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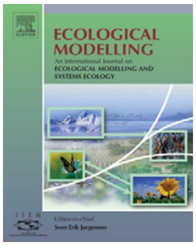

# A stand basal area model for plantation grown New Zealand kauri

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ABSTRACT

The research covered in this paper is part of a program designed to establish the New Zealand kauri (*Agathis australis* (D.Don) Lindl.), as a short rotation crop of 80 years by determining optimum silvicultural strategies. Growth models are essential planning tools that aid the development of these strategies. This paper only covers the development of a stand basal area model responsive to thinning. The model was developed with all the available data from planting trials. The plantings trials were unrepresentative and from different localities, which meant different growth rates. The re-measurement data spanned short time periods and at different growth stages of kauri. Irregular measurements were characteristic of these short time periods. A state space model was identified with properties that exhibited stability and robustness in simulation analyses.

## 1. Introduction

New Zealand kauri is one of 21 species comprising the genus *Agathis* that along with *Araucaria* and *Wollemia* make up the Araucariaceae family. It is a warm-temperate tree species that is dominant in the natural forests in the northern part of New Zealand at latitudes 34–38° S, occupying a total area of 80,000 ha. The map in Fig. 1 shows the current natural distribution of kauri on the North Island. The remaining dense stands or groves of kauri tend to occur on ridgetops, spurs and upper slopes on generally infertile soils. Mean annual rainfall of 1000–2500 mm, a mean maximum temperature of 28 °C and mean minimum temperature of −3 °C are archetypical of kauri habitat. Kauri tree reaches a height of 30–50 m and when mature it has a straight, untapered, cylindrical stem that is free from branches and epiphytes to a height of 12–25 m (Ecroyd, 1982). The stem diameter of trees aged 400–800 years is commonly 1–2 m and occasionally 3–5 m.

Kauri forests had cultural significance for Maori who used the timber for making seagoing canoes and buildings. European settlement saw most of kauri forest logged, cleared for farming or destroyed by fires. Kauri was an important timber resource during the development of the New Zealand economy from the mid-19th to early 20th centuries. The small remaining areas of mature kauri are in reserves managed mostly by the Department of Conservation (the central government organisation charged with conserving the natural and historic heritage of New Zealand).

Kauri timber is light, durable and of a straw or amber colour, virtually free from knots and other defects. The heartwood

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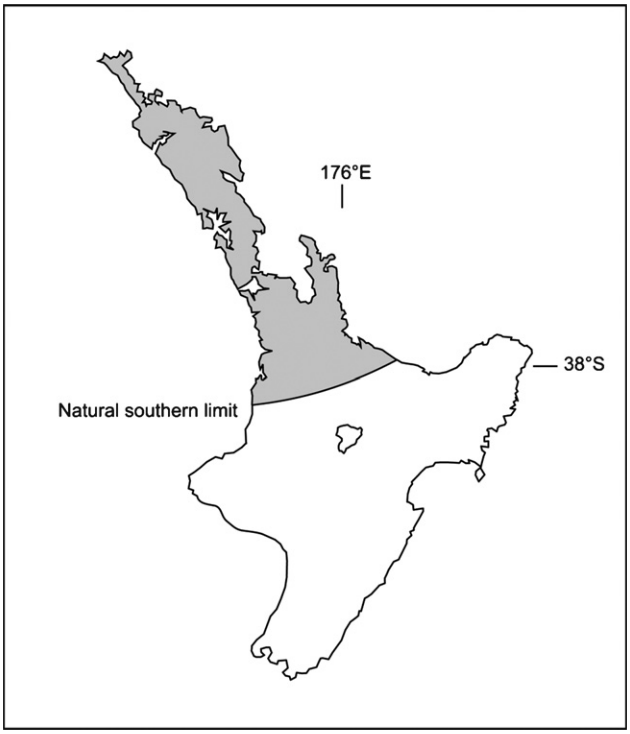

**Fig. 1 – Distribution of kauri on the North Island, New Zealand.**

of mature kauri trees is highly valued for craftwork and the majority of the current supply of this resource is salvaged from peat swamps (where trees have been buried for 40,000 or more years) and forest floors. Continuing demand for swamp kauri cannot be sustained. However, in New Zealand there is a huge interest from tree growers and investors in establishing kauri as a plantation timber tree species (Ecroyd et al., 1993). There are hurdles to be overcome, in that kauri cannot yet compete economically with shorter (20–30 years) rotation exotic conifers and hardwoods. Non-timber benefits may need to be factored into the economic equation if kauri plantation forestry is to reach the expected rates of return for investment in New Zealand. It is encouraging that significant progress has been made towards developing techniques for valuing environmental costs and benefits (The Economist, 2005). This will make it easier in the future to put values to non-timber benefits such as biodiversity richness, water quality, water quantity and mitigation of soil erosion.

Management of plantation kauri has been targeted at fast growing rates with a maximum rotation age of 80 years. Although this is possible, kauri growth is extremely variable and dependent on many factors such as quality of planting stock, quality of planting site, climate and competition from other plants. While it is the heartwood from mature old growth kauri that is highly valued, young fast grown kauri trees have a high proportion of sapwood, timber that is pale, soft and non-durable. A recent study of the wood quality of plantation grown kauri sapwood has identified it to be similar to that of old growth heartwood (Steward and McKinley, 2005). However, the lack of durability is unlikely to detract the use of kauri for the production of high-value, interior paneling products (Ecroyd et al., 1993).

Current research on plantation grown kauri is focused on:

(a) monitoring silvicultural performance in plantations so that predictive growth models may be developed;
(b) evaluating the effects of thinning on natural and planted stands; and
(c) establishment of planting trials for monitoring performance on open sites using shelter or nurse vegetation.

Growth and yield models are indispensable for forest managers who want to make the correct decisions about their timber investments. Growth and yield systems can help forest managers avoid common costly mistakes, keep up-to-date databases for all stands, make stand-level decisions on the frequency, timing and intensity of thinning, and create forest-level management plans that take into account variables such as cash-flow constraints and the number of hectares harvested. This paper looks at the development of a component of a forest manager's toolbox of growth and yield models, stand basal area model that will be essential for (a) and (b) using available data.

Factors that influenced the approach for model development were, limited thinning trials, re-measurement data spanning over short periods of time, re-measurement data at unequal time intervals, unrepresentative planting trials at different sites, differences in quality of planting sites and differences in management. Trying to develop a growth model based on physiology with such limiting data was going to be difficult if not impossible. An empirical approach using continuous-time, allometric relationships was also going to present its own problems, in particular estimating the non-linear parameters (Ratkowsky, 1983). As a result a decision was made to develop 'dynamical models' that were successfully applied to other species with similar data limitations, for estimating growth and subsequently stand optimisation (Chikumbo et al., 1996, 1998, 1999; Chikumbo, 2001; Chikumbo and Mareels, 2002).

## 2. Dynamical model description

It was important to start looking at stand basal area and ultimately develop the other growth models for mortality, stand height and volume later. A discrete-time, stand basal area model for kauri-managed stands that is responsive to thinning was developed. The characteristics of this model were also intended to fit criteria that may meet a future need, that is, integration in an optimal control and parameter selection formulation (Anderson and Moore, 1989; Chikumbo and Mareels, 2002). This formulation will enable the determination of optimal planting density, optimal rotation length, optimal final crop density, and optimal frequency, timing and intensity of thinning (Chikumbo and Mareels, 2003). The discrete-time stand basal area model developed was typically a dynamical model.

Dynamical models are extensively used in systems engineering for system identification and optimal control. System identification is a method of building mathematical mod-