DIVERSIFIED SPECIES TECHNICAL NOTE

Number: DSTN-029
Date: August 2011

Indigenous Plantation Survey

Summary

This Technical Note describes the results of a national survey conducted and managed by Tāne's Tree Trust (TTT). The objective of the survey was to locate and measure the growth of significant plantings of indigenous species throughout the country and thus provide growth data for developing and refining growth and carbon accounting models for native trees and shrubs.

Over 6000 individual trees and shrubs in 120 plots covering 61 species were measured for height and diameter growth. The data were combined with a smaller survey carried out in the mid-1980s, producing a database containing growth measurements for 70 planted indigenous tree and shrub species with an age range of 5-110 years. Stands were located in most regions of New Zealand from Northland to Southland and from coastal lowland sites to inland sites over 500 m above sea level. Stockings averaged 1900 stems/ha for trees and 3500 stems/ha for shrubs.

Mean annual diameter growth rates of 6-9 mm and up to 33 cm annual height growth for the faster growing conifers and hardwood trees measured in this latest survey are similar to those reported earlier for planted stands of indigenous trees. Variability between individual stands across all species is substantial due to the wide range of site and climatic factors that occur between stand locations, as well as differences in stand characteristics, particularly stocking.

Tāne's Tree Trust is currently developing an Indigenous Plantation Forestry Database in collaboration with FRR and other stakeholders. This survey supports the development of this database aimed at providing information on the growth and management of key indigenous forestry species for multiple objectives including the option of long-term specialty timber production. Once the indigenous plantation database is completed in 2012, FFR members will be able to access summaries of growth data through the Tāne's Tree Trust website www.tanestrees.org.nz.

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Introduction

Over the past 150 years, at least 80 million seedlings of indigenous timber trees have been planted throughout New Zealand (Ian Barton, pers. comm.). Substantial planting programmes involving hundreds of thousands of seedlings over a range of species were planted by the Lands Department even before 1900, and these were continued with various levels of intensity by the New Zealand Forest Service up to the 1980s[1]. Over the last decade, planting of indigenous timber species by private individuals and public organisations has increased exponentially. A conservative estimate of the number of indigenous trees and shrubs currently being planted in New Zealand is at least 10 million per year[1].

A survey of indigenous plantations was undertaken by the Forest Research Institute in the mid-1980s, but included only selected stands on mostly private or local authority land[2]. Further plantations have since been established but most have not been systematically measured.

The objective of this project was to measure the growth of significant plantings of indigenous tree species throughout the country. This involved both re-measurement of plots from key plantations covered in the earlier survey, and also locating and assessing other suitable native plantations. The intention was to provide records of stand histories and growth performance assessments of the indigenous trees and shrubs suitable for developing and refining growth and

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carbon accounting models for native trees and shrubs.

The project was managed by Tāne's Tree Trust (TTT) and jointly funded by the Ministry of Agriculture and Forestry's Sustainable Farming Fund and TTT, with complementary funding from the Future Forest Research (FFR) Diversified Species programme.

Methods

A questionnaire was circulated via the post, email and various forestry and farming networks nationwide requesting information on the location, history and access for measurement of significant stands of indigenous tree and shrub species. Over 100 replies to the survey were received. Most of the plantations identified in the survey were inspected, and trees were assessed for growth. This included re-measurement of selected stands covered in the earlier Forest Research Institute survey.

Permanent Sample Plots (PSPs) or inventory growth plots were established within representative areas within most planted stands of known age and management history. Establishment of PSPs followed the methods of Ellis and Hayes[2] using circular or square plots up to 400 m^2, although smaller plots had to be established in less extensive stands. From 1 to 6 plots were established at most sites depending on the range of species and ages of stands. For sites dominated by shorter-lived shrub hardwoods and for younger plantations, a representative sample of up 30 plants for each of the major species was measured.

The following parameters were measured:

- Species
- Age since planting
- DBH (diameter at breast height – 1.4 m above ground level) of tree species;
- RCD (root collar diameter) – diameter approximately 10 cm above ground level of shrub species;
- Heights of a minimum of 12 trees per plot;
- Calculation of stand stocking within bounded plots and estimates of stem density in inventory plots using a minimum of 30 intra-tree distances.

Site factors including location, elevation, topography, soil type and climate, status of understorey vegetation and presence of browsing animals known to significantly influence performance of the stand were recorded. The history of site and stand management was collated from owners and managers, including the objectives for planting, site preparation, weed and pest animal control, and any silviculture of planted trees.

Datasets from both the earlier plantation survey and the recent TTT survey were combined. The dataset included a small number of stands that were re-measured during both surveys and where individual trees could be relocated.

For the purposes of analysis and presentation of results, each of the 25 species most commonly measured during the survey was placed into one of four categories. The species within each category, along with their species codes, are:

1. **Beeches**
   - Red beech – *Nothofagus fusca* (NOTFUS)
   - Silver beech – *Nothofagus menziesii* (NOTMEN)
   - Black beech – *Nothofagus solandri* (NOTSOL)
2. **Conifers**
   - Rimu – *Dacrydium cupressinum* (DACCUP)
   - Totara – *Podocarpus totara* (PODTOT)
   - Kauri – *Agathis australis* (AGAAUS)
   - Kahikatea – *Dacrycarpus dacrydioides* (DACDAC)
   - Tanekaha – *Phyllocladus trichomanoides* (PHYTRI)
   - Matai – *Prumnopitys taxifolia* (PRUTAX)
   - Miro – *Prumnopitys ferruginea* (PRUFER)
   - Kawaka – *Libocedrus plumosa* (LIBPLU)
3. **Other hardwood trees and cabbage tree**
   - Karaka – *Corynocarpus laevigatus* (CORLAE)
   - Puriri – *Vitex lucens* (VITLUC)

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- Kohekohe – *Dysoxylum spectabile* (DYSSPE)
- Rewarewa – *Knightia excelsa* (KNIEXC)
- Pohutukawa – *Metrosideros excelsa* (METEXC)
- Ti kouka, cabbage tree – *Cordyline australis* (CORAUS)

4. **Shrub hardwoods**
   - Wineberry, makomako – *Aristotelia serrata* (ARISER)
   - Karamu – *Coprosma robusta* (COPROB)
   - Kanuka – *Kunzea ericoides* (KUNERI)
   - Manuka – *Leptospermum scoparium* (LEPSCO)
   - Rautaawhiri – *Pittosporum colensoi* (PITCOL)
   - Tarata – *Pittosporum eugenioides* (PITEUG)
   - Kohuhu – *Pittosporum tenuifolium* (PITTEN)
   - Whauwhaupaku, fivefinger – *Pseudopanax arboreus* (PSEARB)

While some of the species listed in the shrub hardwoods category develop into trees (e.g., kanuka), the assessment of these species focussed on the younger stands, mainly around 10-20 years since planting. The majority of plants in these species were multi-leadered and low branching, requiring measurement of root collar diameters rather than DBHs. They were therefore included in the shrub rather than the tree category.

Sigmoidal growth curves of the Bertalanfy-Chapman form were fitted using nonlinear regression. Models were obtained for mean height, quadratic mean DBH (for tree species), and quadratic mean RCD (for shrub species). Separate models were fitted for each species category, and separate slope or asymptote parameters were fitted for each species. This analysis was restricted to stands with stockings greater than 200 stems/ha.

Results

The total number of trees measured during the TTT survey was 6246 across a total of 120 plots. This comprised 756 beech, 2946 conifers, 610 other hardwood trees and 1684 shrub hardwoods.

In the earlier mid-1980s survey, 2203 trees in 101 stands were measured[2] indicating that many of the stands contained on average significantly fewer trees.

Seventy planted indigenous tree and shrub species with an age range of 5 to 110 years were measured. Stands were located in virtually every region of New Zealand from Northland to Southland and from lowland coastal sties to inland sites over 500 m above sea level. Stockings averaged 1900 stems/ha for trees and 3500 stems/ha for shrubs.

Early plantings were often carried out for amenity and aesthetic reasons similar to those reported in the earlier survey[2]. There has been increased interest in establishing and managing a long-term resource of indigenous timber trees (especially the indigenous conifers and beeches) as an option for future generations. Very few plantations had been pruned or thinned, the most common treatment being only a low pruning for improved access.

Shrub hardwood species were planted primarily along riparian areas on steep hill country recently retired from grazing as part of improving land use and water quality in pastoral landscapes. While many owners recognised the need to provide a nurse of hardy shrub hardwoods for the later planting of indigenous trees, there were few instances of this next step having been undertaken.

Plot mean heights along with fitted height/age regression curves for the four species categories are given in Figure 1 for combined data from the 1980s survey and the recent plantation survey. Curves indicate that growth rate decreases with age as expected across all species categories. At 100 years after planting, beeches average 29 m in height compared to conifers at 21 m and other hardwoods around 19 m. At 40 years after planting shrub species average 9 m in height.

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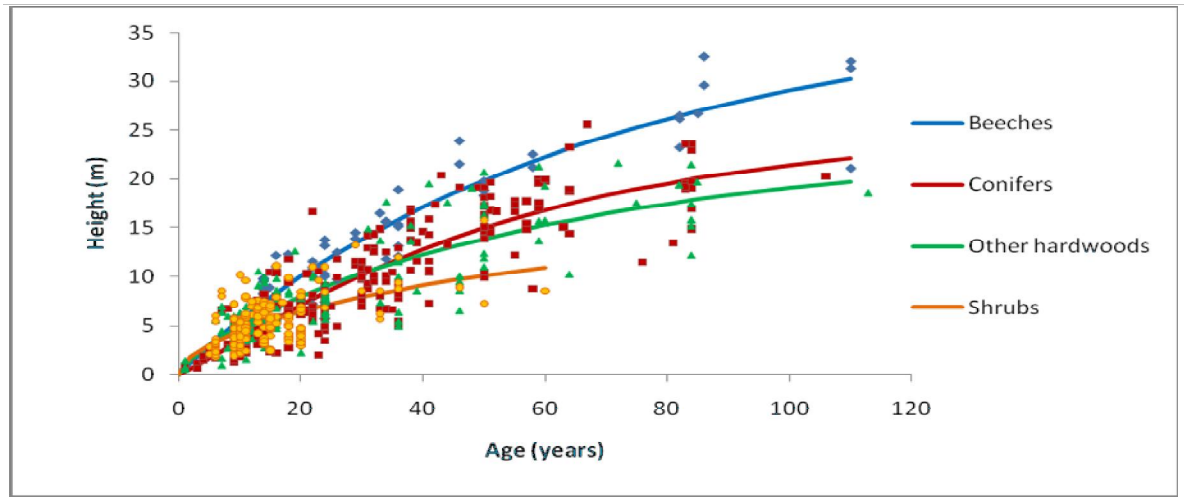

Figure 1: Height/age regression curves for the major species categories – beeches, conifers, other hardwoods and shrubs – for over 200 planted stands assessed.

Height/age regression curves for the individual species within each category up to 80 years of age are shown in Figure 2. Across all the major indigenous tree species included in this analysis, red beech and black beech are predicted to have the greatest average height 80 years after planting at 26-27 m, while the silver beech average is 21 m.

The tallest conifer is kauri which averages 22 m 80 years after planting. Rimu and kahikatea (20 m) and totara (19 m) are slightly slower growing while tanekaha and kawaka are the slowest growing conifers.

The hardwood trees other than beech with fastest height growth are pohutukawa, puriri and rewarewa, with predicted average heights of 19-20 m at age 80 years. Both karaka (15 m) and kohekohe (14 m) are significantly ($p<0.05$) slower in height growth.

Mean annual height increment (MAI) at age 80 years averaged 33 cm for red and black beech, 27 cm and for kauri, 26 cm for silver beech, and 24-25 cm for rimu, kahikatea and totara. The fastest growing hardwoods other than beech are puriri, rewarewa and pohutukawa, with 24 cm average MAI.

Shrub hardwoods, most of which were relatively young when measured, have a predicted range of 5-7 m high after 20 years (Figure 3). The fastest growing species in term of height at age 20 include lemonwood, kanuka, makomako and manuka, all within 6-7 m. Based on the limited data for shrub species beyond 20 years, the regression curve indicates that height growth rate is reducing rapidly so that by age 40 years, height growth is predicted to range from 7 to 9 m.

DBH/age curves to age 80 years are shown for the beeches, conifers and other hardwood trees in Figure 4. The fastest growing species for DBH are pohutukawa (72 cm), puriri (68 cm) and karaka (62 cm) 80 years after planting. These are followed by the beeches with red beech the fastest at 57 cm DBH, then silver beech (54 cm) and black beech (51 cm) at 80 years.

The conifers kauri and rimu have a similar predicted diameter at 80 years of 48 cm followed closely by totara (45 cm) and kahikatea (44 cm).

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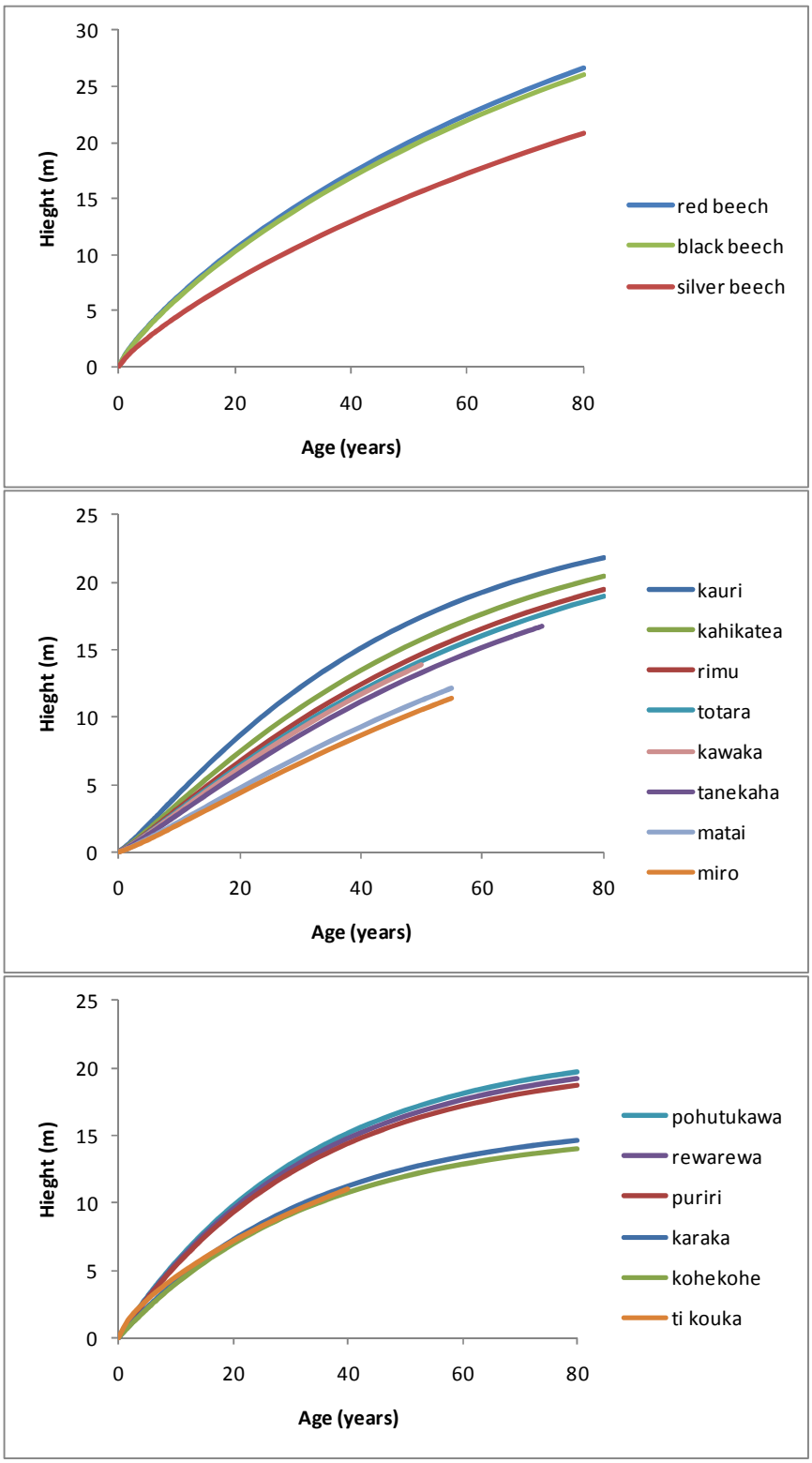

Figure 2: Mean height/age regression curves to age 80 years for beeches (top), conifers (middle) and other hardwood trees including ti kouka (lower).

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The limited data on kawaka up to 50 years predict DBH of 27 cm at age 40 years but with a growth rate on a similar trajectory to the faster growing conifers. The smaller and younger datasets for the other conifers (tanekaha, matai and miro) indicate significantly slower diameter growth rates (Figure 4).

The slower hardwood trees include rewarewa (47 cm DBH at 80 years) and kohekohe (36 cm). Cabbage tree had a similar early growth rate to kohekohe and a DBH at 40 years of 21 cm (Figure 4).

Mean annual diameter increment at age 80 years for the faster growing hardwoods ranges from 9 mm for pohutukawa and puriri to 7 mm for red beech. Mean annual diameter increment for the faster growing conifers average 5-6 mm for kauri, rimu, totara and kahikatea.

RCD/age regression curves are shown in Figure 5 for the major shrub hardwood species to age 40 years. Fastest growing is makomako with average RCD exceeding 40 cm at 40 years. The next fastest diameter growing shrub species include the three *Pittosporum* species – rautaawhiri, tarata and kohuhu – as well as five finger. The slowest growing species are kanuka, karamu and manuka.

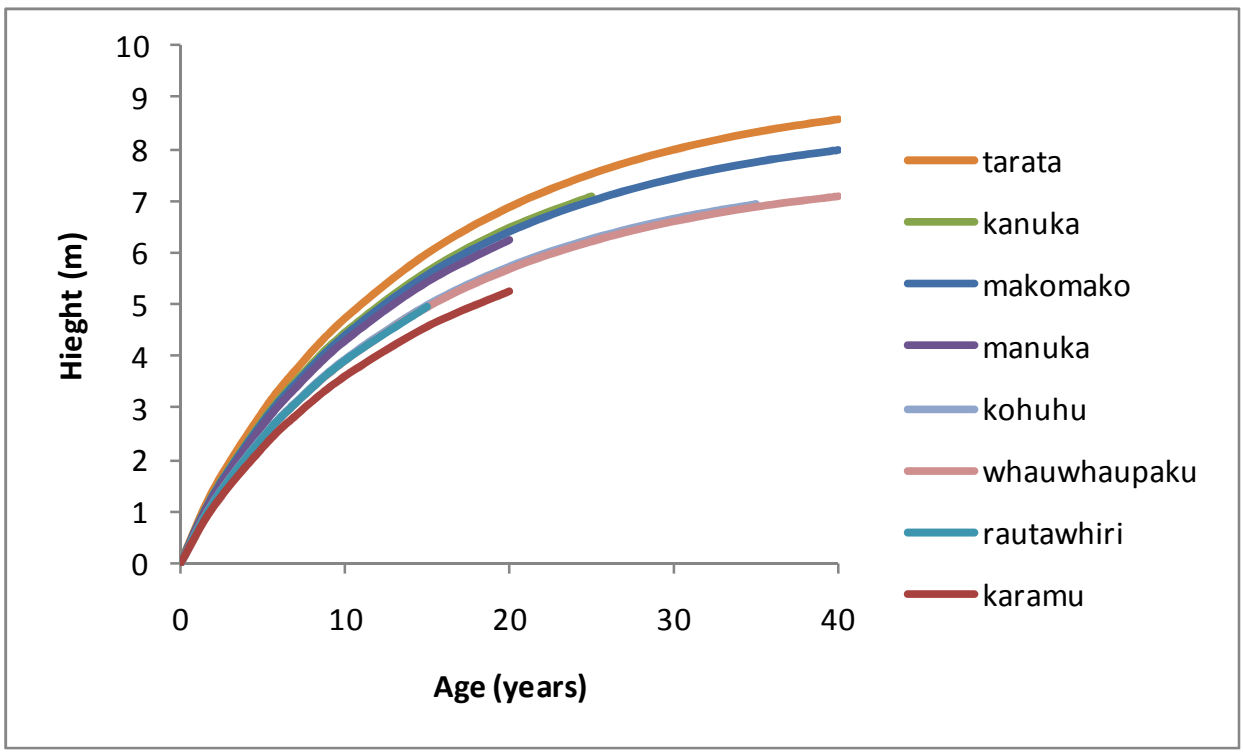

Figure 3: Mean height/age regression curves for the eight most commonly planted indigenous shrub hardwood species up to 40 years after planting.

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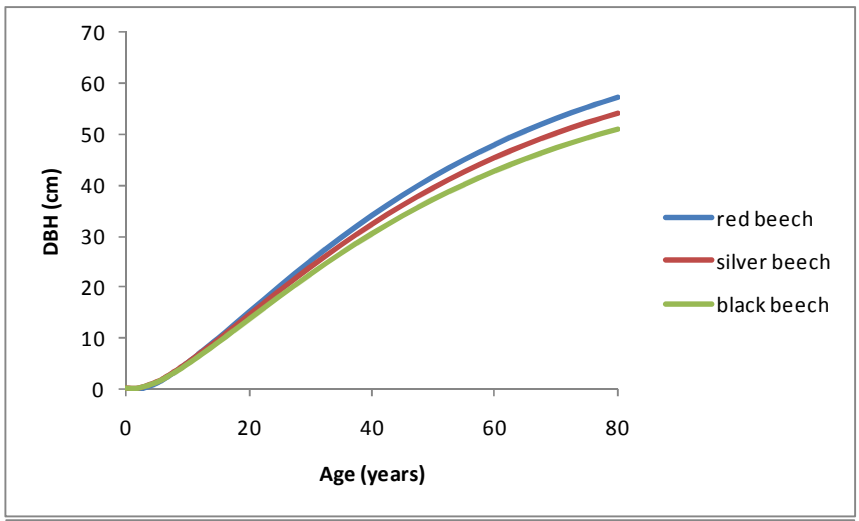

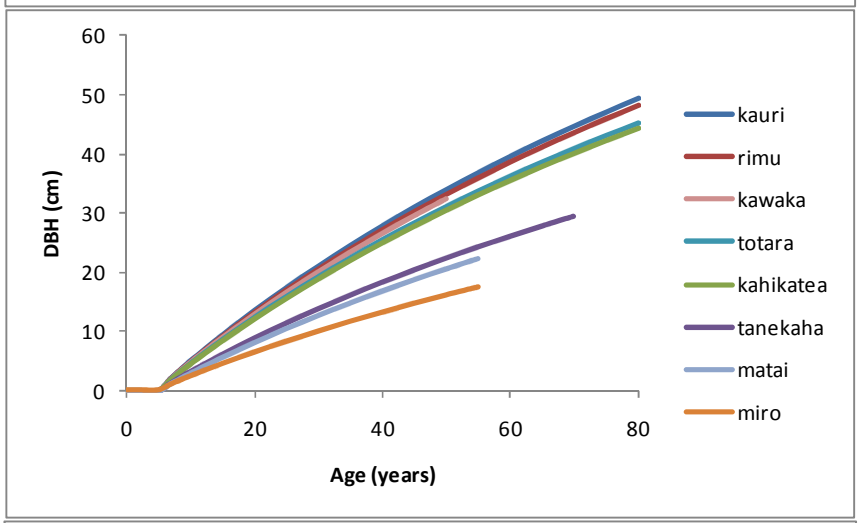

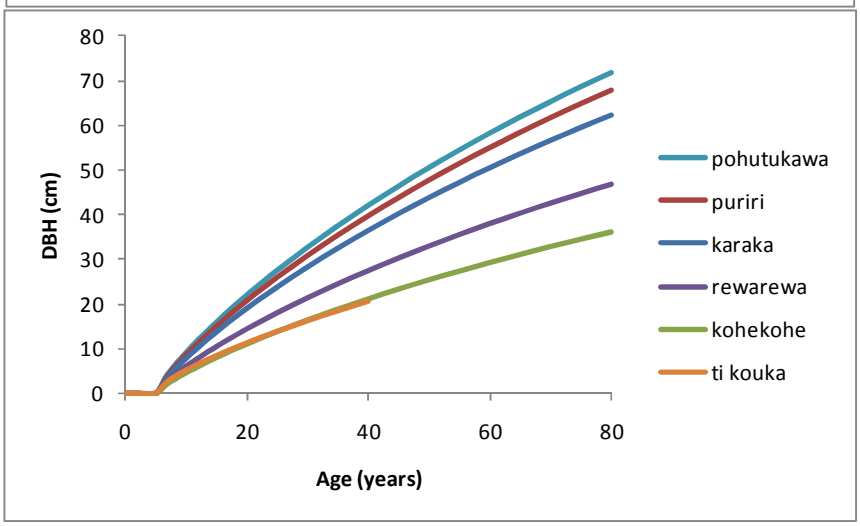

Figure 4: Mean DBH/age regression curves to age 80 years for beeches (top), conifers (middle) and other hardwood trees including ti kouka (lower).

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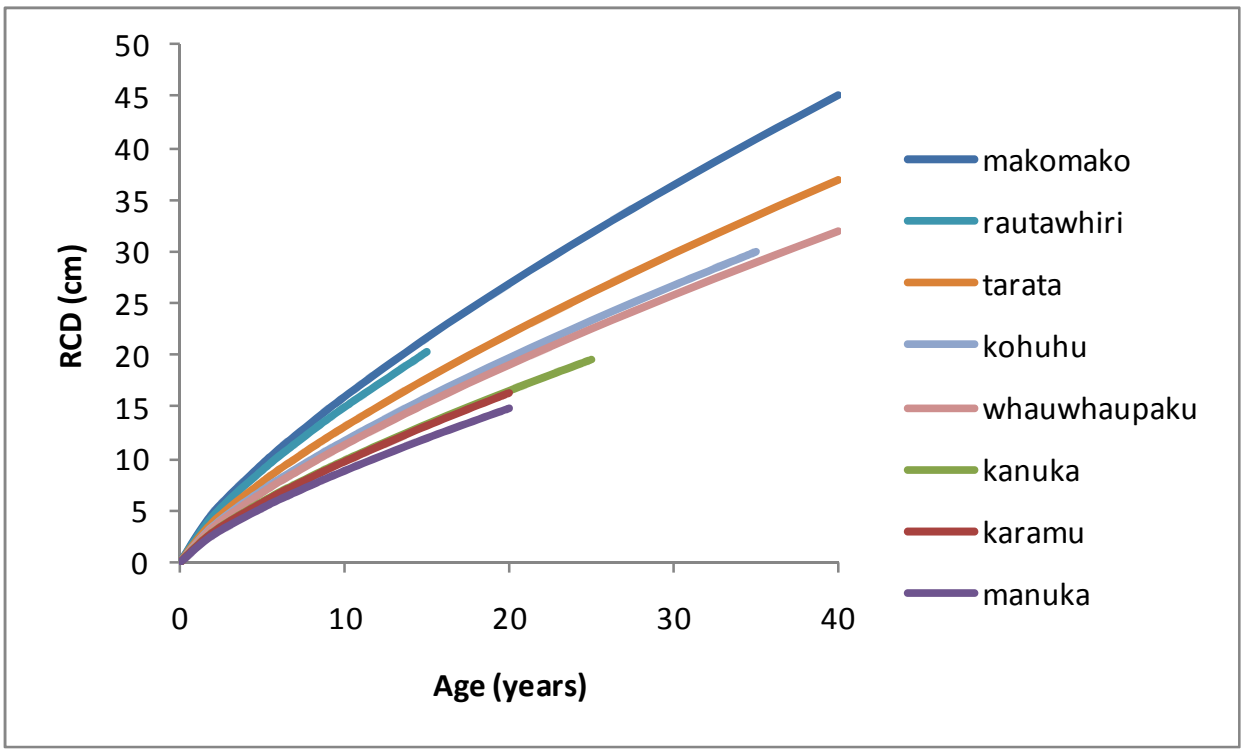

Figure 5: Mean root collar diameter (RCD)/age regression curves for the eight most commonly planted indigenous shrub hardwood species up to 40 years after planting.

Discussion

The most popular native conifers for planting continue to be totara, rimu, kauri and kahikatea. This is particularly the case where the objective is to provide a sustainably managed indigenous forest with potential as a long-term timber resource. There is increasing interest in planting beeches particularly in more southerly latitudes. There are relatively few planted stands of the other tree hardwoods, although many of these species such as pohutukawa and puriri are widely planted for amenity purposes as specimen trees or as small groves in gardens and parks.

Mean annual diameter growth rates of 6-9 mm and up to 33 cm for height for the faster growing conifers and hardwood trees measured in this latest survey are similar to those reported elsewhere for planted stands of indigenous trees[1]. However, variability between individual stands across all species is substantial due to the wide range of site and climatic factors that occur between stand locations. There are also significant differences in stand characteristics, particularly stocking, that can influence growth. Many of the stands in the survey were not well managed after planting so that growth performance, particularly within 5-10 years of planting, is likely to have been seriously compromised. Consequently, these average growth rates do not necessarily reflect the true potentials of each species.

The most commonly planted shrub hardwoods in many regions throughout New Zealand continue to be makomako, the *Pittosporum* spp., five finger, kanuka, manuka and karamu, and the monocot ti kouka. These are the preferred

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species for planting open areas recently retired from grazing or other difficult open sites as they are hardy, produce seed easily collected in large quantities, and are readily raised on a large scale using standard nursery practices. On most sites with good site preparation and maintenance, this suite of indigenous shrub species has high survival and relatively fast growth including lateral spread to achieve canopy cover that suppresses weed growth. Most species also flower and seed when young, thus attracting birds to facilitate natural regeneration.

Growth data will become available for further use in developing and refining growth and carbon accounting models for planted native trees and shrubs. As part of this, Tāne's Tree Trust is currently developing an Indigenous Plantation Forestry Database in collaboration with FRR and other stakeholders. This survey is a component in the development and maintenance of this database aimed at providing information on the growth and management of key indigenous forestry species for multiple objectives, including the option of long-term specialty timber production. Once the indigenous plantation database is completed in 2012, FFR members will be able to access summaries of the growth data through the Tāne's Tree Trust website www.tanestrees.org.nz,

Conclusions

A summary of key findings of this project is:

- A nationwide survey planted indigenous planted stands has involved measurement of over 6000 trees and shrubs in stands ranging in age from 5 to 110 years and comprising over 60 species.
- Height and diameter growth models have been developed for the major indigenous conifer, hardwood tree and shrub species.
- The major native conifers for planting continue to be totara, rimu, kauri and kahikatea.
- Mean annual diameter increment for the faster growing conifers average 5-6 mm for kauri, rimu, totara and kahikatea.
- Selected hardwood trees have faster growth rates than the major conifers. Mean annual diameter increment at age 80 years for the faster growing hardwoods ranges from 9 mm for pohutukawa and puriri to 7 mm for red beech.
- Variability between individual stands is substantial due to the wide range of site and climatic factors as well as differences in stand characteristics, particularly stocking.
- These data will eventually be uploaded onto the Tāne's Tree Trust Indigenous Plantation Forestry Database where FFR members will be able to access growth summaries via the Trust's website www.tanestrees.org.nz.

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