameter over stubs). Keeping the DOS as small as possible ensures higher yields of clearwood.

Cost of pruning on a per hectare basis depends on how many trees are being pruned, the number of pruning lifts and the height the trees are pruned to. Some species also tend to be more expensive to prune than others, for example macrocarpa, because of the high number of branches. Cost also depends on frequency of pruning, i.e. how many lifts are required for a given pruned height. Radiata pine is often pruned to 6 m in three lifts, with each lift costing approximately $2.40. Therefore, pruning 400 stems to 6 m might cost approximately $3000 per hectare.

Thinning

The grower should clearly understand the tradeoff between thinning too many trees in one operation and not thinning enough. Thinning too many trees at once increases the risk of windthrow in the residual crop trees, because these trees are more exposed to the elements. Not enough thinning results in too much height growth in proportion to tree diameter (this is called the crown: stem ratio). The art of thinning is knowing how far to go in each thinning operation, without going too far. The more often you thin and the less trees you thin each time, the better the results will be. However, the tradeoff is that this comes at a cost – each thinning intervention costs money and so the more interventions there are the more the total cost of thinning will be.

Thinning costs per hectare depend primarily on the number of trees being thinned. Also, the more thinning operations that are required, the higher the cost tends to be per tree.

Chainsaw thinning of radiata pine from 1000 stems down to 500 stems should cost between $500 and $850 per hectare, a cost of between $1.00 and $1.70 per tree. Thinning is usually undertaken as two or three operations, with a greater number of thinning operations being required where initial tree stocking is high. For example, an initial stocking of 2000 stems per hectare could be reduced to 1200 in the first thin, then 700, then 400 in the final operation, each operation spaced two years apart.

Chemical thinning methods are available that offer cost reductions per tree, so are suitable for plantations that start with high tree stockings. Holes are drilled in the standing tree and chemical is injected into the holes. Glyphosate 360 is used at a concentration of 3-4 parts water to 1-part glyphosate. Holes are drilled 10 cm apart around the trees circumference at a convenient height, with a downward slope and only deep enough to retain the dose in the sapwood. The solution (3 ml) is injected into each of these with a sheep drench gun. Trees may take 6 months or more to die depending on season.

Advantages with chemical thinning include low cost, better access into the trees for progressive thinning operations and reduced risk of windthrow in crop trees because the reduction in stocking takes place more progressively. However, poisoned trees pose a safety risk to people, because as the standing dead trees decay, they can collapse without warning. Access to the forest should be restricted during this decomposition phase.

4. Individual species descriptions

This section provides descriptions of a range of tree species suitable for forest plantings intended to produce timber commercially.

Pine

A range of pine species have historically been grown in Northland, but the only commercial species is *Pinus radiata*.

Radiata pine, *Pinus radiata*

Radiata pine is the primary plantation forest species grown in Northland and throughout New Zealand. Northland has a reputation for growing some of the strongest and densest radiata timber in New Zealand. The well-established industry provides a ready market for logs, high-quality genetically improved planting stock and well-established management regimes with good data on productivity and expected yields. Radiata pine is a versatile timber used for a wide range of products, with reasonable strength and stiffness properties suitable for most structural applications. The key to its historical success as a timber in New Zealand is that it is easy to treat with water-based preservatives, notably Chrome Copper Arsenic (CCA) formulations. Being very permeable, radiata is the only species authorised for treatment to hazard classes H3.2 and above in the building code standard NZS 3602, with proven durability performance in a range of exterior applications. However, because radiata heartwood is so permeable this can also be seen as a double-edged sword, because radiata is both treatable and perishable. By holding very low natural durability, industry depends on treatment of the timber with preservatives. Radiata pine also has reasonably low and variable stiffness properties so applications are limited by this, for example longer structural spans can sag.

Health: Subject to foliar diseases, including cyclaneusma needle cast and red needle cast. Red needle cast is worst in high-elevation Northland sites. Dothistroma doesn't appear to be prevalent in Northland. Incidences of flagging (death of branchlets) seem to be on the increase. Subject to root disease where drainage is poor.

Timber: Low durability, fairly soft, moderately strong and moderately stiff. Radiata timber processes well into a range of structural products because it is easy to machine and glues well. Perhaps its greatest claim to fame is the ease with which radiata takes chemical treatment — even the heartwood can be pressure-treated with water-borne preservatives such as CCA.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Radiata pine, *Pinus radiata*	500	85.8	8.2	3.6

Siting: Radiata pine is hardy to strong wind and poor soil fertility but does have some siting limitations. Trees are prone to toppling and root disease where soil drainage is poor, so the species should only be planted on free-draining soils. Radiata will grow on slip faces, skeletal soils devoid of topsoil and soils with a low nutrient status, but growth rate is reduced on these sites. It is recommended that phosphate be applied if the soil is especially poor. Radiata will grow reasonably well on exposed ridgetops but poorer form and slower growth will result compared with less-exposed sites.

Steep slopes: Because radiata's roots decay rapidly after harvest, clearfell radiata regimes pose environmental concerns in respect to post-harvest erosion risk. The higher costs involved with harvesting under a continuous canopy regime, along with the relatively low commodity log value, suggest this option is not economically viable.

Species characteristics: Hardy and "bulletproof", with fast growth rates and a short rotation length.

Recommended regime: Plant at 600-1200 stems per hectare. For clearwood production prune to 6-8m in 3-4 lifts and thin down to 200-400 stems per hectare for a 25 year harvest. For unpruned framing regimes final crop stocking can be as high as 600 stems per hectare.

Key message: The conservative option, well proven.

Cypress

Cypress timber is generally identified as "macrocarpa" in New Zealand. Cypress species require free draining soils with moderate fertility.

Regimes for growing cypress include:

- unpruned shorter rotations with higher stockings that target dressing grade appearance timber (that includes sapwood);
- clearwood regimes where clear heart/sapwood is targeted; and
- regimes for clear heartwood production.

If cypress trees are to be pruned for clear heartwood production it must be understood that diameter over stubs (DOS) must be kept to a minimum, final crop stocking should be low (200-400 stems per hectare) and rotation length should be a minimum of 35 years to maximise tree diameters and therefore clear heartwood production. The grower must understand that if clear heartwood production is the goal, pruned log diameters must be large.

Macrocarpa, *Cupressus macrocarpa*

Macrocarpa has a history of being widely planted in Northland, with considerable volumes of timber grown and sold from the region. What we know as "macrocarpa", the old shelter rows and farm woodlots throughout the region, were more likely to be macrocarpa hybrids grown by nurseries that collected seed from healthy locally-grown trees.

Most of that resource is gone now and attempts to replant have mostly failed because of cypress canker disease. Although this failure is often presented in a negative light, research in Northland has shown that there are genotypes available that offer canker resistance. Indeed, the current prevalence of canker resulted from nurseries growing a single Southland-sourced seedline available commercially from the 1980's through the 2000's, without realising its high susceptibility to the disease. For over twenty years growers have had disappointing results, all traceable to that Southland seedline, resulting in a severely tarnished reputation for the species. The opportunity for Northland is to rebuild that lost reputation and the clear message to growers is be sure that the seedline they use is of proven canker-resistant origin.

Health: Macrocarpa as a species is susceptible to canker disease. Only carefully selected seedlines, hybrids and cultivars should be planted in Northland, which because of its warmth and humidity, is considered to be a marginal region for the species.

Cattle and deer will strip the bark from macrocarpa at all ages if given access to the plantation.

Timber: Macrocarpa has earned a reputation for being a high-quality timber and substitute for kauri. Much of the locally produced macrocarpa originated from large old trees, which produce the best quality timber in terms of durability, colour and strength. A plantation industry would need to build on that good reputation but also ensure

that consumers are aware that plantation timber from younger trees is not as richly coloured as the historical resource. Rotation length can be as short as 20 years provided sapwood is accepted in the product.

Macrocarpa heartwood is highly scented, has a rich golden colour and decorative appearance, with good natural durability. Sapwood is paler but still holds decorative appeal and is suitable for interior applications, being resistant to anobium borer. Tests have shown that even the sapwood holds reasonable durability, greater than Douglas fir. This property offers an opportunity for utilising untreated macrocarpa in structural applications, specifically for *Exceptions for the use of untreated timber* under clause B2 of the building code.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Macrocarpa, *Cupressus macrocarpa*	475	74.3	6.9	2.6

Siting: Requires free-draining soils. All cypress species require very free draining soils that are moderately fertile.

Macrocarpa is very hardy to wind exposure, including salt-laden winds. However, it becomes heavily-branched in highly-exposed sites. Such sites are not very well suited for timber production. Macrocarpa prefers cooler south-facing slopes.

Steep slopes: Macrocarpa roots are slow to decay and if crop trees are not pruned can be held at a fairly high stocking to maturity. A species suitable for controlling erosion in steeper slopes and provided log values were high enough could be grown under continuous forest cover to further reduce erosion risk.

Species characteristics: Requires high initial stockings to limit size and number of branches. Macrocarpa is notoriously branchy and slower to prune than radiata pine using traditional loppers.

Recommended regime: Plant at 1600-2000 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 25-year rotation. This gives a 4:1 thinning ratio. A higher thinning ratio provides better growth rates, health and form in residual trees. For clearwood production prune to 6-8m in 3-4 lifts and thin down to 200-300 stems per hectare for a 35-year rotation.

Key message: If you are wanting to grow macrocarpa, ensure you collect or purchase seed from canker-resistant Northland-grown trees, or grow cultivars with a proven track record in the region.

Mexican cypress, *Cupressus lusitanica*

Lusitanica cypress is closely related to macrocarpa and has a very similar timber. Lusitanica is a common plantation forest species in Northland and provided it is well sited, is a reliable species producing good volumes of timber in rotations of 25-40 years. Like all the cypress species, growth is slower than radiata pine but because shade tolerance is greater, stocking can be higher. This means productivity can be high, provided the market accepts smaller diameter logs. New regimes are being considered for specialised small diameter log processing that involve no pruning but produce decorative timber with live ("green") knots. Export log markets also accept small diameter logs.

Health: Lusitanica cypress is generally a healthy tree in Northland and with a low incidence of cypress canker disease. Possums and kaka can cause damage to the tops of trees. Cattle and deer will strip the bark from this species at all ages if given access to trees.

Timber: The timber is scented, decorative, has reasonable structural properties and is naturally durable. Suitable for interior trim, furniture, sarking and framing. Heartwood is suitable for exterior cladding.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Mexican cypress ***Cupressus lusitanica***	460	69.6	6.5	2.5

Siting: Lusitanica cypress needs careful siting, requiring shelter from strong winds and with a low tolerance of salt-laden winds. Lusitanica requires moderate soil fertility and free draining soil is essential.

Steep slopes: Lusitanica roots are slow to decay. A species suitable for steeper slopes and provided log values were high enough, could be grown as a continuous cover forest to further reduce erosion risk.

Species characteristics: A reliable, well proven species for Northland provided it is appropriately sited.

Recommended regime: Plant at 1600-2000 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 20-30-year rotation. This offers a 4:1 thinning ratio. A higher thinning ratio provides better growth rates and form in residual trees. For clearwood production prune to 6-8m in 3-4 lifts, targeting a maximum diameter over stubs of 10cm and thin down to 200-300 stems per hectare for a 35-year rotation length.

Key message: Prune for clearwood production on a longer rotation or grow as an unpruned stand on a shorter rotation.

Oven's cypress, *Cupressus ovensii*

Ovensii is a clonal cypress hybrid, meaning that trees are cutting-grown and genetically identical, originating from one parent tree. Ovensii is a cross between lusitanica cypress and Nootka cypress and has inherited desirable traits from both parent species. Although only planted for 25 years or so in Northland, Ovensii cypress is gaining a good reputation among growers for resilience and reliability.

Although slightly slower growing than macrocarpa and lusitanica, Ovensii timber has a slightly higher durability than those species. Furthermore, wood properties are consistent between trees, unlike the variability inherent in seedling-grown trees. However, because Ovensii is cutting-grown, trees can be expensive unless sourced from a nursery specialising in producing them.

Health: Good resistance to canker and healthy in Northland. Cattle and deer will strip the bark from this species at all ages if given access.

Timber: Ovensii produces a decorative, lighter-coloured wood than macrocarpa and lusitanica, with less "lustre". It has fairly good mechanical properties and durability, lending itself well to structural applications where natural durability is specified. The wood is stable and suitable for a range of joinery applications such as windows, doors and fittings and heartwood can be used for cladding.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Oven's cypress ***Cupressus 'Ovensii'***	495	85.6	7.9	NA

Siting: Ovensii is fairly resilient to wind exposure but is not well adapted to coastal conditions and salt-laden winds. Like other cypresses, Ovensii requires free draining soil and moderate fertility.

Steep slopes: Suitable for exposed eroding slopes but may require the addition of phosphate where eroded soils have become skeletal. Ovensii roots are slow to decay and provided log values were high enough Ovensii cypress could be grown as a continuous cover forest to further reduce erosion risk.

Species characteristics: Well formed, healthy and moderately fast growing. Prone to some ramicorn-type (large, upward growing) branches.

Recommended regime: For clearwood production interplant 600 stems per hectare with 800-1000 seedling macrocarpa or lusitanica. Prune all Ovensii to 6-8m in 3-4 lifts and progressively thin the seedlings. Thin Ovensii down to 300 stems per hectare for a 35-40 year rotation. For a 25-30 year rotation plant 600 stems per hectare and prune off any double leaders and large ramicorns.

Key message: A reliable choice for Northland but planting stock can be expensive. An increased scale of planting would reduce the price per tree.

Cedar

Cedar timber is light, stable and durable, suitable for cladding and exterior joinery but not suitable for structural applications. The only cedar species well suited to Northland's subtropical climate is the Japanese cedar, *Cryptomeria japonica*.

Japanese cedar, *Cryptomeria japonica*

Japanese cedar is highly productive on the right site and very adaptable to windy sites. Japanese cedar grows well in Northland's climate and is relatively untroubled by pests and diseases.

Health: Very healthy. Cattle and deer will strip the bark from this species at all ages if given access.

Timber: Japanese cedar timber is reddish-brown, light and stable. The heartwood is durable and suitable for cladding and exterior joinery but not suitable for structural applications. A similar timber to redwood but strongly scented. Suitable for appearance applications such as panelling but too soft for furniture.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Japanese cedar *Cryptomeria japonica*	384	66.1	7.2	1.8

Siting: Requires good soil drainage and moderate fertility. Adaptable to strong winds but not coastal conditions.

Steep slopes: Tolerates high wind exposure and fairly thin topsoil, provided fertility is reasonable. Exposed ridgetop slopes devoid of topsoil may require the addition of fertiliser (in particular phosphate).

Species characteristics: A tall narrow-conical tree that tends to be lightly branched. For this reason, initial stocking does not need to be high to control branch size. Management should avoid overstocking and formation of black (dead, bark-encased) knots.

Recommended regime: Plant at 600 stems per hectare. Prune to minimise diameter over stubs, to a height of 5-8m in annual lifts. To maximise heartwood production harvest in 35+ years.

Key message: A reliable species for steep slopes, provided livestock are excluded from the stand (especially cattle, deer and goats).

Redwood

Redwood timber, like cedar, is light, stable and durable, suitable for cladding and exterior joinery but not suitable for structural applications. There are two species of redwood from North America grown in New Zealand, the giant sequoia and the coast redwood. Giant sequoia is a cold-climate species whereas coast redwood, from the fog belt of California, suits Northlands humid subtropical climate.

Coast redwood, *Sequoia sempervirens*

Some of the largest Coast redwood trees in the country are found in Northland. Coast redwood grows well in Northland's humid climate and is relatively untroubled by pests and diseases.

Good growth rates and form are achieved from improved clonal stock. Research is still underway for improved heartwood content and durability.

Health: Relatively untroubled by pests and diseases.

Timber: Redwood timber is red, light and stable. The heartwood is durable above ground and is suitable for cladding and exterior joinery but not very suitable for structural applications because of issues with fixings. Suitable for appearance applications such as panelling but too soft for furniture. A similar timber to Japanese cedar but not strongly scented.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Redwood				
Sequoia sempervirens	380	24.4	6.6	1.9

Siting: Requires moderately fertile soils with sufficient soil moisture and good depth. Not suitable for exposed slopes deficient in topsoil.

Steep slopes: A coppicing species, i.e. the roots do not die. The stump stays alive after felling and re-sprouts. Coppicing species hold the soil from slipping even after harvest. However, redwood requires adequate soil depth and shelter so is not suitable for eroding upper slopes.

Species characteristics: Coppices. Not suitable for exposed and skeletal sites. Pruning requires careful management because of epicormic shoots that emerge from pruning scars. A tall narrow-conical tree that tends to be lightly branched. For this reason, stocking does not need to be high. Management should avoid overstocking and dead branches which form black (dead, bark-encased) knots.

Recommended regime: Plant clonal stock at 600 stems per hectare. Prune to minimise diameter over stubs, to a height of 5-8m in annual lifts. To maximise heartwood production harvest in 35+ years.

Key message: A reliable choice for lower slopes with a potential market for sawn timber to California.

Eucalypt

Northland experience has identified eucalypt species that grow well in our region, are relatively untroubled by insects, and offer high quality, attractive hardwood timber production.

Eucalypt species produce hardwood of varying densities, durability and strength. Timber colour also varies with species, from pale brown to rich red.

For simplicity, species can be grouped (and marketed) according to timber properties. The "rule of thumb" for eucalypts is that species with greater durability, strength and density will have slower growth rates.

Table 5: Eucalypt species for Northland

Timber properties	Growth rate	Density	Species
Group 1: Red timber, wide sapwood, moderately durable to durable, strong	Fast to very fast	Medium	*E. botryoides*
			E. saligna
Group 2: Pale brown timber, narrow sapwood, moderately durable to durable, strong	Fast	Medium	*E. globoidea*
			E. muelleriana
			E. pilularis
Group 3: Pale brown timber, durable to very durable, very strong	Medium	Medium to high	*E. microcorys*
			E. sphaerocarpa

Eucalypt species have very different siting requirements and limitations. The most important is soil drainage and tolerance of wind exposure:

Table 6: Site requirements for eucalypt species

Species	Tolerance to wind exposure	Tolerance of Salt-laden wind	Soil requirements
Eucalyptus botryoides	high	good	poor - free draining
Eucalyptus globoidea	good	moderate	free draining
Eucalyptus microcorys	low	low	average - free draining
Eucalyptus muelleriana	medium	moderate	free draining
Eucalyptus pilularis	medium	moderate	free draining
Eucalyptus saligna	low	good	poor - free draining
Eucalyptus sphaerocarpa	high	moderate	free draining

Species selection can also be based on economic factors that influence risk, log value and species productivity:

Table 7: Economic factors influencing eucalypt species selection

Species	Growth rate	Sapwood width[1]	Compression core[2]	Biological risk[3]	Timber value
Eucalyptus botryoides	fast	wide	large	high	high

Species	Growth rate	Sapwood width[1]	Compression core[2]	Biological risk[3]	Timber value
Eucalyptus globoidea	fast	narrow	small	low	high
Eucalyptus microcorys	medium	medium	negligible	low	very high
Eucalyptus muelleriana	fast	narrow	small	low	high
Eucalyptus pilularis	fast	narrow	small	low	high
Eucalyptus saligna	fast	wide	large	high	high
Eucalyptus sphaerocarpa	medium	narrow	negligible	low	very high

1. Sapwood width affects recovery of heartwood products from the log, which tend to hold significantly higher value than those containing sapwood.
2. Compression core is the wood in the centre of a eucalypt tree. This wood has very low strength and durability resulting from compressive forces that cause micro-fractures in the wood and make it brittle. This can negatively affect sawn recoveries from a log.
3. Biological risk is the assumed risk of a new incursion occurring that impacts on the health of the species, evaluated based on historical incursions of insect pests and fungal pathogens.

Eucalypt nursery stock and planting

Eucalypts should be container grown and planted out when 15-25 cm tall, well hardened and with 6-8 pairs of leaves. The root system should not be constricted and excessively deformed in the container. The bottom quarter of the plug should be cut off in root-trainer stock to encourage new roots and reduce deformation in regenerating roots. Side-slot containers are the best option for reducing root deformation, which can strangle the growing plant and increase the risk of windthrow in the first few years after planting. A sample of trees should be removed from the containers and the soil removed to expose the taproot. This should be checked for deformation resulting from poor pricking out procedures. Generally, eucalypts are planted in early spring when the risk of hard frosts is over, but soil moisture is still good. Winter planting is acceptable only on slopes above where frost drains to.

Weeds are usually desiccated prior to planting by spot spraying with glyphosate. Eucalypts are sensitive to weed competition, particularly grasses. Containerised trees should not be "slit & stuff" planted. The soil should be sufficiently-well cultivated, and clods of soil well broken up so that the plug does not get squashed and deformed when the soil is firmed back into place. Air cavities must not be present in the planting hole after the soil is tramped back in place. Trees should not be planted deep in winter-wet soils, to avoid collar rot. Trees respond well to fertiliser tablets placed in the planting hole underneath the tree. If weed control is adequate, 50g DAP can be spread immediately above the tree on sloping ground or around the tree on flat ground. Fertile soils should not be fertilised at all.

Eucalypt silviculture

Silviculture of eucalypts can be very different from radiata pine. If planted at a high stocking, eucalypts self prune (shed their lower branches), negating the need to prune for clearwood, which can offset the high costs of planting at a high stocking rate.

Efficient methods are available for thinning high stockings of eucalypts, such as chemical injection, which kills the tree to the roots. Chainsaw thinning is useful for thinning eucalypts where it is desired for them to coppice from the stump and remain as an understory tree, for example within a continuous cover forest. Most eucalypt species coppice (re-grow) from the stump when felled. The roots stay alive and a new stem grows, providing a second tier of understory trees and an opportunity to regrow a poorly formed tree with improved form. Because their roots do not die when cut down, eucalypts are a desirable species for retaining soil in erodible hill country.

Eucalypts also require different processing methods than softwoods such as pine to overcome tension in the logs. The grower must determine what the optimum log diameter is for processing in order to design a regime that maximises profit. Key variables influencing tree diameters are rotation length and stocking. Traditionally larger diameter logs were favoured because of inherently lower tension stresses, but modern specialised sawmills (e.g. twin saws) offer solutions to overcome the higher levels of stresses inherent in smaller diameter logs and produce straight boards cost-efficiently. Large logs take longer to grow and require a low final crop stocking, so the grower should be well informed on processing options when thinning eucalypts. Extending the rotation length and reducing tree stockings to achieve large diameters carries with it risk of windthrow. However, larger logs can be sawn with low-tech portable sawmills. The recommended regime is a final crop stocking of 300-400 stems per hectare and a 25-30-year rotation.

Southern mahogany, *Eucalyptus botryoides*

Closely related to *E. saligna*, producing a rich red-brown durable heartwood. Form not as good as *E. saligna* but *E. botryoides* is fairly resistant to wind, including salt-laden wind. Fast growing, growth rate comparable with radiata pine.

Health: Susceptible to a range of insect pests. There are provenances available in Northland that offer good resistance to these. Susceptible to browsing by possums at all ages.

Timber: Medium density. Heartwood rich red with interlocked grain, very decorative and hard. Sometimes the interlocked grain can cause processing problems. Large logs are preferred by processors because of low sawn recoveries due to large core of compression wood and wide sapwood band. The heartwood is moderately durable and suitable for exterior hardwood decking, flooring and structural applications. Because the sapwood is white, this is usually excluded for appearance applications. However, the sapwood is resistant to lyctus borer so can be used for internal applications such as flooring.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Southern mahogany ***Eucalyptus botryoides***	675	100	13.5	6.75

Siting: *E. botryoides* grows best in moist sites and can tolerate poor soil drainage. It also grows well in soils with low fertility, provided the soil has some depth. *E. botryoides* is adaptable to a wide range of soil conditions, including drier clays. Best form is in sheltered sites but *E. botryoides* is tolerant of wind.

Steep slopes: Suitable for steep slopes. Well-suited to continuous cover forestry because of high timber value, adaptability to a range of sites, ability to coppice and fast growth rates. A coppicing species, i.e. the roots do not die but the stump stays alive after felling and re-sprouts. Coppicing species hold the soil from slipping even after harvest.

Species characteristics: Fast growing, yielding a high quality rich red heartwood but with low sawn recoveries. Prefers sites with good soil moisture and can grow in poorly drained (but not swampy) soils.

Recommended regime: Plant at 1600-2000 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 30-year rotation. This provides a 4:1 thinning ratio. Because available seedlines are unimproved, a high initial stocking is recommended for a sufficiently high thinning ratio and greater selection for growth and form. Lower tree stockings require costly form pruning for residual crop trees to have adequate stem quality.

For clearwood production prune potential crop trees to 6-8m in 3-4 lifts and thin down to 300 pruned stems per hectare for a 35-year rotation. However, although pruning improves grade recoveries from those logs, this is not necessary to produce clearwood because trees self-prune, provided tree stocking is high enough to induce this. The tradeoff is therefore between the cost of pruning and higher establishment costs. A higher thinning ratio also provides greater selection for growth and form, so a high initial tree stocking is recommended.

Key message: Best planted on moderately fertile sites with good soil depth and moisture, but adaptable to a range of conditions and sites. Because of variable form a high initial stocking is required for selection of well formed, fast growing trees. Large sapwood band and a compression core reduces sawn recovery compared with other species.

White stringybark, *Eucalyptus globoidea*

A true "stringybark" eucalypt, this species has been widely grown throughout Northland with good success. Originating from coastal New South Wales, *E. globoidea* is well suited to Northland's climate, with some very large trees grown and harvested in Northland. Fairly good growth rates and a very narrow sapwood band offer good productivity and a quality hardwood with moderate durability and good strength properties. Durability and mechanical properties improve with tree age. Slightly slower growing than *E. muelleriana* and *E. pilularis* but tolerates slightly more wind exposure.

Health: Resistant to insect pests and with no health problems in Northland.

Timber: Medium density. Similar to *E. muelleriana* and *E. pilularis*, a moderately durable light brown heartwood with good strength properties. Sapwood band is narrow, and sapwood is resistant to lyctus borer attack. Compression core is negligible and sawn recoveries are high. Suitable for flooring, decking, appearance joinery and structural applications.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
White stringybark ***Eucalyptus globoidea***	675	100	13.5	6.75

Siting: Requires free draining soils of moderate fertility. Quite good wind tolerance but stem breakages can occur in sites with high wind exposure.

Steep slopes: Well suited to steep erodible slopes provided soil drainage is adequate and fertility reasonable. Well-suited to continuous cover forestry because of high timber value, adaptability to a range of sites, ability to coppice and fast growth rates. Coppicing species hold the soil from slipping even after harvest.

Species characteristics: The stem can be significantly tapered, and double/multiple leaders can occur. Usually a straight tree with little sweep. Because available seedlines are unimproved, a high initial stocking is recommended, or alternatively form pruning practiced to remove multiple leaders and retain a single leader in crop trees.

Recommended regimes: Plant at 1600-2000 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 25 year rotation. This gives a 4:1 thinning ratio. Because available seedlines are unimproved, a high initial stocking is recommended for a sufficiently high thinning ratio and greater selection for growth and form. Lower tree stockings require costly form pruning for sufficient quality in residual crop trees.

For clearwood production prune potential crop trees to 6-8m in 3-4 lifts and thin down to 300 pruned stems per hectare for a 30-year rotation. However, although pruning improves grade recoveries from those logs, this is not necessary to produce clearwood because eucalypt trees self-prune provided tree stocking is sufficiently high to induce this. The tradeoff is between the cost of pruning and higher establishment costs. A higher thinning ratio also provides greater selection for growth and form.

Key message: A well-proven performer in Northland producing valuable hardwood timber.

Tallowwood, *Eucalyptus microcorys*

Eucalyptus microcorys is a subtropical eucalypt from Northern New South Wales. It is considered one of the finest hardwoods in Australia. Because of its reputation tallowwood has been widely planted in Northland, one of the few regions in New Zealand where it can be grown, being frost tender.

Health: Susceptible to possum browsing as a young tree. Few insect or disease problems.

Timber: Medium to high density. The timber is pale brown, hard and very durable with exceptional stiffness and strength properties. Produces high density, durable and strong wood from an early age. Applications include high-quality timber decking, timber flooring, external structural applications (above ground), posts and poles. The sapwood band is fairly wide, and sapwood is susceptible to lyctus borer. Sapwood can be treated with boron for internal applications. Compression core is negligible and sawn recoveries can be high.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Tallowwood				
Eucalyptus microcorys	750	100	13.5	6.75

Siting: Requires shelter from strong winds. Susceptible to frost damage in the first winter following planting, best planted in spring after winter frosts have finished.

Steep slopes: A coppicing species, i.e. the roots do not die but the stump stays alive after felling and re-sprouts. Coppicing species hold the soil from slipping even after harvest. Excellent shade-tolerance so well-suited to continuous cover forestry. However, *E. microcorys* requires adequate soil depth and shelter so not suitable for eroding upper slopes.

Species characteristics: Slower-growing at first than other eucalypts, but capable of a very high volume production because the crown is very dense and shade-tolerant.

Recommended regime: Plant at 1600-2000 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 30-year rotation. This gives a 4:1 thinning ratio. Because available seedlines are unimproved, a high initial stocking is recommended for a sufficiently high thinning ratio and greater selection for growth and form. Lower tree stockings require costly form pruning to ensure quality in residual crop trees.

For clearwood production prune potential crop trees to 6-8m in 3-4 lifts and thin down to 300 pruned stems per hectare for a 35-year rotation. However, although pruning improves grade recoveries from those logs, this is not necessary to produce clearwood because eucalypt trees self-prune provided tree stocking is sufficiently high to induce this. The tradeoff is between the cost of pruning and higher establishment costs. A higher thinning ratio also provides greater selection for growth and form.

Key message: Exceptional timber and with high volume production on the right site. Perhaps the best species for carbon production.

Yellow stringybark, *Eucalyptus muelleriana*

A true "stringybark" eucalypt, this species has been widely grown throughout Northland with good success. From coastal New South Wales and Victoria, *E. muelleriana* is well suited to Northland's climate with some very large trees grown and harvested in Northland. Fairly good growth rates and a very narrow sapwood band offer good productivity and a quality hardwood with moderate durability and good strength properties. Durability and mechanical properties improve with tree age. Slightly faster growing than *E. globoidea*. Suitable for flooring, exterior decking, appearance joinery and structural applications.

Health: Relatively resistant to insect pests and with no health problems in Northland.

Timber: Medium density. Similar to *E. globoidea* and *E. pilularis*, a moderately durable light brown heartwood with good strength properties. The sapwood band is narrow, and sapwood is resistant to lyctus borer attack. Compression core is negligible and sawn recoveries are high.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Yellow stringybark ***Eucalyptus muelleriana***	675	100	13.5	6.75

Siting: Requires free draining soils of moderate fertility. Reasonable wind tolerance but stem breakages can occur in sites with high wind exposure.

Steep slopes: Well suited to steep erodible slopes provided soil drainage is good and fertility reasonable. Well-suited to continuous cover forestry because of high timber value, adaptability to a range of sites, ability to coppice and fast growth rates. Coppicing species hold the soil from slipping even after harvest.

Species characteristics: Some sinuosity and sweep can occur in the stem. Fast growing with high quality timber.

Recommended regimes: Plant at 1600-2000 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 25-year rotation. This gives a 4:1 thinning ratio. Because available seedlines are unimproved, a high initial stocking is recommended for a sufficiently high thinning ratio and greater selection for growth and form. Lower tree stockings require costly form pruning for sufficient quality in residual crop trees.

For clearwood production prune potential crop trees to 6-8m in 3-4 lifts and thin down to 300 pruned stems per hectare for a 30-year rotation. However, although pruning improves grade recoveries from those logs, this is not necessary to produce clearwood because eucalypt trees self-prune, provided tree stocking is sufficiently high to induce this. The tradeoff is between the cost of pruning and higher establishment costs. A higher thinning ratio also provides greater selection for growth and form.

Key message: A well-proven performer in Northland producing valuable hardwood timber.

Blackbutt, *Eucalyptus pilularis*

Not a true "stringybark" eucalypt but very closely related, *E. pilularis* has been widely grown throughout Northland with good success. From coastal New South Wales, *E. pilularis* is well suited to Northland's warm humid climate with good volumes of trees grown and harvested in Northland. Fairly good growth rates and a very narrow sapwood band offer good productivity and a quality hardwood with moderate durability and good strength properties. Durability and mechanical properties improve with age. Slightly faster growing than *E. globoidea* and similar growth rates to *E. muelleriana*. Suitable for flooring, decking, appearance joinery and structural applications.

Health: Resistant to insect pests and with no health problems in Northland.

Timber: Medium density. Indistinguishable from *E. muelleriana* and *E. globoidea*, a moderately durable light brown heartwood with good mechanical properties. Sapwood band is narrow, and sapwood is resistant to lyctus borer attack. Compression core is negligible and sawn recoveries are high.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Blackbutt, *Eucalyptus pilularis*	675	100	13.5	6.75

Siting: Requires free draining soils of moderate fertility. Reasonable wind tolerance but stem breakages can occur in sites with high wind exposure.

Steep slopes: Well suited to steep erodible slopes provided soil drainage is good and fertility reasonable. Well-suited to continuous cover forestry because of high timber value, adaptability to a range of sites, ability to coppice and fast growth rates. Coppicing species hold the soil from slipping even after harvest.

Species characteristics: Sinuosity and sweep occurs where exposed to wind or on fertile sites, although provenances have been identified in Northland that grow straight in these situations. Usually a straight tree in sheltered sites of moderate fertility. Because the available seedlines are unimproved, a high initial stocking is recommended, or alternatively form pruning practiced to remove multiple leaders and retain a single leader in crop trees.

Recommended regimes: Plant at 1600-2000 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 25-year rotation. This gives a 4:1 thinning ratio. Because available seedlines are unimproved, a high initial stocking is recommended for a sufficiently high thinning ratio and greater selection for growth and form. Lower tree stockings require costly form pruning for adequate quality in residual crop trees.

For clearwood production prune potential crop trees to 6-8m in 3-4 lifts and thin down to 300 pruned stems per hectare for a 30-year rotation. However, although pruning improves grade recoveries from those logs, this is not necessary to produce clearwood because eucalypt trees self-prune, provided tree stocking is sufficiently high to induce this. The tradeoff is between the cost of pruning and higher establishment costs. A higher thinning ratio also provides greater selection for growth and form.

Key message: A well-proven performer in Northland producing valuable hardwood timber.

Sydney blue gum, *Eucalyptus saligna*

Closely related to *E. botryoides*, producing a rich red moderately durable heartwood. Excellent growth rates and form, sometimes superior to radiata pine. Not as resilient to wind as *E. botryoides* and prefers sheltered valleys with deep soil. Does not require good soil drainage or fertility but prefers deep soils.

Health: Susceptible to a range of insect pests. There are provenances available in Northland with some resistance to these. Susceptible to browsing by possums at all ages.

Timber: Medium density. Heartwood red with straight grain, decorative and hard. Large logs are preferred by processors because of low sawn recoveries resulting from the large compression core along with a wide sapwood band. The heartwood is moderately durable and suitable for exterior decking, flooring and structural applications. Good potential for structural products such as appearance glulam, because of excellent stiffness properties. Because the sapwood is white, this is usually excluded for appearance applications. The sapwood is susceptible to lyctus borer so would require boron treatment for internal applications.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Sydney blue gum ***Eucalyptus saligna***	675	100	13.5	6.75

Siting: *E. saligna* grows best in moist, sheltered sites and can tolerate reasonably poor soil drainage. It also grows well in low fertility soils, provided there is some soil depth. An adaptable species to a wide range of soil conditions, including heavy clays. Best form is in sheltered sites. Intolerant of high wind exposure (can suffer from limb and top breakages).

Steep slopes: Suitable for the bottom of steep slopes and reasonably sheltered mid-slopes with good levels of soil moisture. Well-suited to continuous cover forestry because of high timber value, adaptability to a range of sites, ability to coppice and fast growth rates. Coppicing species hold the soil from slipping even after harvest.

Species characteristics: Fast growing, yielding a high quality rich red heartwood but with low sawn recoveries. Prefers sites with good soil moisture and can grow in poorly drained (but not swampy) soils.

Recommended regime: Plant at 1600-2000 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 30-year rotation. This gives a 4:1 thinning ratio. Because available seedlines are unimproved, a high initial stocking is recommended for a sufficiently high thinning ratio and greater selection for growth and form. Generally a very straight tree, but lower tree stockings may require some form pruning.

For clearwood production prune potential crop trees to 6-8m in 3-4 lifts and thin down to 300 pruned stems per hectare for a 35-year rotation. However, although pruning improves grade recoveries from those logs, this is not necessary to produce clearwood, because eucalypt trees self-prune provided tree stocking is sufficiently high to induce this. The tradeoff is between the cost of pruning and higher establishment costs. A higher thinning ratio also provides greater selection for growth and form.

Key message: Adaptable to a range of soil conditions, but best planted on sheltered moderately fertile sites with good soil depth and moisture. A high initial stocking is recommended for self-pruning and selection of the fastest-growing trees. Large sapwood band and a compression core reduces sawn recovery compared with other species.

Blackdown stringybark, *Eucalyptus sphaerocarpa*

Eucalyptus sphaerocarpa has only been grown in New Zealand and Northland for 20 years but the species is proving to have many desirable traits, showing good potential for commercial production forestry.

This species combines the resilience to wind exposure of the ash group of eucalypts with the good timber properties of the stringybark eucalypts. Indeed, the timber is superior in strength, stiffness and durability to blackbutt and the

stringybark eucalypts and at an earlier age. Like tallowwood, this species produces durable and strong timber from an early age, but unlike tallowwood has a very narrow width sapwood band.

Health: Few insect or disease problems. Some leafminer damage to young trees in exposed sites.

Timber: The timber is pale brown, very strong, hard and very durable. Produces high density, durable and strong wood from an early age.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Blackdown stringybark ***Eucalyptus sphaerocarpa***	750	100	13.5	6.75

Siting: Requires good soil drainage. Adaptable to low fertility but best growth is on moderately fertile sites. The most wind-hardy of the recommended eucalypt species for Northland.

Steep slopes: Very well suited to steep erodible slopes, provided soil drainage is good and fertility reasonable. Well-suited to continuous cover forestry because of high timber value, adaptability to a range of sites, ability to coppice and fast growth rates. Coppicing species hold the soil from slipping even after harvest.

Species characteristics: Slower-growing at first than stringybark eucalypts, similar growth rate to tallowwood. Although called a "stringybark", this species is an ash eucalypt. Seed is available commercially from Northland stands and although a high initial stocking is recommended to ensure selection of the fastest growing trees with the best form, the species is well enough formed to grow at radiata stockings.

Recommended regime: Plant at 1200-1800 stems per hectare. Thin in 3-4 stages down to 400-600 stems per hectare for a 30-year rotation. This gives a 3:1 thinning ratio. Because available seedlines are unimproved, a high initial stocking is recommended for a sufficiently high thinning ratio and greater selection for growth and form.

For clearwood production prune potential crop trees to 6-8m in 3-4 lifts and thin down to 300 pruned stems per hectare for a 35-year rotation. However, although pruning improves grade recoveries from those logs, this is not necessary to produce clearwood because eucalypt trees self-prune provided tree stocking is sufficiently high to induce this. The tradeoff is between the cost of pruning and higher establishment costs. A higher thinning ratio also provides greater selection for growth and form.

Key message: High quality durable timber, adaptable to steep slopes with thin soils and wind.

Poplar

A range of poplar varieties are grown in Northland but the best-performing of these for plantation forestry and timber production is 'Kawa', a Chinese poplar hybrid.

Poplar is not suitable for planting in exposed, drier hill country or where soils are thin.

Poplar, Kawa

The "Kawa" variety poplar was bred in New Zealand in 1986 and is a hybrid between *Populus yunnanensis* (Chinese poplar) and *P. deltoides* (black poplar). Kawa has good form for timber production and is a vigorous variety well suited to Northland's subtropical climate, holding its foliage well into winter and flushing fairly early in spring.

Health: Very healthy, not damaged by poplar rust and with some resistance to possum browsing. Pruning wounds are a risk factor for entry of silverleaf fungus which can kill the tree. Low susceptibility to blackheart.

Timber: Poplar has a pale whitish coloured timber with a very attractive sheen or lustre. Poplar timber is low density, very soft and of low natural durability. Although for its density it has good mechanical properties, it does not meet the density and strength requirements for structural applications under the building code. Air-dry density is 440 kg/m^3 (lower than for radiata pine) and stiffness (modulus of elasticity) is below 6 MPa, the threshold for structural radiata. However, because density varies so little within and between trees, this suggests potential for customised structural grades and applications that take advantage of the cultivar's consistent strength and stiffness. Because the heartwood is perishable, poplar would require H1.2 boron treatment for interior structural applications. For exterior structural applications CCA treatment to H3.2 would be required, along with evidence that treatment methods achieve penetration and retention requirements as per NZS 3640.

Because the wood is odourless, potential applications for poplar wood may include fruit and vegetable packaging crates. Finishing grades of timber are suitable for appearance applications such as internal joinery and panelling, but low surface hardness tends to detract from using poplar for furniture manufacture. Research into hardening technologies could open market opportunities for high-value appearance applications.

High quality pruned logs have excellent potential for sliced and peeled veneer and poplar is suitable for paper pulp.

Sawn CCA treated fence posts have proven to be a successful product in Hawkes Bay but growers would need to be confident that treated products have adequate durability performance before a plantation forest industry were to become viable. The export log market is available however, with ongoing demand for logs from Asian countries.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Poplar, Kawa *Populus deltoides x yunnanensis*	440	56.9	5.4	2.3

Siting: Requires good soil fertility and moisture but tolerates poor soil drainage. Requires adequate moisture through the summer months, therefore adequate soil depth. Adaptable to reasonably strong winds but not coastal conditions and salt spray. A good site is important for volume production.

Steep slopes: Often used for stabilising steep pastoral slopes to retain grazing. Rough bark takes some years to form and although the bark on younger trees appears rough it is thin and susceptible to stock browsing. Stumps and roots remain alive and coppice after harvesting. Wide spaced poplar would take longer to achieve high levels of soil binding than where closer planted. Where erosion potential is high, a closed canopy tree cover is recommended.

Species characteristics: A fast growing hardwood with a soft, low-density timber. Suitable for lower slopes and alluvial soils with some fertility.

Recommended regime

- Production forestry, Plant 90cm forestry wands or rooted cuttings at 600 stems per hectare. Prune to 10 m and thin to 300 stems per hectare by year 15. Harvest at 25-35 years old.
- Timberbelts (pastoral), Poles, not less than 4 m apart in single rows.

- Conservation/timber plantings (pastoral), Poles at 100-200 stems per hectare, approximately 8 m x 8 m, pruned to 10m. Log volumes of 500 m^3/ha can be expected by year 30, with approximately 40% of the total log volume being pruned logs.

Planting and establishment: Forestry wands require pre-plant spot spraying with glyphosate and one release in late spring. If glyphosate is used for releasing it must not come into contact with the green stem. Larger poles require plastic sleeves to protect them from stock browsing. Smaller poles and wands require exclusion of stock for 2-3 years, until the trees are sufficiently well established and the bark thick enough to overcome browsing temptation.

Silviculture: Poplar prolifically produces epicormic shoots when pruned. Pruning should be undertaken in late summer to reduce the incidence of epicormic shoots. Epicormic shoots tend to arise with lower tree stockings and those that do arise need to be removed

Key message: A good species for soil stabilisation in pastoral settings. Markets for the wood are under-developed and research is required to generate market opportunities for the timber.

Native softwoods

Native softwood species (conifers) include kauri, totara, rimu, matai and miro. These species are notoriously slow to grow but all produce high quality timbers from natural old-growth forests. Kauri, although faster growing than other indigenous conifers and a species subject to a historical research effort including establishment of plantations in Northland, in recent times has succumbed to kauri dieback disease. Because this disease appears to be spread by wild animals, and kills trees that it comes into contact with, the risk may be too high to grow kauri timber plantations.

The growth of native softwood species is particularly slow during the establishment phase and will benefit from good weed control for at least the first five years.

Totara, *Podocarpus totara*

Totara is reasonably fast growing when compared with other indigenous conifer species and is also well positioned as a species suitable for market development, with an existing resource of regenerating trees in Northland.

Totara is a hardy pioneer conifer species suitable for planting in open and exposed sites. Although initial growth is slow, this can accelerate during the pole phase provided stand density is managed by thinning out poorer quality trees.

Health: Generally a healthy tree, however totara can be susceptible to defoliation by insects. Native insects such as stick insects, scale and cicadas can damage totara, with leafroller damaging terminal shoots and affecting tree form. Possums can severely browse totara during the spring growth flush.

Timber: Totara heartwood is a dull pinkish-red to pinkish-brown colour and the sapwood a pale brownish white. Heartwood is very durable. Totara timber is relatively light, straight grained and soft and has a very even texture and excellent stability. The timber is of medium strength but with a rather low shock resistance.

Totara machines well and is easily brought to a smooth finish. Totara is renowned as an excellent joinery timber, with good screw and nail holding capacity and resistance to denting.

Totara sapwood is resistant to attack by Anobium borer. Although the sapwood can be treated with CCA preservatives for in-ground or outdoor use, it is moderately resistant to pressure treatment.

Totara is suitable for interior and exterior joinery, door frames, window sashes, boat building, furniture and carving and totara wood is in demand for cultural use by Maori.

Second growth ("farm totara") trees less than 100 years old have a high proportion of sapwood but the wood is suitable for all interior uses, particularly feature linings, joinery and furniture.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Totara, *Podocarpus totara*	480	55.0	7.39	2.4

Siting: Tolerates the presence of livestock. Can grow on boney dry soils but best growth requires some soil depth and fertility. Tolerates some wind exposure.

Steep slopes: Perhaps the best-suited of the native conifers for steep eroding slopes that are exposed to wind. Well suited to continuous cover forestry.

Species characteristics: A light-demanding coloniser. Unlike most native conifers, totara is not well adapted to shade. Totara responds well to silvicultural management (i.e. thinning, pruning, lightwell management).

Recommended regime: Requires a high stocking rate or a nurse crop for good pole form. Recommended planting of 1666-2222 stems per hectare (3 m between rows and 1.5-2 m between trees), or alternatively 833-1111 stems per hectare interplanted with 833-1111 stems manuka for honey production and as a nurse crop to draw the totara upwards. Requires good weed control in the establishment period. Totara tolerates many herbicides commonly used for weed control around trees, however is moderately susceptible to damage from clopyralid, used to control broadleaf weeds around young trees. Form-pruning of open planted totara is essential and pruning is desirable in stands where existing pole trees are heavily branched. Thinning of dense stands is essential for diameter growth and volume production. A well-managed stand could have a rotation length of 70+ years.

Key message: Very suitable for less productive pastoral slopes and compatible with livestock farming. An average diameter of 55cm can be expected in 75 years.

Kahikatea, *Dacrycarpus dacrydioides*

Kahikatea is a fairly slow growing native conifer species well suited to infertile sites, especially those with poor soil drainage. Where correctly sited, kahikatea has proven to be reliable in Northland plantings with good survival. The species has a narrow conical form and is straight, but with a high level of stem taper.

Health: Healthy with no significant pest problems.

Timber: Heartwood is white to pale yellow-brown and sapwood is white and very wide. Sapwood is highly susceptible to borer but can be treated with boron salts. Fine and even in texture and straight-grained. Holds nails, screws well and is easily worked. Kahikatea's resistance to splitting allows it to be machined and turned without difficulty into mouldings, joinery and turnery. Kahikatea's rather flat appearance and lack of colour may limit its appearance applications, but the non-tainting properties of the timber have been and can be used for applications associated with food. Potential for plywood, decorative veneers and boatbuilding.

The wood is easily dried but highly susceptible to sap stain. Kahikatea wood cannot be adequately pressure treated with CCA preservatives for in-ground use. Similar to radiata pine in structural properties with a good strength to weight ratio. Good bending and gluing properties.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Kahikatea ***Dacrycarpus dacrydioides***	450	75	10.7	4.2

Siting: Prone to compression wood on exposed sites. Well suited to poorly drained sites of low natural fertility. Responds well to improved fertility.

Steep slopes: Suitable for planting on sites too wet for totara.

Species characteristics: Not a particularly exciting timber for appearance applications (white with a flat appearance), but among the few native species suited to poor fertility waterlogged soils.

Recommended regime: Regular releasing from weed competition is necessary for early survival and good growth rates. Susceptible to damage from clopyralid, used to control broadleaf weeds around young trees. Recommended planting of 1600-2000 stems per hectare, or alternatively 800 stems per hectare interplanted with 800 stems manuka per hectare for honey production and as a nurse crop to draw the kahikatea upwards.

Key message: Not a fast-growing species, heights of 4-6 m can be expected in 20 years, with a rotation length of 100 years. Can be used to integrate indigenous biodiversity within areas of plantation forestry otherwise too wet for other tree species.

Tanekaha, celery pine, *Phyllocladus trichomanoides*

Tanekaha is a hardy but slow growing native podocarp. Like kauri, tanekaha sheds its lower branches (self-pruning) to produce knot-free timber.

Health: Healthy with no significant pest problems.

Timber: Heartwood is yellow-brown and moderately durable. Sapwood is white. The timber is lustrous, reasonably hard, strong and very flexible. Easy to dry and work.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Tanekaha ***Phyllocladus trichomanoides***	500	85.8	8.2	3.6

Siting: Copes with low fertility and skeletal soils, but growth can be slow where soil becomes dry in summer. Requires free draining soils. Responds well to improved fertility.

Steep slopes: Suitable for planting on eroded sites and slip faces but prefers a nurse crop that provides some shade to the young tree. Once established tanekaha tolerates full light and resists drought and wind, but young plants may not tolerate exposure and require some vegetative cover to shelter them.

Species characteristics: Grows on exposed sites and shallow soils, provided drainage is adequate. A slow growing species, reaching 30cm diameter in 60 years.

Recommended regime: Slow growth at first so regular releasing from weed competition is necessary. Recommended planting of 800 stems per hectare interplanted two years after planting 800 stems manuka per hectare for honey production (and as a nurse crop) to draw the tanekaha upward. Expect a rotation length of 100+ years.

Key message: A slow-growing species, but well suited to difficult sites. Heights of 4-6 m can be expected in 20 years.

Kauri, *Agathis australis*

Kauri is adaptable to dry soils and exposure, but newly planted seedlings require shelter and side shade to establish successfully on all but the easiest of sites. A nurse crop (e.g. manuka) is best planted at least one year ahead of the kauri. Once a nurse crop is established, even small low-cost seedlings establish well under the cover provided.

Health: kauri tends to be healthy unless infected by kauri dieback disease (*Phytophthora agathidicida*). Good hygiene is required in the nursery and when planting to ensure the disease isn't carried on to the plantation site. Kauri dieback disease spreads on soil particles and can be introduced by pigs, goats or other animals. Noting the severity of the disease, the presence of kauri dieback disease may render a kauri plantation valueless.

Timber: Heartwood is yellow-brown and durable above ground. Sapwood is paler and perishable. The timber is lustrous, strong and stiff. Easy to dry and work. Sapwood is highly susceptible to anobium (household) borer, requiring treatment (e.g. with boron preservative for indoor applications).

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Kauri, *Agathis australis*	472	88	10.8	2.9

Siting: Copes with low fertility and grows on exposed ridges but prefers deeper soils and sheltered sites. Growth can be slow where soil gets dry in summer. Requires free draining soils. Responds well to improved fertility.

Steep slopes: Suitable for planting on eroded sites and slip faces but requires a nurse crop on these sites that provides side shade to the young tree. Kauri is an emergent species that once established becomes light demanding, thus requiring full light to grow well.

Species characteristics: Grows on a wide range of sites, provided drainage is adequate. A relatively fast growing species on better sites, reaching 40cm diameter in 60 years.

Recommended regime: Slow growth for the first few years so regular releasing from weed competition is beneficial. Recommended planting of 800 stems per hectare interplanted two years after planting 800 stems manuka per hectare for honey production and as a nurse crop to draw the kauri upward. Depending on site and management, a rotation length of 60-100 years can be expected.

Key message: A long-lived species, well suited to difficult sites. Heights of 6-10 m can be expected in 20 years.

Native hardwoods

Native hardwood species to consider for timber plantations in Northland include puriri, rewarewa and pohutukawa.

Puriri, *Vitex lucens*

Puriri produces a high quality, dense, durable and strong timber with significant market potential.

Puriri is the fastest growing native timber hardwood in Northland but requires soils of good fertility. Free draining clay soils with a good fertiliser history are suitable, as are good quality volcanic soils.

Health: Generally of good health, but can be susceptible to drought and possum browsing. The puriri moth *Aenetus virescens* can damage the wood with its tunnelling. The level to which this insect damages timber plantations is unknown.

Timber: Traditionally puriri was utilised for fence posts, railway sleepers and house piles because of its exceptional ground durability. Puriri is also suitable for decorative furniture and joinery. However, because of its dense, interlocked grain it can be difficult to work.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Puriri, *Vitex lucens*	1000	Very strong	Very stiff	Very hard

Siting: Puriri is frost tender and prefers sheltered, coastal locations.

Open grown trees should be pruned for clearwood production and plenty of room left for residual crop trees to grow in diameter. Puriri is well suited to growing through a nurse crop established before or at the same time as the puriri.

Steep slopes: Suitable for planting on steep erodible sites provided soil depth and fertility is good and the site has some shelter. A nurse crop is beneficial on such sites to provide side shade to the young tree. Puriri is an emergent species that once established becomes light demanding, i.e. requiring full light to grow well.

Species characteristics: Grows on fertile sites with adequate drainage and some shelter. A relatively fast-growing species on better sites, reaching 40cm diameter in 40 years.

Recommended regime: Fast initial growth but needs some soil moisture for the first summer. If the site is frost-prone the trees should not be planted until the last frosts have finished (spring). Recommended planting of 800 stems per hectare interplanted with 800 stems manuka per hectare for honey production and as a nurse crop to draw the kauri upward. On a good site with good management a harvest age of 70+ years is possible.

Key message: A fast growing native species suitable for planting on sites with good soils.

Rata x Pohutukawa hybrid, *Metrosideros* spp.

Pohutukawa does not generally have a form suitable for timber production. However, reasonable growth rates, adaptability to harsh conditions and excellent timber properties suggest the species is a good contender for timber production on steep erodible slopes.

Anecdotal evidence suggests that straight, single-stemmed pohutukawa occur naturally in Northland as hybrids with northern rata. A range of named hybrid clones are also available and are grown as ornamental trees. However, these have not been tested for form and site requirements in plantation forests.

Pohutukawa and its hybrids can be clonally propagated (i.e. grown from cuttings), so selection and propagation of vigorous straight-formed trees offers a fast route to improved genotypes being available to growers.

Average growth rates of 50 cm diameter in 50 years can be expected. Annual diameter growth of up to 2 cm is possible on good sites, which is good for a native hardwood species.

A range of Graham Platt's hybrid selections are available, including Mistral, Sirocco, Hauparapara, Mercer Bay and Waikakariki, which are reputed to be straighter and faster growing than the pure species. The pohutukawa clones Maori Princess and Pink Lady also have a reputation for good form.

Health: Susceptible to browsing by possums. A range of native insects feed on pohutukawa but do not impact significantly on tree health.

Timber: very dense, strong, hard and durable. Cuts out red but ages to a rich reddish-brown colour.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Rata x Pohutukawa hybrid *Metrosideros umbellata x excelsa*	880	114	11.4	NA

Siting: Resilient to both poor soil conditions and strong winds. However, growth rates would be expected to be slow in such conditions. Seedlings can grow fast but are frost tender and vulnerable to desiccation by wind and drought. Trees should be planted in spring after the last frosts have finished and need to be kept free of weed competition for the first year. Does not cope with wet soils and waterlogging.

Steep slopes: Perhaps the most suitable of the native plantation forest species for exposed eroded slopes. A coppicing species, i.e. the roots do not die but the stump stays alive and re-sprouts after felling. Coppicing species hold the soil from slipping even after harvest.

Species characteristics: Reasonable growth rates, excellent timber properties and adaptability to harsh conditions offers potential for production forestry on exposed eroding slopes deficient in topsoil.

Recommended regime: Epicormic shoots are likely to result from pruning open-grown trees. Therefore, plant clonal selections at 800 stems per hectare, interplanted with 800 stems manuka per hectare for honey production and as a nurse crop to draw the *Metrosideros* upwards. It should be noted that pohutukawa is a light demanding species that does not grow well in the shade, so some thinning of nurse trees may be required. On bony, dry windswept sites a harvest age of 80+ years is possible.

Key message: Hybrids grow straighter and faster than true pohutukawa. Research is required to trial hybrid selections and develop management techniques.

Rewarewa, *Knightia excelsa*

Rewarewa is well adapted to phosphate-deficient soils and is a good nectar producer for beekeepers in spring. Rewarewa is hardy, slow growing and if open-grown tends to have poor form with multiple leaders.

Rewarewa grows into a large tree up to 30m tall and 1m diameter and is well adapted to phosphate-deficient soils, provided these are not too acid. Average growth rates of 30-40 cm diameter in 50 years can be expected.

Rewarewa is a pioneer species and grows well in the open or under a tree canopy, provided this is not too dense.

Health: No obvious health issues. Rewarewa tends to be susceptible to root rot on wetter sites.

Timber: The timber is very stiff and strong with a distinctive, attractive grain that has prominent medullary rays. The wood is not durable but is suitable for interior applications. Sapwood is highly susceptible to borer and requires preservative treatment for all applications.

Species	Density, dry (kg/m^3)	Bending strength, MoR (MPa)	Stiffness, MoE (GPa)	Hardness, Janka (kN)
Rewarewa *Knightia excelsa*	721	125	18.3	NA

Siting: Grows best in sheltered locations. Does not cope with waterlogging.

Steep slopes: Survives in nutrient deficient eroded sites. Suitable for planting on steep slopes.

Species characteristics: Reasonable growth rates, excellent timber properties and adaptability to harsh conditions offers potential for production forestry on exposed eroding slopes deficient in topsoil and nutrients.

Recommended regime: Plant seedlings at 800 stems per hectare, interplanted with 800 stems manuka per hectare for honey production and as a nurse crop to draw the rewarewa upwards. Open-grown trees require repeated form pruning to remove multiple leaders for a single trunk. A harvest age of 80+ years can be expected.

Key message: If open grown, form pruning is essential. Suitable for phosphate-deficient soils.

5. Sourcing planting stock

The tree planter must have some knowledge on assessing plant quality and be able to source quality plants and planting contractors at the right time of year.

Nurseries and plant availability

Availability of planting stock is dependent on ordering of trees well in advance. Nurseries tend to only grow plantation forestry species to order. Usually one year's notice is required for trees to be available for planting, but this may be extended if seed or cuttings are not available for the nursery to grow. If you are wanting a specialised line, then think ahead.

Planting stock may be supplied either bare-rooted or containerised. Freight costs are in addition to the price of each plant and packaging of planting stock should be discussed with the nursery.

Containerised stock

Root distortion in container-grown trees has two different origins and may increase likelihood of windthrow in young trees:

Container walls redirect and distort root development. Root trainer pots redirect roots downwards to avoid circular winding of roots. Although better than square or round pots ('tubes"), root trainers are implicated in causing a "root cage" in young trees which directs roots into a congested group of downward pointing fingers rather than a single vertical taproot and radiating lateral roots. Side slot (air-prune) containers are recommended for forestry stock as these minimise root distortion cause by the container walls and encourage fibrous root growth inside the container.

Poor pricking out practices can cause root distortion in containerised stock, such as "J roots". Appraisal of nursery stock is by removing the soil media from a sample of trees and inspecting the inner root.

Both causes can be mitigated, and it is recommended that the grower discusses these issues with their nursery.

Bare-rooted stock

This should have a fibrous root system. Regular wrenching in the nursery induces a more fibrous root system so that when the trees are lifted and long roots cut back, there is still plenty of root mass to supply moisture and nutrients to new growth.

The importance of seed provenance

The importance of contracting nurseries to grow from seed procured from proven trees cannot be over-emphasised. It is preferable that the nursery be supplied with the seed by the grower, who should if possible purchase the seed from a knowledgeable collector with access to proven mother trees in Northland to collect seed from. Where possible progeny should have been tested and proven to be reliable for health, growth and form in Northland.

Eucalypt and cypress seedlings should only be grown only from reliable and well proven seed sources. This is necessary to ensure disease and pest resistance along with adequate growth and form characteristics.

Table 8: Nurseries supplying plantation forestry stock

Nursery	Species	Contact person	Postal address	Physical address	telephone no.	email
Arborgen SuperTree Nursery, Northland	Radiata pine, bare-rooted. Other species grown to order, containerised	Jude Parsons, Kaikohe nursery; Mark Ryan other species	4766 Taheke Road, Kaikohe, 0405	4766 Taheke Road, Kaikohe, 0405	Jude, 021 983 276; Mark 021983275	jude.parsons@arborgen.co.nz; mark.ryan@arborgen.co.nz; sales@arborgen.co.nz
Babylon Coast Gardens Ltd	Wholesale contract nursery specialising in coastal natives		1246 Babylon Coast Road, Omamari 0373, New Zealand	1246 Babylon Coast Road, Omamari 0373, New Zealand	09 4394223	info@babyloncoastgardens.co.nz
Forest Floor Nurseries	Manuka, containerised. Other species grown to order	Simon Vallings	50 Mangakahia Rd, Maungatapere 0179	50 Mangakahia Rd, Maungatapere	09 4347216 021 1468243	office@forestfloor.co.nz
Hokianga Harbour Care						tiakingawaiohokianga@gmail.com
Kauri Park Nurseries	Manuka, containerised	Terry or Andrew Wearmouth	PO Box 63 Maungaturoto, 0547	2180 State Highway One Kaiwaka, North Auckland	09 431 2125	trade@kpn.co.nz

Nursery	Species	Contact person	Postal address	Physical address	telephone no.	email
Kerikeri plant production	Species grown to order, containerised	Tom Lindsay	Riddell Road Kerikeri 0230	Riddell Road Kerikeri	09 4079448	sales@kerikeriplantproduction.co.nz
Nga rakau Nurseries	Clonal lines and containerised forestry species	Greg Palmer	2 Mudgeways Road, Massey, Auckland	2 Mudgeways Road, Massey, Auckland	09 833 8046	sales@ngarakau.co.nz
Ngate Hine Wairoa	Wholesale Manuka, can include delivery + tablets ($1.20 each)	Dave Bristow		Ngapipito Road, Moerewa	0211130967	davidbristow5@gmail.com
Northland Forestry Nursery	Radiata pine, bare-rooted. Other species grown to order, bare-rooted	Kevin Strawbridge	Northland Forestry Nursery Limited PO Box 577, Kaikohe 0440	75 Thorpe Road, Kaikohe	Kevin 0274 830 460	nfn@xtra.co.nz
Northland Regional Council, Mata nursery	Poplar wands, stakes and poles	Matthew Mabbitt	http://www.nrc.govt.nz/poplars	Flyger Rd, Mata	0800 002 004	nursery@nrc.govt.nz
PF Olsen nursery	Radiata pine, containerised	Kevin Haine	442 Glenbrook Beach Rd, Waiuku 2681	442 Glenbrook Beach Rd, Waiuku 2681	09-235 3877 021 402148	Kevin.Haine@pfolsen.com

Nursery	Species	Contact person	Postal address	Physical address	telephone no.	email
Scion nursery	Cutting propagation	Paul Keech	Te Papa Tipu Innovation Park, 49 Sala Street, Rotorua Private Bag 3020, Rotorua 3046	Te Papa Tipu Innovation Park, 49 Sala Street, Rotorua Private Bag 3020, Rotorua 3046	027 385 0954	paul.keech@scionresearch.com
Springfield Nurseries	Containerised forestry species	Barbara Parker	PO Box 7131, Taradale, Napier 4141	107 Springfield Road, Taradale, Napier 4141	06 8447028	springfield-nursery@xtra.co.nz
Te Hana nurseries	Full range of species, containerised. Mostly grown to order	Chris Boyd	251 State Highway 1, Wellsford 0974	251 State Highway 1, Te Hana RD4, Wellsford	09 423 8595	https://tehananurseries.co.nz/contact/ info@tehananurseries.co.nz
Te Roroa environs	Setting up native nursery at Waipoua	Courtney Davis		Waipoua		cdavis@teroroa.iwi.nz
Tipu Ora Nurseries	Manuka only (no experience as at 2020 with other species)	Awhina Allen		Cumber road, Kaikohe	0211359019	awhinaallen@live.com
TKEMKT nursery Te Kotahitanga E mahi Kaha Trust	Contract growing. Manuka, canopy native species	Hone Dalton (Ops manager)		Kaikohe	Hone 02102308358	hdalton@tkemkt.co.nz dotene@tkemkt.co.nz

Nursery	Species	Contact person	Postal address	Physical address	telephone no.	email
(Charitable trust, work scheme putting kids into gainful employment)		Deidre Otene (CEO)				
Kukupa native tree nursery	Manuka and natives for revegetation	Terry Scott	72 Lodore road, kerikeri	72 Lodore road, RD 1 Okaihau 0475	021 02170690	landtscott@slingshot.co.nz
Bakerboy's Wholesale Nursery	Revegetation, large plants		60 Stanners road, Kerikeri	60 Stanners road, RD 2 Kerikeri, 0295	09 4076948 Andrew 0274734379	bakerboysnursery@xtra.co.nz
Rural design	Native nursery and design service	Heath Worsfold (Manager) Also Eden and Blake	300 Kaiwaka Mangawhai Road, Kaiwaka, Northland 0975	300 Kaiwaka-Mangawhai road, Kaiwaka	09 4312481 Heath: 021431320 Eden: 021995666 Blake: 0211489743	info@ruraldesign.co.nz
Green Infrastructure Nurseries (GIN) Ltd	Native nursery specialising in revegetation	Hannah Scott	734 Pataua North Road, R.D.5, Whareora 0175	734 Pataua North Road, Whareora, Northland	09 4595987 021 0585229	ginltd@icloud.com https://www.ginltd.co.nz/

Nursery	Species	Contact person	Postal address	Physical address	telephone no.	email
Alter-natives	Native plants	Phil Grindle (Director)	Whangarei	101 Kioreroa Road, Whangarei	09 9748733	sales@alter-natives.co.nz https://alter-natives.co.nz/contact/
CBEC Kaitaia	Native plants for revegetation	Lisa	190 Pukepoto road, Kaitaia 0410	190 Pukepoto road, Kaitaia	09 4081092 Lisa: 0272455517	lisa@cbec.co.nz https://www.cbec.co.nz/
Nga Uri o Hau native nursery	Community-based nursery	Jane Mehana	Kaipara catchment		09 4597001	jane@kaiparaharbour.net.nz
Ngawha prison nursery		Andrew Martin	Kaikohe			Andrew.martin@corrections.govt.nz
Otamatea harbour care nursery	Riparian – flax, cabbage trees, manuka	Mark Vincent		Maunguturoto area	09 4317353 021 08298037	Mark.vincent@gmail.com https://otamateaharbourcare.org.nz
The Landing nursery	Native plants, revegetation	Caleb Scott		Purerua Peninsula, kerikeri	027 4951715	https://www.thelandingnz.com/nursery/ caleb.scott@thelandingnz.com

Nursery	Species	Contact person	Postal address	Physical address	telephone no.	email
Ngataki native plants	Native plants and trees	Vicky Rawnsley	Far North	Kimberly Road, Ngataki 0484 (Far North)	021 0665152 09 4098898	Beaudowns12@gmail.com
Tawapou Coastal natives	Coastal natives	Guy and Sandra Bowden	606 Matapouri Rd, RD 3 Whangarei 0173	606 Matapouri Rd, RD 3 Whangarei 0173	09 4343971 Guy: 027 289 6827 Sandra: 027 3443 971	tawapou@tawapou.co.nz
He Kakano community nursery	30% Wetland riparian natives, 70% native trees	Jordie McDonald		8 First Avenue, Whangarei	027 3548745	https://www.whitebaitconnection.co.nz/
Waimarie Nurseries	Native plants, wholesale nursery	Sharon Ware, Toma Adams	131 Draffin Road, Poroti, Whangarei	131 Draffin Road, Poroti, Whangarei	09 4373627	info@waimarienurseries.co.nz http://www.waimarienurseries.co.nz/
The Shadehouse	Community, small operation, DOC partnership agreement	Rod Brown or Anthea Goodwin	Kerikeri, Shepherds Road		0274409777	summerhouse.kerikeri@gmail.com