

# The three potentially most useful exotic forest species for south eastern North Island marginal hill country

Ian Nicholas<sup>1</sup> and Michael Watt<sup>2</sup>

## Abstract

The aim of this research was to determine the most suitable plantation species for the south eastern North Island (Gisborne, Hawke's Bay, Taranaki, Manawatu/Wanganui and Wellington regions) hill country as this region includes a large area of marginal land suitable for future afforestation. Key attributes examined as part of the selection process were health, siting and productivity. Based on these criteria the species selected were *Pinus radiata*, *Sequoia sempervirens* and *Eucalyptus fastigata*.

## Introduction

Within the southern and eastern North Island, (Gisborne, Hawke's Bay, Taranaki, Manawatu/Wanganui and Wellington regions) there are large areas of erosion prone marginal land that are suitable for future plantations. Despite this little is known regarding the suitability of species other than *Pinus radiata* for this region. The aim of this research was to identify the three most suitable exotic forest species for afforestation within this region.

## Species choice

Species choice was based on robustness and resilience. This means they must be healthy, tolerant of a range of sites and long-lived. They were also chosen for their desirable timber characteristics as well as high levels of productivity. The selected species were:

- *Pinus radiata*
- *Eucalyptus fastigata*
- *Sequoia sempervirens*.

The reasons for selection of the three species are outlined below.

## Species health

*Sequoia sempervirens* is considered to be a relatively pest resistant tree species, with no major insect or disease problems in New Zealand or overseas (Bain and Nicholas, 2009; Gilman and Watson, 1994; Sinclair and Lyon, 2005). New Zealand disease records show there are a limited number of pathogens recorded on *S. sempervirens* and all are secondary or inconsequential (Ganley and Berndt, 2009). A few insects have been recorded damaging *S. sempervirens* in New Zealand, however these are not significant problems (Ganley and Berndt, 2009).



Figure 1: 13 year old *Eucalyptus fastigata*, Manawatu

*Eucalyptus fastigata* (Figure 1) is one of the most healthy eucalypt species in New Zealand. Of the six insect and three pathogens that currently exist within *E. fastigata* plantations, only one insect (*Uraba lugens*, gum leaf skeletoniser) is of particular concern to this species (Ganley and Berndt, 2009). The other pests and diseases have been present in New Zealand for some time and have not made any significant impact on *E. fastigata* plantations to date.

For *P. radiata* there are several diseases that cause economic losses to the forest industry, some of which have limited control or management options. The five diseases that currently cause damage include the following pathogens/diseases; *Cyclaneusma minus* (cyclaneusma needle cast), *Neonectria fuckeliana* (nectria flute canker), *Dothistroma septosporum* (Dothistroma needle blight), *Armillaria novaezelandiae*, *A. limonea* (Armillaria root rot) and *Diplodia* (syn. *Sphaeropsis*) sensu lato (Diplodia shoot blight). There are no insect pests of *P. radiata* that are currently of serious concern (Ganley and Berndt, 2009).

<sup>1</sup>Ian Nicholas Consulting Ltd

<sup>2</sup> Scion

## Siting

### *Pinus radiata*

*Pinus radiata* is well suited to a very wide site range throughout New Zealand and particularly within eastern and southern regions of the North Island (see section on growth data). Despite this broad adaptability the species does have some site limitations (Burdon and Miller, 1992). It does not tolerate very wet soils and growth can be poor on soils deficient in nitrogen or low in available phosphorus. Productivity declines markedly as annual rainfall drops below 1,000 mm and areas with less than 500 mm are generally unsuitable for commercial plantation forestry (Burdon and Miller, 1992). Frost damage does occur but can be greatly mitigated through good establishment practice. Snow damage is a widespread constraint to siting becoming a serious issue above 1,000 m in the North Island, 700 m in Canterbury and 350-500 m in the far south (Burdon and Miller, 1992).

### Eucalypt

New Zealand has approximately 240 introduced eucalypt species established in the country (Nicholas 2008). Nicholas (2008) considered that five major factors are important in matching eucalypt species to climatic conditions of a site:

- Air drainage. Frost tolerant species can be grown on sites in unsuitable areas if there is adequate air drainage.
- Out of season frosts. While some species can tolerate cold, out of season frosts can be devastating to many eucalypt species.
- Seed source. Depending on where seed is obtained from, seed source variation in climate tolerance can be as great as species variation.
- Aspect. Warm north facing aspects provide added insurance to cold damage, especially if there is adequate air drainage.
- Young seedlings are more prone to cold events than saplings. While saplings can be burnt, this is not always fatal.

While individual eucalypt species have different siting characteristics, the importance of seedlot cannot be over-emphasised, especially when it comes to frost resistance. On very cold sites, seedlot can be critical to the success of *E. fastigata* plantations. At a trial in Kaingaroa forest at 950 m, two of five seedlots tested gave acceptable survival (80-100%) while the other three seedlots ranged from 10-20% survival (C. Low pers comm). The importance of seedlot in frost resistance has also been confirmed by field and laboratory studies (Wilcox *et al.*, 1980, Wilcox, 1982).

There are several historical publications that describe eucalypt siting. While not always accurate, as species knowledge has been improved since their

publication, they do provide valid comparisons between species. Simmonds (1927) allocated eucalypts into broad siting groups. He placed *E. fastigata* in Group IV which he described as "Species adapted to localities where there are light falls of snow some years, where hard frosts occur in winter and early spring, but where summer and autumn are usually warm and without extremes. Jackson (1965) identified a siting matrix for 35 species for the Hawke's Bay region. He suggested *E. fastigata* required rainfall around 1,000 mm and a soil depth of 75 cm to 1 m.

Many authors have reported *E. fastigata* tends to grow best in well sheltered valleys of the Bay of Plenty and Taranaki regions on well-drained volcanic soils. It is intolerant of strong winds but can tolerate high rainfall and some snow. It is more tolerant of cold than *E. regnans*. In a study within the central North Island, Johnson and Wilcox (1989) concluded that *E. fastigata* was one of the best species at a low altitude (70m) site, and a possibility at the intermediate (380m) and the cold high altitude (920m) site, but at the latter site seed source was important. Of the twenty species and two hybrids tested in this series *E. fastigata* was the only species favoured as a winner or possibility across all three sites.

Weston (1957) comments that *E. fastigata* does well in Waikato and Rotorua-Bay of Plenty, but has not succeeded at lower altitudes north of Auckland, where, apparently the climate is too warm. He states it is frost tender when young, but soon becomes hardy and has tolerated up to  $-8^{\circ}\text{C}$  of frost. In the North Island the species has succeeded at altitudes up to 550m and it prefers light loamy soils, though clays are tolerated. Carter (1989) commented that *E. fastigata* was more wind firm than *P. radiata*. King (1980) considered *E. fastigata* as one of the best species in the higher rainfall areas of the Wairarapa and suggested it will grow well in slightly harder conditions than *E. regnans*. However he stated *E. fastigata* tended to have heavy branching when open-grown.

There are several key references that broadly describe eucalypt siting (Nicholas, 1991, Hay *et al.*, 2005, Nicholas *et al.*, 2005). In these, *E. fastigata* and *E. globoidea* have the distinction of being the only two species that are included in two climatic categories; warm temperate and cool temperate.

Recent activity has provided a valuable data set on eucalypt siting. The Eucalypt Action Group of the New Zealand Farm Forestry Association conducted a Sustainable Farming Fund project to test siting of eucalypt species. Eucalypt research packs, comprising 15 trees of 10 species, were planted by farm foresters on 55 sites throughout New Zealand. Evaluation of survival from the national data set identified *E. fastigata* as part of a group of hardy eucalypt species (Gordon *et al.*, 2007).



*Sequoia sempervirens*

In its natural habitat, *S. sempervirens* grows from sea level to 900 metres altitude but prefers altitudes lower than 750 m (Figure 2). It prefers mild climates, although in many parts of its natural range it experiences winter snow and frosts of up to  $-10^{\circ}\text{C}$ . The presence of well performing stands near Winton, Southland; North Canterbury; and Hamurana Springs, Whakarewarewa and Waiotapu near Rotorua, attest to the species' ability to do well in some cold sites in New Zealand. However, it is vulnerable to out-of-season frosts, and this is perhaps the reason for the much publicised early establishment failure of various stands in the Central North Island during the 1920s and 1930s (Nicholas, 2008).



Figure 2: 29 year old *Sequoia sempervirens* (redwood), Taranaki

Assessment of the performance of *S. sempervirens* on a wide range of New Zealand sites over the last ten years has shown that the species has a wider range of site tolerances than previously thought. However, redwood performs best on soils of moderate to high fertility in areas with reasonable year-round rainfall. *Sequoia sempervirens* is intolerant of strong prevailing winds, but is surprisingly resistant to toppling and breakage from periodic storms. Despite *S. sempervirens* common name, coast redwood, derived from its natural range being close to the coast, *S. sempervirens* is not tolerant of salt-laden coastal wind (Nicholas, 2008). Brown (2007) suggested *S. sempervirens* needs a temperate climate, good soils and regular rainfall. He suggested the species does not tolerate heavy frosts, salt spray or strong prevailing winds.

Recent research using a national dataset of permanent sample plots shows strong positive linear relationships between air temperature and *S. sempervirens* volume (400 Index) and height growth (site index). Of the environmental variables considered in this study, air temperature was found to be by far the most important (Palmer *et al.*, 2009).

**Growth data**

Within the Scion Permanent Sample Plot database there is a substantial set of data for *P. radiata* across the regions of interest. Of the key species identified for marginal land in this project, there were more plots in *S. sempervirens* than *E. fastigata*, but these were concentrated in Gisborne and Hawke's Bay, a legacy of recently established silvicultural trials. These plots were supplemented with additional plots established throughout the area of interest and five plots established by other agencies.

Mean and maximum productivity for *E. fastigata* and *S. sempervirens* were derived directly from the plot data, as was the maximum regional productivity for *P. radiata*. Productivity was described by site indices determined from mean top height (height of the largest 100 diameters/ha) at respective ages of 20, 15 and 40 for *P. radiata*, *E. fastigata* and *S. sempervirens*.

For mean regional *P. radiata* productivity a national productivity model has been used to determine regional mean 300 Index (mean annual volume increment at age 30 for a stand that has a final crop stocking of 300 stems/ha) and site index (see Palmer *et al.*, 2010 for more detail).

**Variation in mean productivity**

Mean site indices for *P. radiata* within Gisborne (33.2 m), Taranaki (31.2 m), and Hawke's Bay (31.3 m) exceed site indices for Manawatu (28.3 m) and Wellington (27.6 m), and it is worth noting that the site indices for Gisborne are the highest of all New Zealand regions (Palmer *et al.*, 2010). For 300 Index regional mean values throughout

New Zealand are highest in the five regions examined with values of 32.2, 31.3, 31.2, 28.3 and 27.6 m<sup>3</sup>/ha/yr recorded, in Gisborne, Hawke's Bay, Taranaki, Manawatu/Wanganui and Wellington, respectively (Palmer *et al.*, 2010). The mean 300 Index within New Zealand is 27.4 m<sup>3</sup>/ha/yr, ranging from 23.3 m<sup>3</sup>/ha/yr on the West Coast to 32.2 m<sup>3</sup>/ha/yr in Gisborne (Palmer *et al.*, 2010).

The mean *S. sempervirens* site index of 36 plots was 43.5 m, with a range of 27.7 to 60.1 m. From the limited data the Manawatu region plots averaged the highest site index. Productivity surfaces developed for *S. sempervirens* show high values of site index occur in warm coastal regions within the study area (Palmer *et al.*, 2009).

The mean *E. fastigata* site index from 40 plots was 25.2 m with a range of 20.5 to 30.2 m. For the regions of interest Gisborne appears to be slightly superior to the other regions.

## Variation in maximum volume productivity

The data available to review species maximum productivity comes from the Scion Permanent Sample Plot database. To explore the maximum potential of the individual species, the most productive stand for each species was determined which provides an indication of potential productivity (Table 1). Maximum productivity will be influenced by location, stocking, management, soils and rainfall. Analyses show Gisborne to have the highest productivity for both *P. radiata* and *S. sempervirens*, while the Taranaki region had the highest productivity for *E. fastigata*. Overall, for the species represented across at least four regions, productivity was greatest for *P. radiata*, followed by *S. sempervirens*, *E. regnans*, then *E. fastigata*.

## Additional species considered for the region

Many other species were considered in the selection process. In particular there are other species that may warrant attention on cold sites such as Douglas-fir and *E. nitens*. If there is a particular interest in durable timber *E. globoidea* is also a useful alternative because of its wide site

tolerance. Other eucalypts in the same broad group as *E. fastigata*, the ash group, may also be considered where site conditions favour these species, such as *E. regnans* (mild fertile sites) and *E. obliqua* (low humidity drier sites). Cypress species of interest for solid timber production (*Cupressus lusitanica* for the regions considered) does not have the long term volume accumulation of the nominated species although it is worth noting this species does produce a durable timber with an increasing following (Nicholas, 2007).

Poplar species have a role to play on marginal hill country as through the use of poles and protective sleeves they can allow the establishment of a tree crop without significant disruption to grazing practices. In a case study from Hawke's Bay, Poole (2010) indicated a good return from poplar grown on a carbon regime. However the combination of low timber density and site sensitivity has restricted the uptake of poplar as a plantation species in New Zealand despite its suitability for hill country planting.

Another deciduous species with potential is willow which is mostly used for erosion control and in a few cases fodder. There has been recent interest in establishing dedicated bioenergy plantations using willow as a multi product feed source for lignin, ethanol and sugars (Snowdon *et al.*, 2008). Based on a 3 year rotation this requires land no steeper than 15 degrees. It has been suggested that willow is a competitive bioenergy crop to other tree options (K. Snowdon pers. comm. 2010), generally on topography that allows regular harvesting. However for best performance willow requires fertile sites with adequate rainfall.

## Conclusion

The three species most suited for southern and eastern North Island regions were *P. radiata*, *S. sempervirens* and *E. fastigata*. *Pinus radiata* was selected as this species has very high productivity outperforming all other species. Furthermore productivity surfaces show the species to be well adapted to the area of interest, with the highest mean

Table 1: Maximum productivity (m<sup>3</sup>/ha/yr) for each species by region

	Gisborne	Hawke's Bay	Taranaki	Wanganui/Manawatu	Wellington
<i>P. radiata</i>	72	56.2	43.6	47.6	48
<i>S. sempervirens</i>	48	44.6	28.6	42.5	na
<i>E. fastigata</i>	30.1	29.8	33.8	16.9	na
<i>E. regnans</i>	31.5	54	46.3	26.8	na
<i>E. nitens</i>	na	28	na	na	na
<i>E. globoidea</i>	na	14.7	27.2	12.7	5.9
<i>E. maidenii</i>	na	13.2	na	na	na
<i>C. lusitanica</i>	26	30	21.3	18	23.5
<i>P. menziesii</i>	25	29.4	11.4	37	27.2



regional 300 Index values occurring within eastern and southern regions of the North Island. *Sequoia sempervirens* was selected as this species is not seriously affected by any pest species within New Zealand. As the species responds well to increasing air temperature it is very productive across eastern areas of the North Island. *E. fastigata* was selected as it is more healthy than other eucalypt species and demonstrates good growth rates and tolerance to frost. Although the data is limited for *S. sempervirens* and *E. fastigata*, neither species seems to show the wide variation in site index that would be expected from extremely site sensitive species. However, as with all tree species they can be placed on microsites where they do not grow well. On a landscape scale all three species are expected to perform well, provided they have been well established.

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