Planting Pattern and Density for Natives on Open Sites

INTRODUCTION

Many planting programmes using natives involve the establishment of trees and shrubs on an open site, usually grassland recently retired from grazing. Choice of planting pattern and density can vary from high to low densities, from mixed to single species plantations, or from rigid line-planting to flexible placement of plants. For open sites, planting pattern and density depends on several factors including:

- objectives of planting;
- scale of the planting project;
- species to be planted;
- site conditions, particularly the degree of exposure;
- resources available for purchase of stock;
- degree of site preparation undertaken including animal control;
- potential of vigorous weeds to colonise the site; and
- commitment to after-planting care, particularly weed control.

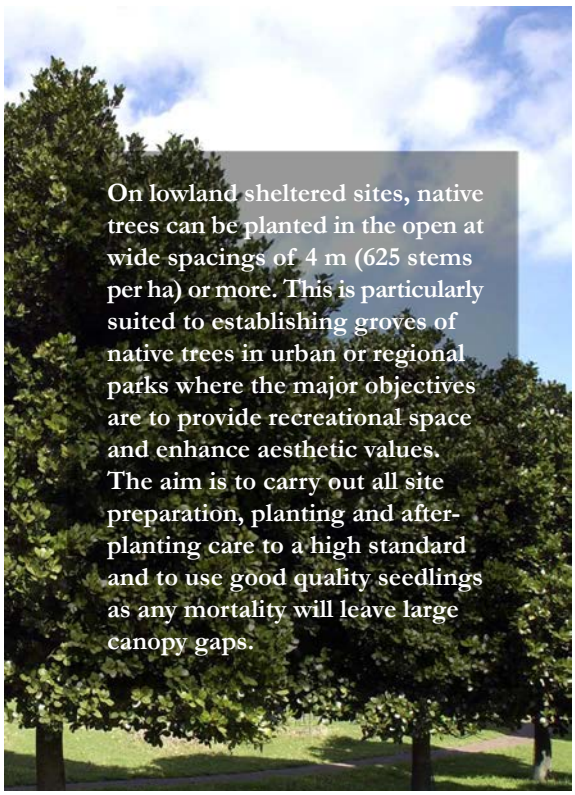
Balancing act!

The choice of planting pattern and density is a balance between planting at a dense spacing to achieve canopy cover and hence weed control quickly, and wider spacing requiring a commitment to monitoring and controlling potential weed invasion over longer timeframes (Davis et al. 2009). While a dense planting can give a canopy cover within 2-3 years, this option requires large numbers of plants and intensive site preparation and planting for this option to succeed. Conversely, a low plant stocking may take a decade on some sites to become fully covered in native woody vegetation, especially if growth rates are slowed by poor climatic conditions and with a low maintenance regime.

PLANTING DESIGN FOR NATIVE FORESTRY

Where the objective is to establish native trees for long-term timber production, choice of density has implications for growth rates of planted trees, tree form and cost of establishment.

Low-density planting



Depending on the species, trees in lower stocked stands will tend to have, from a production forestry perspective, poor tree form with coarse low branching and multiple leaders. If merchantable sawlogs are desired, native trees planted at wide spacing will inevitably require removal of multiple leaders and lower large branching as with exotic production forestry. Some species such as kauri (*Agathis australis*), kahikatea (*Dacrycarpus dacrydioides*) and tanekaha (*Phyllocladus trichomanoides*) will require less silviculture as they naturally form a largely erect mono-podial habit usually with a single leader. Other species such as totara (*Podocarpus totara*) and puriri (*Vitex lucens*) will, if given the space, tend to form large, spreading rounded crowns, and will require repeat form-pruning to produce a single stem.

High-density planting

For establishing a plantation as a dense stand, the stockings may have to be in excess of 5000 stems/ha (plant spacing less than 1.5 m apart) to achieve canopy closure within five years. Trees planted at high-density will reach canopy closure more quickly than trees established at lower stockings. With the onset of between-tree competition as the stand develops, increasing competition will reduce growth rates of stem diameter but will encourage the development of straight, tall stems and branch-free lower boles. Totara, kahikatea, kauri and the beeches (*Nothofagus* spp.) have been successfully planted on open sites at high stockings. For example, a 90-year-old untended plantation of totara established originally at 1.2 to 1.5 m tree spacing is growing at less than half its potential stem diameter rate compared to totara at wider spacing on similar sites but there is a high proportion of trees with single-leadered stems and clear boles over 10 m in height (Bergin and Kimberley 2003).

Once canopy closure is achieved and within-stand competition intensifies, thinning will be needed or growth rates will reduce substantially. Depending on initial growth, this may need to be done within 1-2 decades of planting. It is likely that ongoing form-pruning of residual trees may be required as the stand is opened up.

Costs of establishment

A major disadvantage with planting native trees species at high density is the high cost of establishment. Davis et al. (2009) calculate that establishment costs for planting of trees species such as rimu (*Dacrydium cupressimum*) would be $35,000 per ha at a medium-density planting of 4444 plants per ha (tree spacing 1.5 x 1.5 m). This is not too dissimilar to Bergin and Gea (2007) who calculated cost for trees planted at the same density was $30,000. Both scenarios are based on planting nursery-raised seedling in planter bag (PB) containers at a cost of $4 each.

Bergin and Gea (2007) indicate that planting native trees at 10,000 stems per ha (1 x 1 m) is likely to be in excess of $60,000 per ha. In contrast, lower stocking options such as trees planted at 4 m spacing (625 stems per ha) is estimated to cost $5500 per ha to establish. This allows for up to five years of weed control. However, depending on growth rate and tree species used, plantations established at low-density are likely to take at least a decade before canopy closure. The vulnerability of the planting site to be invaded by vigorous weeds has seen the demise of many planting programmes where trees have been established at wide spacing. Lower planting densities require a long-term commitment by landowners to ensure that inspection of sites is carried out regularly until canopy closure and problem weeds are controlled before they overtop any planted seedlings. Extended periods of monitoring and maintenance will add further to establishment costs.

Trees planted at high density will reach canopy closure more quickly than trees established at lower stockings. Increasing between-tree competition will reduce growth rates but will encourage the development of straight, tall stems and branch-free lower boles.

Planting pattern

Regular planting patterns including line-planting and establishment of monocultures of key species may be appropriate for some landowners establishing blocks of native trees where the objective is long-term timber production. Planting seedlings in lines on open sites ensures that even plant spacing and the desired density are achieved, particularly for large-scale operations. It also permits easier location of plants for releasing. Views of lines may detract from a natural appearance, but this effect is minimised with canopy closure and with subsequent effects of competition and thinning.

Establishment of new native forest does not necessarily have to follow rigid planting practices as used in the exotic forest industry. Flexibility in planting pattern when establishing new native forests will allow species to be planted on ecologically appropriate sites and the development of mixed-aged and mixed-species stands more akin to natural forest patterns.

Continuous Cover Forestry - mimicking natural patterns

Information about Continuous Cover Forestry (CCF) applicable to New Zealand conditions, Barton (2008) indicates that native species appear to offer very good potential. He argues that in future years it is likely more of our timber will need to be managed by methods other than clearcut forestry, and this is especially so for our native forests. Continuous cover principles mimick natural forest processes and produce not just timber but also the associated benefits of "multiple-use forestry" including a wide range of environmental and social outcomes.

NURSE SPECIES

Pioneers

Native tree species establish naturally amongst pioneer vegetation, which provides protection from extremes of local climate. Planting of a hardy vegetation cover in advance of the chosen tree species can mimic this process of natural succession. The use of quick-growing, generally hardy, shrub hardwood species (nurse species) is a favoured method for providing shelter on an exposed site and a canopy cover to reduce the time needed for weed control.

Many native tree species favoured for timber production grow slowly in early years, but performance of some is improved when they are planted within shelter. For instance, totara planted at 2500 stems per ha took at least 8 years to canopy closure on a south Auckland site (Bergin 2003) whereas manuka (*Leptospermum scoparium*) planted as a nurse crop at the same density on a similar site took only half this time (Steward 2000).

Exposed sites

On severely exposed, open sites, shelter must be provided for more sensitive tree species by advance planting of nurse species such as manuka, kanuka (*Kunzea ericoides*), kohuhu (*Pittosporum tenuifolium*) and karamu (*Coprosma robusta*). Once the nurse species is established, native trees can be interplanted at the desired stocking rate and planting pattern. Depending on growth rate of the nurse species and severity of the site, target timber trees can be planted 1-5 years after the nurse crop. Natural gaps that occur within the cover or are cut by hand can be used to plant target timber species.

On less exposed open sites a mixture of nurse crop species and target timber species can be planted concurrently. Shrub hardwood species are likely to be cheaper than native tree species and can 'bulk-out' a planting site to give early canopy cover and reduce the length of time for weed control from 5-10 years for widely spaced stands to about 2-3 years for dense plantings. The more expensive native conifer and hardwood timber tree species can be interplanted at near final spacing within the nurse crop, using a random pattern if a natural appearance is desired.

Improving tree form

As well as shelter, nurse species provide side shading which encourages apical dominance of main leaders, smaller branch size and a lower incidence of multiple leaders. Regular maintenance will be required to ensure that light levels remain adequate for growth of the interplanted trees. Maintenance of a light-well above each interplanted tree is essential to encourage height growth and in time the nurse species will be suppressed.

PATTERN AND SPACING FOR CONSERVATION PLANTING

Pattern of planting in restoration programmes for largely conservation purposes will likely involve random positioning of plants although consideration of different site types will still govern how species are best matched to the most appropriate sites. The aim with large-scale revegetation on an open site with native tree and shrub species is to quickly achieve canopy closure which is self-sustaining and requires little further intervention.

To achieve conservation and biodiversity objectives, Davis and Meurk (2001) provide the following recommendations for native restoration programmes:

- Distribute plants in their planting places to ensure all the expensive tree species will not be planted in one place or too close together.
- Normal planting density is around 1 plant per square metre. This is more costly than planting at wider spacings but it will achieve more rapid control over grass and weed competition.
- Planting small stock densely will minimise costs and allow for losses from natural mortality. If grass control will be infrequent, less dense planting of larger grade plants may be appropriate on moist sites or in deep soils.
- Not all species need to be planted at the outset, so an allowance for interplanting in subsequent years is required in the initial placing of plants.

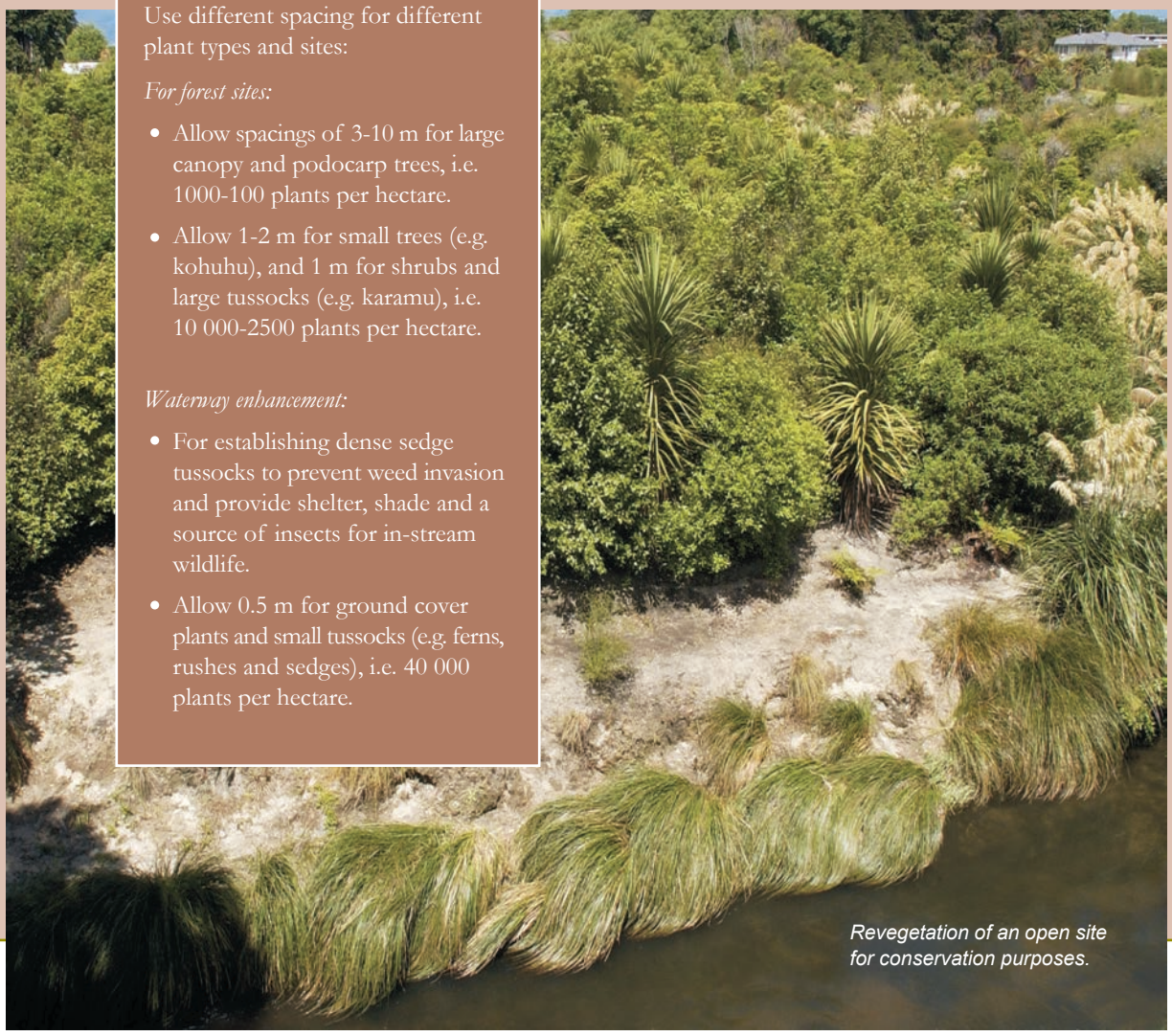
Use different spacing for different plant types and sites:

For forest sites:

- Allow spacings of 3-10 m for large canopy and podocarp trees, i.e. 1000-100 plants per hectare.
- Allow 1-2 m for small trees (e.g. kohuhu), and 1 m for shrubs and large tussocks (e.g. karamu), i.e. 10 000-2500 plants per hectare.

Waterway enhancement:

- For establishing dense sedge tussocks to prevent weed invasion and provide shelter, shade and a source of insects for in-stream wildlife.
- Allow 0.5 m for ground cover plants and small tussocks (e.g. ferns, rushes and sedges), i.e. 40 000 plants per hectare.



Revegetation of an open site for conservation purposes.

TIMELINE FOR ESTABLISHING NATIVE TREES

LOW-DENSITY OPTION **(Plant spacing 2-4 m)**

YEAR 1

Controlling animals

- Erect stock-proof fences
- Graze grass
- Remove stock, control wild animals.

Spraying

- Spot-spray 1 m diameter areas at the required wide spacing (2-4 m apart) using knapsack sprayer
- Use marker dye in spray to assist with determining spray pattern and density and relocation of spots if planting is undertaken before dead grass areas show up.

Planting

- Plant large seedlings 2 weeks after spraying in centre of each spot
  Use hardy shrub species initially for exposed sites
- Plant tree species at near final crop spacing only on sheltered fertile sites and where good maintenance is guaranteed.

Blanking

- Inspect site 3-6 monthly to determine and remedy any causes of mortality
- At wide spacing any losses will leave large gaps
- Re-plant gaps with large seedlings during the next planting season.

YEARS 1-2

Weed control

- Spray weeds around base of seedlings before they reach a height of 30 cm
- Spot-spray or hand cut brush weeds and blackberry.

YEAR 3-5

Supplementary planting of trees

- If not planted in Year 1, supplementary plant native timber species in gaps between existing plants
- Use site preparation as for Year 1 – spot spray grass and weed cover before interplanting native trees.

YEAR 3-10

Continuing weed control and canopy closure

- Grass control becomes less important once trees are 1-2 m in height
- Inspect sites and continue to remove vigorous weeds and blackberry.

Silviculture

- Enlarge gaps to ensure light wells remain above interplanted native tree species
- Continue annual inspections until tree species have grown through canopy of nurse cover.

TIMELINE FOR ESTABLISHING NATIVE TREES

HIGH-DENSITY OPTION **(Plant spacing 1-1.5 m)**

YEAR 1

Controlling animals

- Erect stock-proof fences
- Graze grass to low levels where practical
- Remove stock, control wild animals.

Spraying

- Blanket-spray site with herbicide preferably at least 2 weeks prior to planting.

Planting

- Plant mixture of hardy shrubs and trees for shelter and to bulk out site
- Aim to get at least 5000 spha (plant spacing less than 1.5 m)
- Plant mostly shrubs with native tree seedlings randomly mixed in at near final crop spacing of 4-600 spha (4-5 m plant spacing)
- If necessary leave planting of the tree species on severely exposed sites until shrub cover is established and providing more shelter (Years 2-3).

Weed control and blanking

- Inspect site every 3-6 months
- Determine and remedy any causes of mortality
- Replace dead seedlings (blanking) during the next planting season
- Re-spray areas of grass or weed regrowth before it reaches a height of 20 cm.
- Spot-spray or hand-cut brush weeds and blackberry.

YEAR 2

Continuing weed control

- The need for grass control will reduce as shrub and tree crowns expand
- Continue spot-spraying or hand-cutting of woody weeds and blackberry.

YEAR 3

Canopy closure and silviculture

- Depending on growth rate, canopy closure should occur within 3 years
- After this no further weed control will be required
- Ensure native tree species in gaps are not being overtopped by faster growing shrub hardwoods.

YEAR 4 ONWARDS

Silviculture

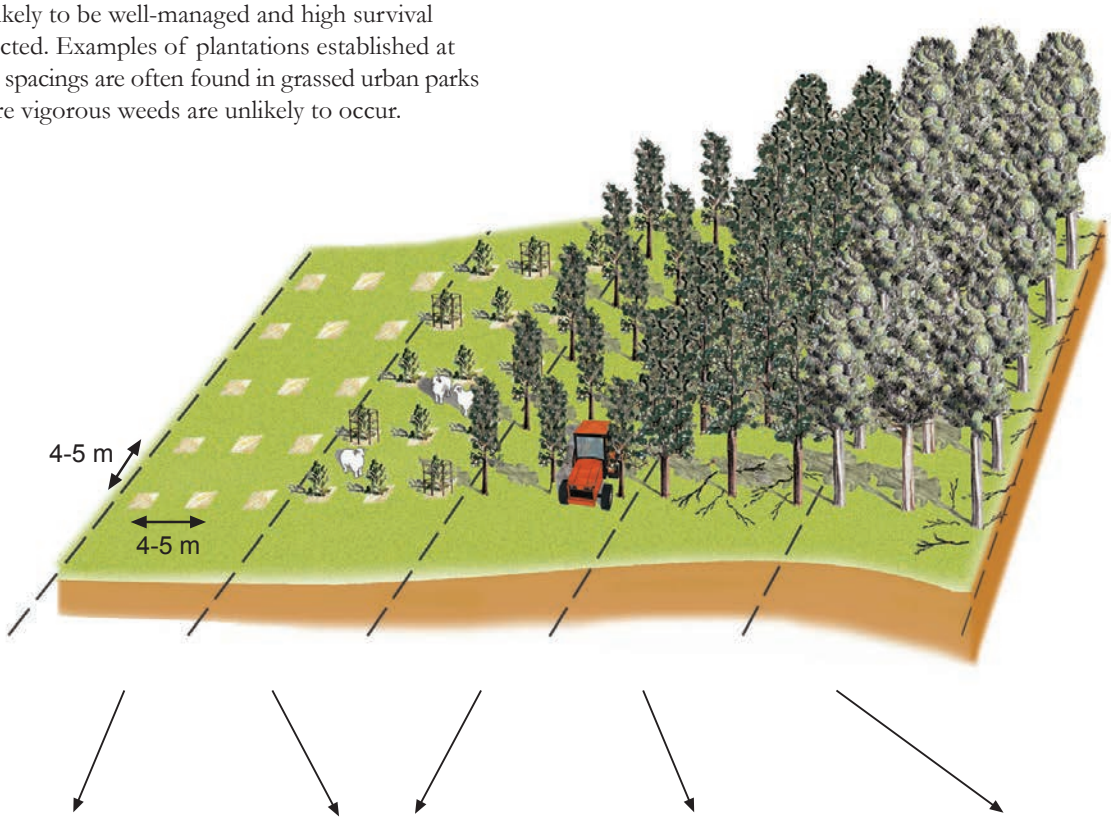
- Enlarge gaps to ensure light wells remain above interplanted native tree species
- Continue annual inspections until tree species have grown through canopy of nurse cover.

SCENARIOS FOR ESTABLISHING PLANTATIONS

Five scenarios demonstrate different planting patterns, densities, and timing for establishing a stand of native timber trees on open sites. Choice of scenario will depend on the site and species to be planted, the degree and type of weed growth expected, resources available for planting and management, and the objectives for establishing the stand.

SCENARIO 1 : Planting native trees at LOW density

Appropriate for sheltered lowland grassed sites that are likely to be well-managed and high survival expected. Examples of plantations established at wide spacings are often found in grassed urban parks where vigorous weeds are unlikely to occur.



Prepare site

Pre-plant spot-spraying of grassed sites with herbicide. Wide plant spacing is likely to be most practical on grassed sites where there are no major vigorous weed species such as gorse or blackberry.

Plant and control weeds

Plant native tree species at near final spacing of 4-5 m (about 500 stems/ha). Use knapsack sprayer to keep rank grass away from seedlings for at least 2 years; large areas between trees can be left to develop into rank grass.

On flat or rolling sites, wide spacing allows for tractor mowing as for urban parks. Alternatively, grazing will keep grass under control with tree protection necessary particularly at early stages.

Form prune

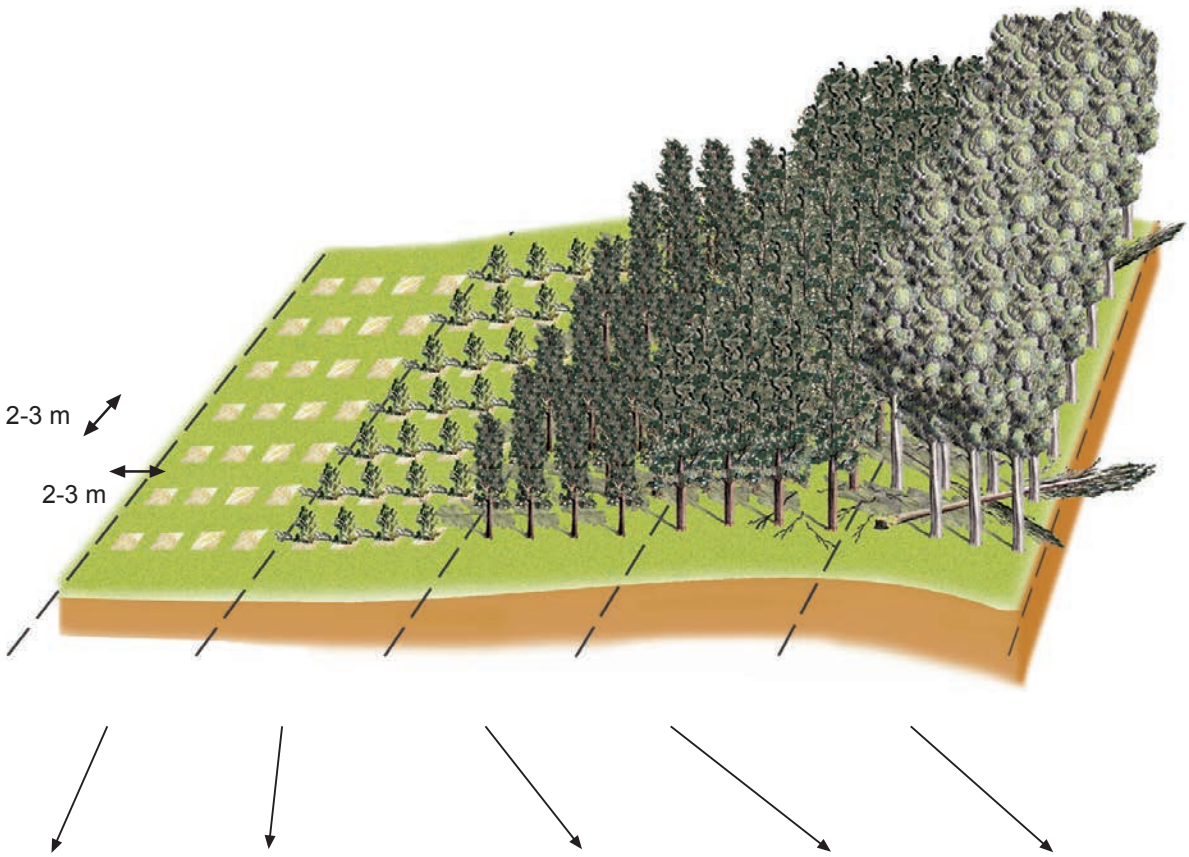
For wood production intensive form pruning will be required to ensure development of straight, single, branch-free lower stems. Kauri, tanekaha and kahikatea usually form single stems although large lower branching will need to be removed. Hardwoods, totara and rimu are often multi-leadered with coarse branching and will require early removal of double leaders and steep-angle branches.

Canopy closure

Canopy closure unlikely to occur for 2 or more decades depending on species and growth rates. While no thinning is necessary at this wide tree spacing, long term commitment to pruning will be required to ensure branch-free lower boles.

SCENARIO 2: Planting native trees at MEDIUM density

Ideal for most grassed areas recently retired from grazing; a practical option over relatively large areas. Initial establishment cost is considerably reduced with lower numbers of seedlings required and less planting.



Prepare site

Pre-plant spot-spraying of grassed sites with herbicide. More intensive site preparation will be required where problem woody or scrambling weeds are present or expected to develop.

Plant and control weeds

Plant native trees at 1100-2500 stems/ha (trees spaced at 2-3m apart); the lower stocking is at a similar density recommended for Douglas-fir (*Pseudotsuga menziesii*) (Miller and Knowles 1994). The higher stocking may be preferable on difficult weedy sites where some mortality is expected.

Canopy closure

Depending on tree species planted and early growth, canopy closure will take at least 10 years to suppress ground cover and before there is an effect on reducing lower branch development.

Form prune

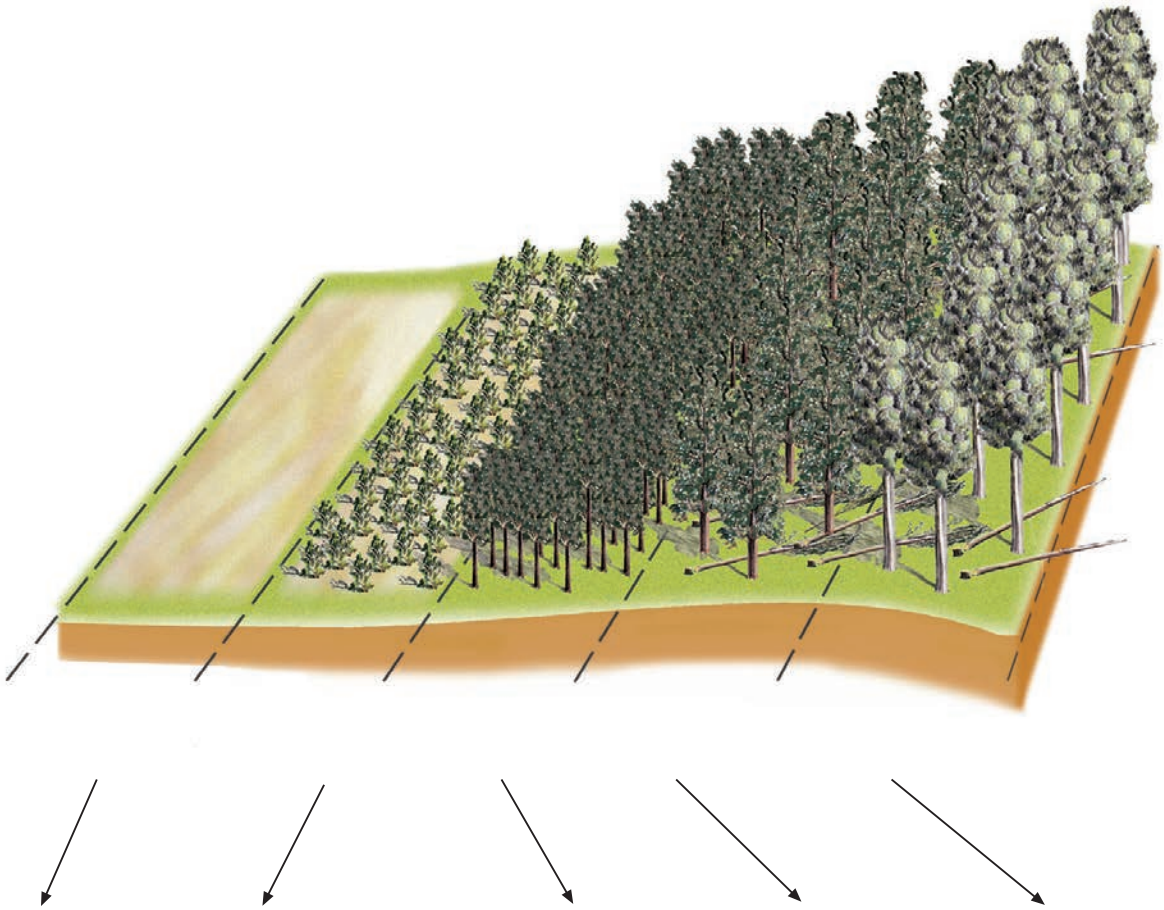
Remove multiple leaders and large lower steep-angle branches from sapling stage for crop trees; prune if desirable.

Thin

Selectively thin at least half of the trees probably starting within 2 decades of planting; timing of thinning depends on speed of canopy closure and may require more than one operation to reduce to 500 stems/ha or less.

SCENARIO 3: Planting native trees at HIGH Density

Only practical for establishing a small woodlot of native timber trees on a small scale due to the cost for the large number of seedlings required per hectare. Most trees will require thinning out eventually.



Prepare site

Blanket-spray planting area with herbicide before planting. More intensive site preparation will be required where problem woody or scrambling weeds are present or expected to develop.

Plant and control weeds

Plant at very high density >5000 stems/ha (less than 1.5 x 1.5 m). Dense planting will give quick canopy cover and hence weed control. Canopy closure should occur in about 5 years.

Tree form

Dense planting will encourage excellent stem form and small or no branching on lower part of the bole on most trees, although stem diameter growth will slow down over time.

Thin

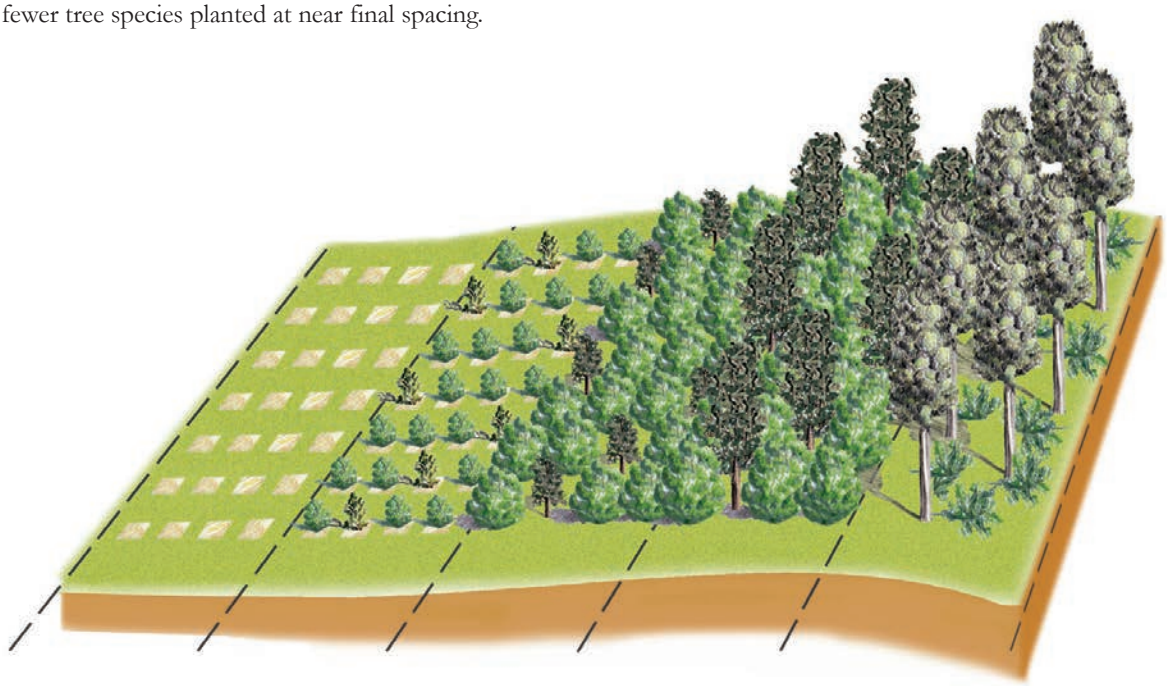
Depending on species planted and growth rate, stands will require thinning starting within 1-2 decades to maintain growth; thinning operations will need to be spread over several operations. Scope to remove trees with poor form during thinning.

Final stocking

Aim is to eventually achieve a stocking of less than 500 stems/ha; the vast majority of planted trees will therefore be removed by thinning.

SCENARIO 4: Planting a MIXTURE of NATIVE TREES and SHRUBS

Involves planting concurrently a mix of native timber species at near final stocking with shrub hardwood species planted as a filler. This scenario allows planting a higher proportion of less-costly faster-growing hardy shrubby species and fewer tree species planted at near final spacing.



Prepare site

Pre-plant spot-spraying of grassed sites with herbicide for grass sites; intensive site preparation and use of brush weed herbicides will be required where vigorous woody weed species and blackberry are present.

Plant

Depending on how quickly canopy cover is required, plant 1500 stems/ha or more of hardy shrub hardwoods and at the same time evenly interplant native trees at a minimum of 500 stems/ha. Increase the proportion of native trees if mortality is likely to be high. Total cost of planting cheaper shrub species (@ $2-3) plus timber species alone (@$3-5) will be less than dense planting of timber species alone.

Canopy closure

Shrub species will develop larger crowns faster than timber species and thus accelerate canopy closure. This will reduce long term weed control and provide early shelter to assist establishment of timber species.

Control weeds

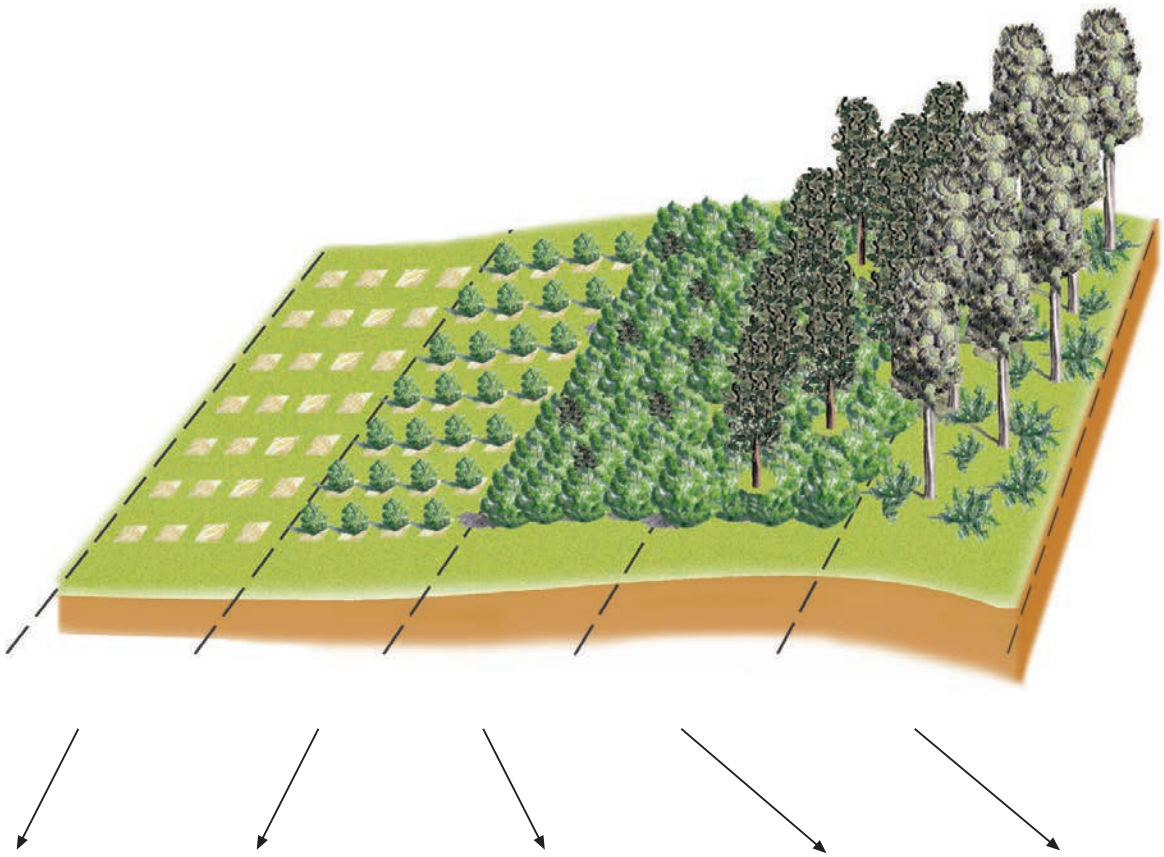
Care will be required to ensure tree species are not suppressed by surrounding shrub hardwoods; cut out overtopping shrub species to keep tops of trees species within a light well.

Final crop

Eventually timber tree species will dominate as they overtop shorter-lived shrub hardwoods. Side shelter of shrub hardwoods will encourage good form of tree species – tall single boles with light or no lower branching, and thus less silviculture.

SCENARIO 5: Interplanting NATIVE TREES into an established NURSE CROP

This option is essential for exposed difficult sites where a hardy pioneer cover of native shrub hardwood species is required to protect later establishment of native timber species.



Prepare site

Pre-plant spot-spraying of grassed sites with herbicide or brush weed herbicides where vigorous woody weed species and blackberry dominate.

Plant

Plant a nurse cover of hardy pioneer shrub hardwood native species at 2-3 m spacing (1000-2500 stems/ha) to provide initial shelter; choice of species should mimic natural regeneration of hardy species on difficult sites locally. Allow development of the nurse crop to provide shelter for later planting of timber tree species.

Canopy closure

An adequate cover of shrub hardwoods may take 1-5 years depending on severity of the site. Time inter-planting of tree species so that trees benefit from shelter provided by nurse crop and can take advantage of natural or cut canopy gaps to encourage height growth and good form. Plant trees at a spacing of 3-4 m (600-1000 stems/ha).

Prune and release

Timely pruning, or if necessary removal, of overtopping nurse canopy is essential to maintain "light wells" for developing inter-planted native trees that eventually dominate.

Final crop

Eventually timber tree species will dominate as they overtop shorter-lived shrub hardwoods. Side shelter of shrub hardwoods will have encouraged good form of tree species – tall single boles with light or no lower branching, and thus less silviculture.

CONCLUSION

A comparison of estimated costs per hectare for establishing native trees at different plant densities shows that the major contributor is the cost of nursery-raised seedlings (Bergin and Gea 2007). Estimated bulk rates for native tree species most commonly raised in polythene planter bags can be up to $4 per tree. Establishment scenarios that favour bulking out the site with a high proportion of the faster-growing and generally cheaper shrub hardwoods are, therefore, likely to be favoured options. Shrub species will not only provide interplanted native trees with shelter and improved performance in early years, but will also assist in faster canopy closure and reduced commitment to weed control.

A line of 3-year-old native hardwood trees kohekohe inter-planted 2 years ago within a nurse cover of 8-year-old manuka.

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