PLANTATION MANAGEMENT COOPERATIVE

# EXECUTIVE SUMMARY

## VALIDATION OF THE 300 INDEX GROWTH MODEL FOR RADIATA PINE ON THREE CONTRASTING SITE TYPES

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The stability of the 300 Index Growth Model was tested against some 1509 sample plots located on three contrasting site types:

- Dry East Coast (from Taradale to North Otago)
- Fertile ex-farmland (previously in pasture, located throughout NZ)
- Coastal sand-dunes (North Island West-Coast, from Waitarere to Aupouri)

For most sites, the 300 Index appears to be relatively stable over a wide range of age classes and stockings. Average drift in 300 Index estimation within a forest will normally lie within a range of ±1%/yr, even when stands as young as five years are used for calibration. Some outliers with drift up to 2%/yr will occasionally appear for no apparent reason.

Sites which are the exception to this general rule are as follows:

- Sand-dune sites north of Auckland. Calibration of 300 Index using young stands (5-10 years) will tend to over-predict the index by a about 65% for stands aged 5-10 years, and 28% for stands age 10-15 years.
- Low-rainfall sites at Taradale (Hawkes-Bay), Marlborough (South Bank) and Eyrewell (Canterbury). The index will be over-predicted by about 39% in stands aged 5-10 years, and 23% in stands aged 10-15 years.
- Ex-farm sites in Otago/Southland. Indices estimated from young stands may tend to be under-predicted.

## INTRODUCTION

The growth model used in the Radiata Pine Calculator is the 300 Index Growth Model (Hansen, Knowles and Kimberley 2004). This Growth Model is calibrated for any site using two measures of site productivity: the Site Index, a measure of height growth productivity, and the 300 Index, a measure of volume productivity. Both Indices can be supplied directly by a user based on knowledge of expected productivity for a particular site. Alternatively, the indices can be estimated from growth measurement data from an existing stand. The model assumes that Site Index and 300 Index do not vary over time and do not change with stocking. This study aims to test this assumption on three contrasting site types, and to provide guidelines for users so that the 300 Index growth model can be used with confidence by relatively inexperienced users on widely varying site types throughout New Zealand.

One way of testing the stability of the model is to predict the 300 Index from permanent sample plot (PSP) growth measurement data (Ellis and Hayes, 1997), and determine whether it remains constant over time, or shows evidence of drift. For example, suppose the Index is found to drift downward over time for a particular site type. On such sites, if the 300 Index Model is run using an early measurement as a starting point, it will tend to increasingly over-predict the basal area. This will occur because the model assumes a constant 300 Index based on the initial measurement, when in practice the Index should be drifting downward. Hansen, Knowles and Halliday (2004) analysed a large dataset of sample plots for Hawkes Bay and Wairarapa, and concluded that the 300 Index did drift downward with age on sites where rainfall was less than 850mm, and where seasonal moisture deficiencies were obvious. However, the Index has since been refitted to a much larger data set, and so validation on a larger scale of the refitted model is considered necessary.

To test the stability of the 300 Index over time, data from the following three contrasting site types were chosen:

- Dry East Coast (from Taradale to North Otago)
- Fertile ex-farmland (previously in pasture, located throughout NZ)
- Coastal sand-dunes (North Island West-Coast, from Waitarere to Aupouri)

Growth data from these site types was then used to predict the 300 Index, and to determine whether there was any consistent pattern of drift in the Index over time. A map showing the location of the forests and farm sites from which plots were obtained for analysis is shown in Fig. 1.

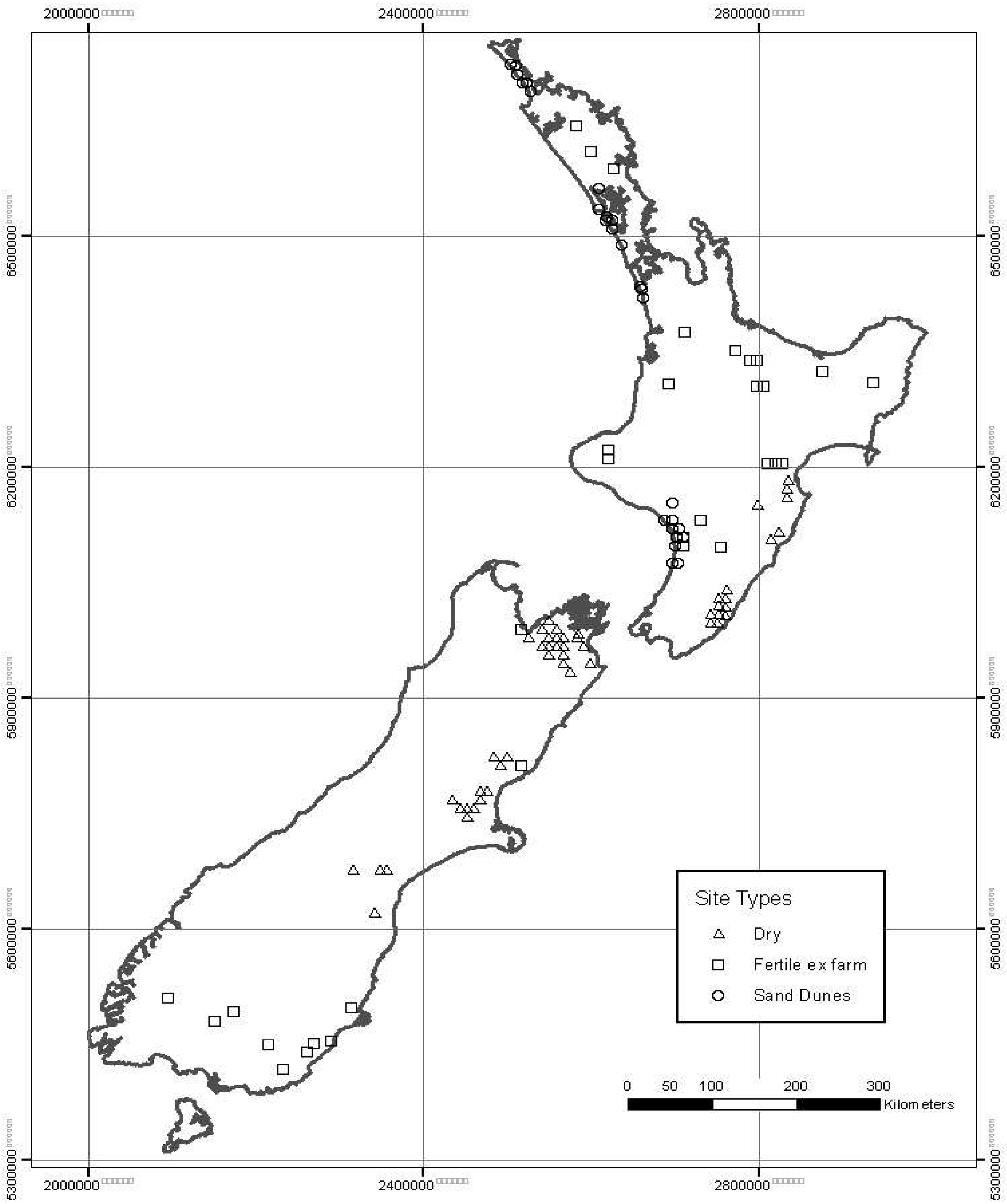


Fig. 1. Map showing the location of forests and farm sites used in the analysis.

## METHODS

Data was obtained from radiata pine permanent sample plots from throughout New Zealand representing the three chosen site types. Only plots with reliable silvicultural histories were used in this analysis. Required history included the stocking at planting, age and stocking at each thinning, and number of stems and pruned height at each pruning lift. Where there was doubt about any of this information, plots were not included in the analysis.

The 300 Index was estimated for each measurement greater than age five years. These indices were then analysed for evidence of drift.

Firstly, the average drift in the Index was calculated and summarised for each site type, and for each of the major forests included in each site type. The average drift was obtained by fitting a regression model with a linear age term, and separate intercepts for each plot. The slope of the regression line was then divided by the mean 300 Index to express the drift as an annual percentage change in the Index.

To examine the behaviour of the index against stand age in more detail, the mean 300 Index was obtained for 5-year age classes: i.e., 5-10 years, 10-15 years, etc., for each site type. Indices calculated from data younger than five years were not included in this analysis. This analysis was performed using the SAS procedure MIXED. The analysis included Plot as a random effect, and stocking class as a fixed effect. By including Plot in the model, the effects of changes in the mix of plots over time were eliminated.

The analysis was extended to incorporate stocking to determine whether the index remains stable over a range of stockings, and whether any drift in the Index varied with stocking. For this analysis, the mean index was obtained over the above age classes for each of the following three stocking classes: <250 sph, 250-450 sph, >450 sph. Mean 300 Indices by age class were also obtained for each of the forests in the dataset containing 10 or more plots to determine whether there might be differences in drift between forests in the same nominal site type. This reduced '10+ plot' dataset represented 89% of all sample plots available for the dry sites, 82% of the fertile ex-farm sample plots, and 84% for the sand-dune sample plots.

## RESULTS

A total of 1,509 plots including 15,260 measurements were used in the analysis- ie each sample plot was re-measured nine times on average. The mean 300 Indices were 22.8 for the dry sites, 31.7 for the fertile ex-farm sites, and 18.6 for the coastal sand-dune sites Table 1). On average there was very little drift in the index on the dry sites, a small negative drift on ex-farm sites, and a fairly large negative drift on the sand-dune sites. Thus if, say, an age seven year measurement was used to predict volume at age 27 years, the prediction would on average be unbiased on dry sites, over-estimated by about 12% on fertile ex-farm sites and overestimated by 32% on sand-dune sites.

**Table 1. Mean 300 Index and mean drift for the three site types**

| Site type | Number of plots | Number of measurements | Mean 300 Index | Mean Drift (%/yr) |
|---|---|---|---|---|
| Dry | 439 | 4005 | 22.8 | 0.04 |
| Fertile | 337 | 4712 | 31.7 | -0.60 |
| Sand | 733 | 6543 | 18.6 | -1.59 |

The behaviour of the index against stand age can be seen more clearly by estimating the mean 300 Index in 5-year age classes for each site type (Fig. 2). The lack of any overall drift on dry sites, the slight downward drift on ex-farm sites, and the pronounced drift on sand-dune sites can be clearly seen. However, the drift on sand-dune sites is not constant, but occurs primarily during the first 15 years, beyond which there is little drift.

When the 300 Index is examined against both stocking and age for dry sites (Fig. 3), there is no strong trend with either age or stocking. However, there is some suggestion of a slight negative drift at the higher stocking. For ex-farm sites, it appears that the negative drift noted above mainly occurs at low stockings (Fig. 4), with no drift evident at stockings greater than 250 sph. For sand-dune sites, the pronounced negative drift before age 15 years occurs for all stockings but is more pronounced at higher stockings (Fig. 5).

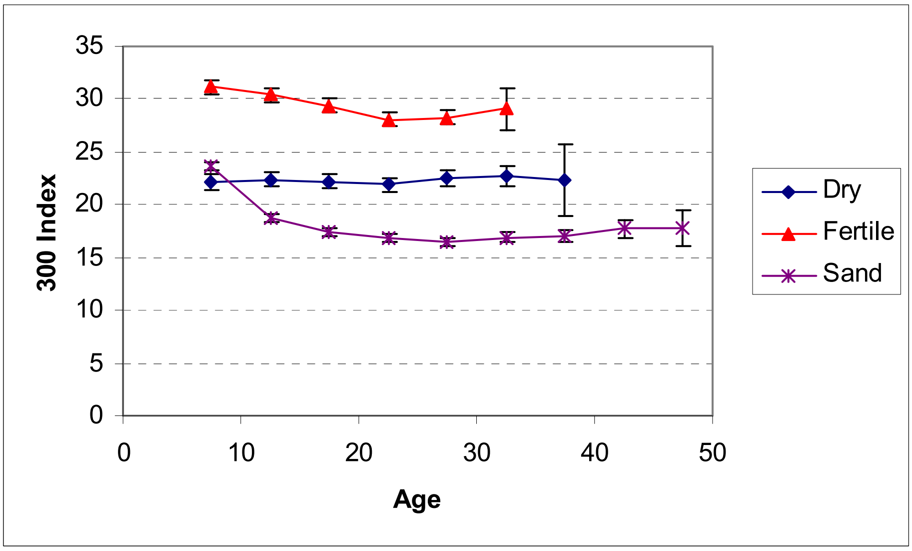


**Fig. 2. Mean 300 Index in 5-year age classes for each site type. The error bars are 95% confidence intervals**

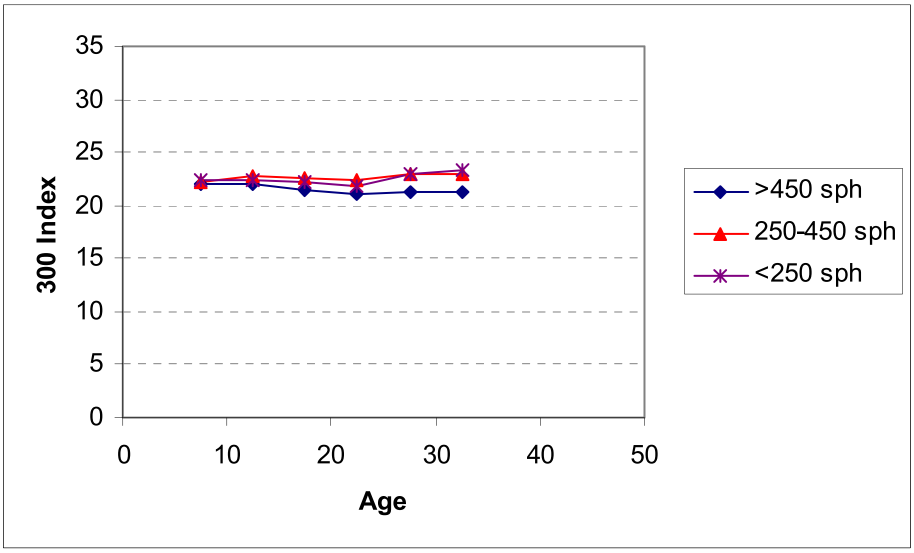


**Fig. 3. Mean 300 Index in 5-year age classes and stocking classes for dry sites**

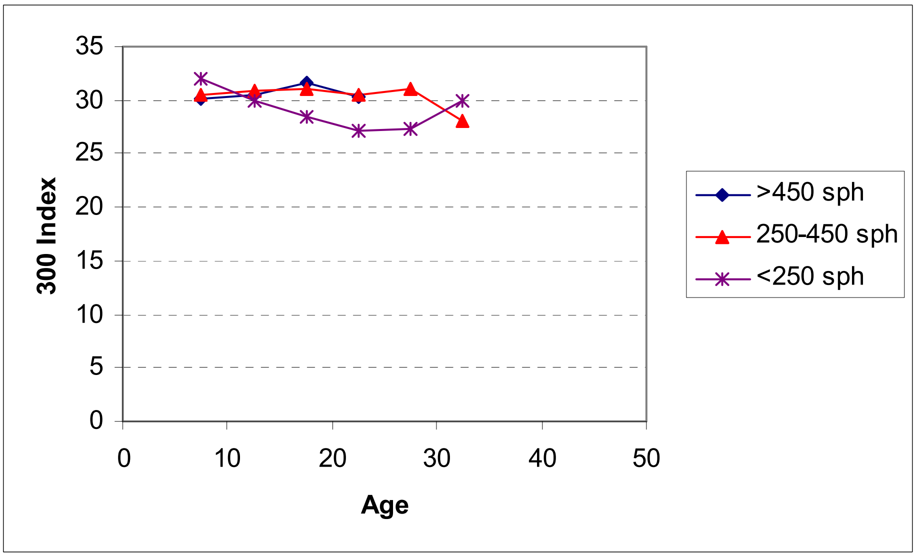


**Fig. 4. Mean 300 Index in 5-year age classes and stocking classes for ex-farm sites**

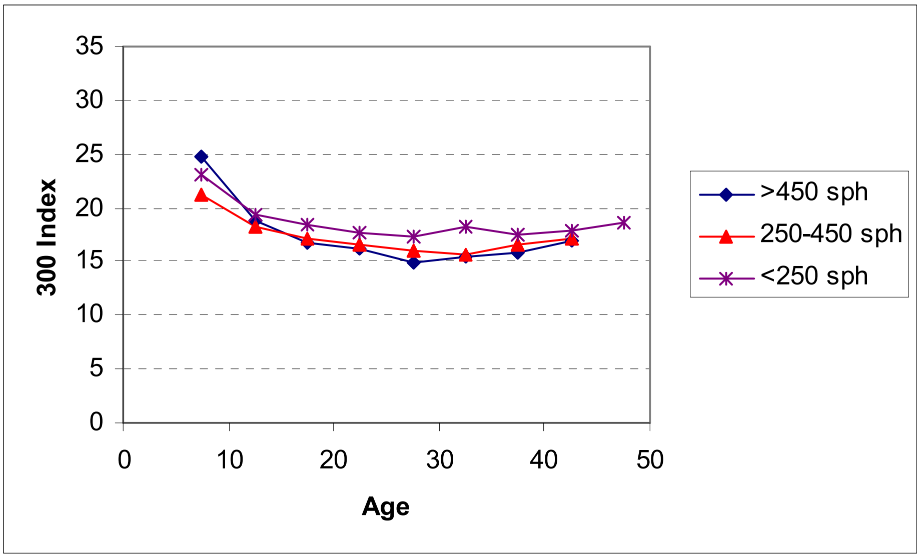


**Fig. 5. Mean 300 Index in 5-year age classes and stocking classes for coastal sand-dune sites**

Mean 300 Index and drift for each forest in the dataset containing more than 10 plots is tabulated in Table 2. There are clear differences between forests of the same site type. On both dry and ex-farm sites a number of forests show negative drift whilst others show positive drift. However, on sand-dune sites, most of the forests show negative drift with none showing significant positive drift, although several show very little drift.

**Table 2. Mean 300 Index and drift for forests containing more than 10 plots**

| Site type | Forest code | Location | No of plots | No of measure-ments | Mean 300 Index | Mean drift (%) |
|---|---|---|---|---|---|---|
| Dry | RTKR | Taradale, Hawkes Bay | 19 | 235 | 23.9 | -2.8 |
| | EYWL | Canterbury | 56 | 535 | 13.5 | -1.7 |
| | MLBH | Marlborough (Sth Bank) | 15 | 68 | 17.2 | -1.5 |
| | DTLG | Marlborough (Sth Bank) | 46 | 591 | 26.0 | -0.3 |
| | WMTE | Waimate, Sth Canterbury | 14 | 156 | 26.4 | -0.1 |
| | BALM | Culverden, Nth Canterbury | 12 | 110 | 11.2 | 0.6 |
| | GERD | Geraldine, Sth Canterbury | 21 | 155 | 25.5 | 0.7 |
| | TIKO | Tikokino, Hawkes Bay | 40 | 446 | 28.3 | 1.0 |
| | NGAU | Ngaumu, Wairarapa | 122 | 987 | 23.2 | 1.0 |
| | WIRU | Marlborough (Nth Bank) | 44 | 353 | 23.3 | 1.2 |
| Fertile | RIDO | Paengaroa, Bay of Plenty | 16 | 168 | 31.5 | -1.7 |
| | MANT | Mangatu, Gisborne | 23 | 160 | 29.9 | -1.3 |
| | TIKI | Tikitere, Rotorua | 80 | 2045 | 35.0 | -0.8 |
| | WHFF | Whatawhata, Waikato | 12 | 249 | 30.3 | -0.3 |
| | REFF | Reporoa, Rotorua | 12 | 125 | 32.3 | 0.0 |
| | GLNG | Glengarry, Napier | 19 | 245 | 32.7 | 0.2 |
| | RKAT | Rakatau, Northland | 16 | 203 | 30.5 | 0.2 |
| | WAIO | Waiotahi, Bay of Plenty | 25 | 221 | 30.7 | 0.7 |
| | OTCO | Otago Coast, Sth Otago | 25 | 289 | 26.1 | 1.6 |
| | DIPT | Dipton, Southland | 16 | 243 | 24.5 | 2.2 |
| Sand | PENG | Aupouri, Northland | 14 | 116 | 19.3 | -3.7 |
| | AUPO | Aupouri Northland | 174 | 1742 | 19.4 | -2.5 |
| | WOOD | Woodhill, Auckland | 124 | 1403 | 19.5 | -2.5 |
| | POUT | Poutu, Northland | 43 | 336 | 17.6 | -2.2 |
| | SANT | Santoft, Wanganui/Manawatu | 90 | 706 | 17.4 | -0.7 |
| | OTAK | Woodhill, Auckland | 20 | 144 | 17.9 | -0.6 |
| | WUKU | Waiuku, South Auckland | 171 | 1465 | 14.7 | -0.5 |
| | TGMO | Tangimoana, Manawatu | 15 | 128 | 18.6 | -0.4 |
| | WATR | Waitarere, Manawatu | 36 | 193 | 21.3 | 0.5 |

Mean 300 Indices versus age for forests from dry sites with drift averaging more than 1% (either positive or negative) are shown in Fig. 6, while the remaining dry-site forests, which showed little overall drift, are shown in Fig. 7. There are three dry-site forests (RTKR, EYWL, MLBH) that show a pronounced negative drift, and two forests (WIRU and NGAU) that show moderate positive drift. The remaining five forests on dry sites show only minimal positive or negative drift. In Figs. 8 and 9, the 300 Index is plotted over time for forests on fertile ex-farm sites. Two forests (DIPT and OTCO) show some positive drift, while two others (RIDO and TIKI) show some negative drift. The remaining six forests on ex-farm sites show little or no drift. Finally, Fig. 10 shows the five sand-dune forests with the most pronounced negative drift, which are all located north of Auckland. Fig. 11 shows the remaining four sand-dune forests. The latter have only a slight overall negative drift showing that not all coastal sand-dune forests have the strong negative drift evident in Fig. 10.

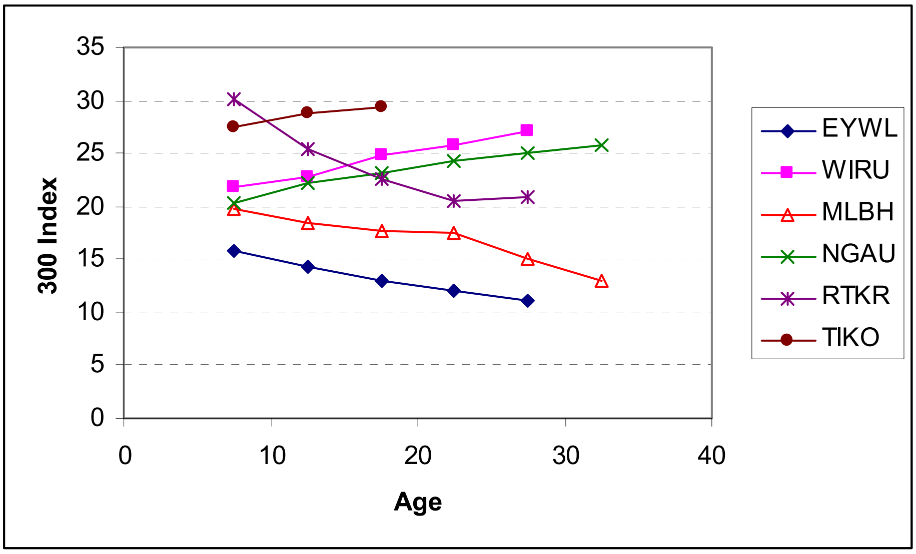


Fig. 6. Mean 300 Index in 5-year age classes for selected forests on dry sites

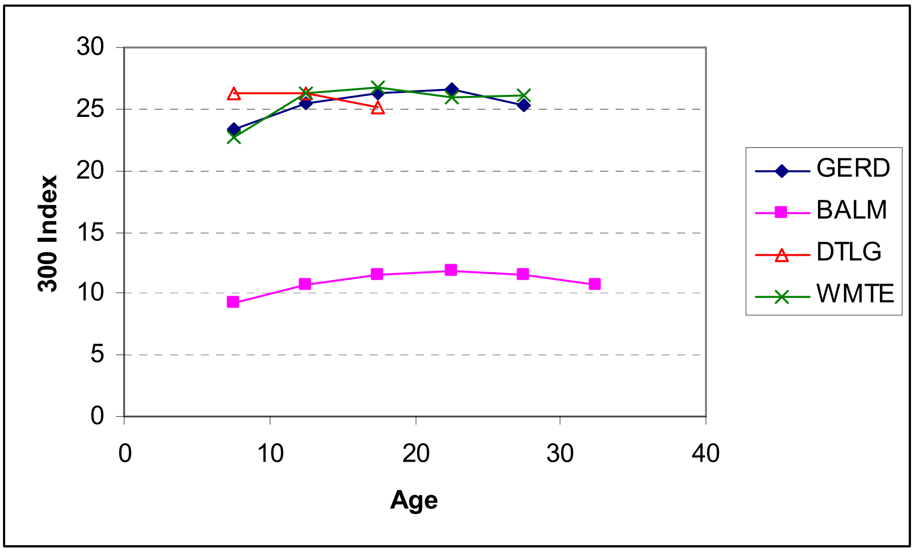


Fig. 7. Mean 300 Index in 5-year age classes for selected forests on dry sites

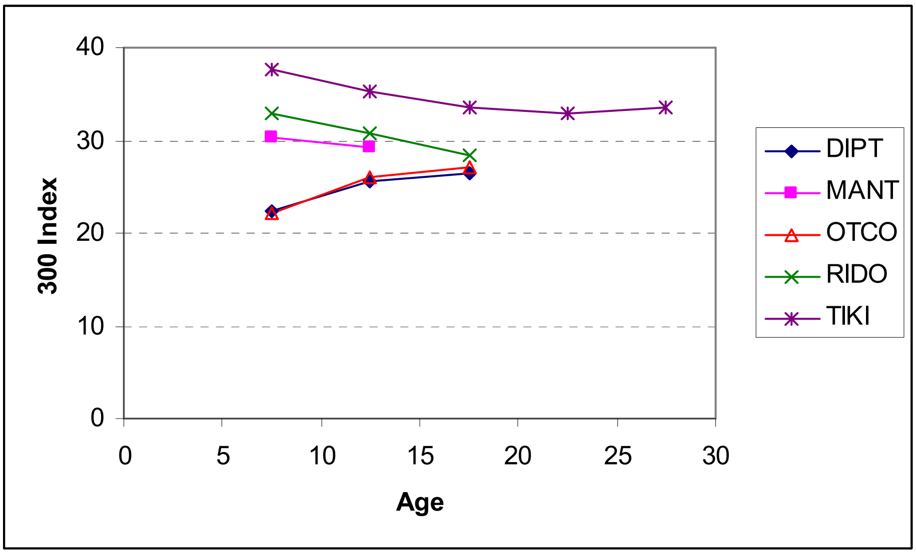


Fig. 8. Mean 300 Index in 5-year age classes for selected forests on ex-farm sites

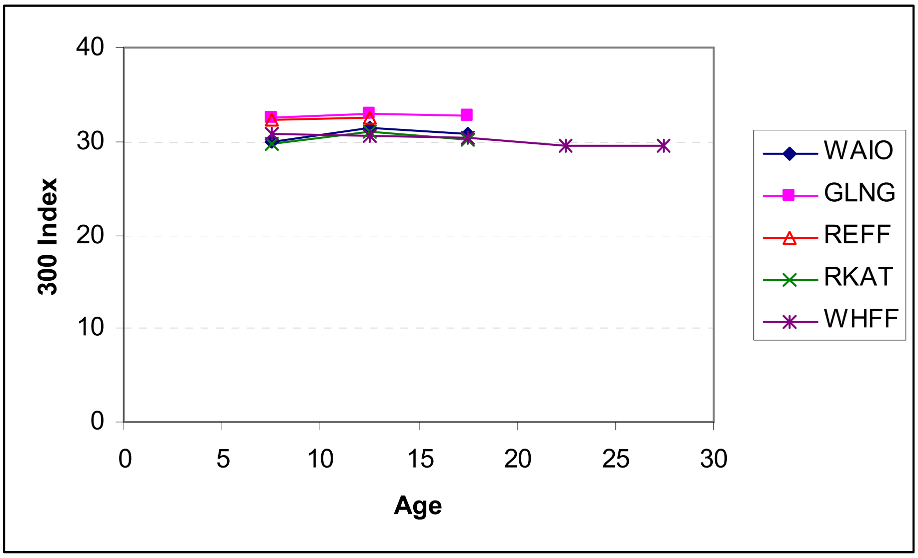


**Fig. 9. Mean 300 Index in 5-year age classes for selected forests on ex-farm sites**

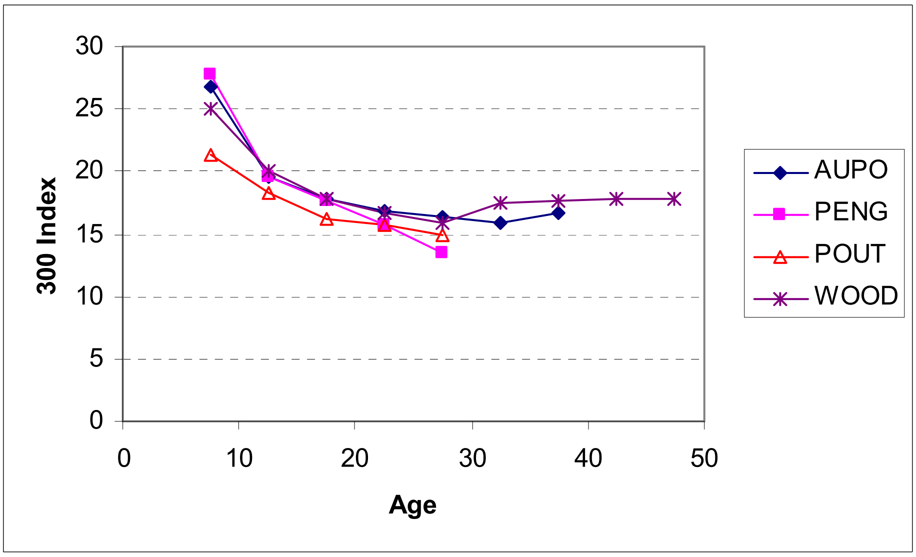


**Fig. 10. Mean 300 Index in 5-year age classes for selected forests on sand-dune sites**

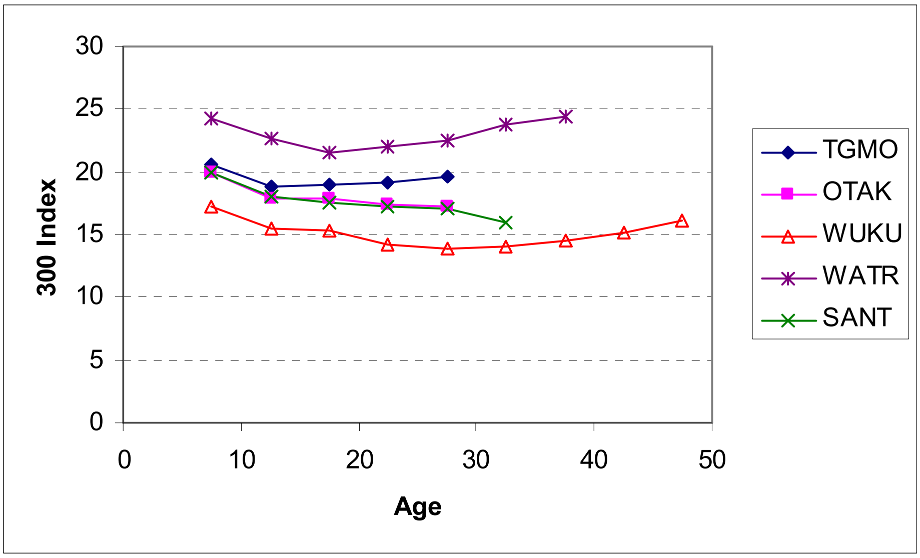


**Fig. 11. Mean 300 Index in 5-year age classes for selected forests on sand-dune sites**

Why does the 300 Index drift in some forests? The 300 Index reflects the growth potential of a site, in terms of climate and soil nutrition and structure. On very good sites where conditions are close to the optimum for radiata pine, the 300 Index can approach 40. None of the farm sites in this analysis averaged 40 although a few individual plots in the database did. The highest average index for an individual plot in the database was 41. However, typical forest sites have indices in the mid 20's, well below this maximum. It can therefore be assumed that on most sites, one or more factors is limiting to growth. For example, the temperature may be outside the optimum range, the soil may be lacking in some important nutrient such as nitrogen or phosphorous, or there may be insufficient available water for part of the growing season.

In most cases, the limiting conditions can be assumed to remain constant over a rotation. For example, average temperature is unlikely to change greatly over a rotation, and soil nutrition has generally been found not to deteriorate significantly. Therefore, the fact that the 300 Index generally remains constant over time is reassuring. However, if the conditions that are limiting growth do change significantly for a particular site, it can be expected that the index will also change for that site. For example, on a site where growth is being limited by insufficient phosphorous, if fertilising alleviates this, there will be a consequent increase in the index.

The strong negative drift in the index for some sand-dune forests identified in this analysis can be explained in terms of a deteriorating nitrogen status during a rotation. Trees growing on these sites receive a considerable input of nitrogen from lupins early in a rotation. However, after suppression of the lupins following crown closure, and with increased demand from the growing trees, the nitrogen status deteriorates over time. Thus growth rates on these sites are not maintained when compared with other less sensitive sites showing similar levels of early growth. Therefore, the index shows a negative drift. However, with the advent of lupin blight, the historic growth trends on these sites may no longer necessarily hold.

On those dry sites where a negative drift in the index was identified, it can be assumed again that some growth condition becomes increasingly limiting over time. It is possible that the supply of water on these sites is reasonably adequate early in a rotation, but that as tree crowns develop and the demand for water becomes more significant, the water supply becomes increasingly limiting later in a rotation. A negative drift in the 300 Index for these sites would reflect this.

## CONCLUSIONS

For most sites, the 300 Index appears to be relatively stable over a wide range of age classes and stockings. Average drift in 300 Index estimation within a forest will normally lie within a range of ±1%/yr, even when stands as young as 5 years are used for calibration. Some outliers with drift up to 2% will occasionally appear for no apparent reason.

Sites which are the exception to this general rule are as follows:

- Sand-dune sites north of Auckland. Calibration of 300 Index using young stands (5-10 years) will tend to over-predict the index by a significant amount. The over-prediction averages 65% for stands aged 5-10 years, and 28% for stands age 10-15 years.

- Low-rainfall sites at Taradale (Hawkes-Bay), Marlborough (South Bank) and Eyrewell (Canterbury). The index will be over-predicted by about 39% in stands aged 5-10 years, and by about 23% in stands aged 10-15 years.

- Ex-farm sites in Otago/Southland. Indices estimated from young stands may tend to be under-predicted.

Where the initial estimation of 300 Index is at variance with the later estimation, then clearly the Radiata pine Calculator will in turn be in error in estimating diameter-over-stubs (DOS) at pruning, and in pruned-log-index (PLI) estimation. In these cases, it is recommended that as an interim measure, the calculator be used twice - initially for determining DOS and for scheduling stands for silviculture, and secondly with an adjusted 300 Index for predicting growth through to clearfelling. Table 3 shows the approximate adjustment factors to apply to the initial 300 Index estimation obtained from young stands so as to achieve an unbiased prediction at age 28 years. These adjustments were obtained by averaging indices from the four sand-dune forests north of Auckland, and from the three dry-site forests showing significant drift (Taradale, Marlborough and Eyrewell).

**Table 3. Adjustment factors to apply to the 300 Index to achieve unbiased predictions of the index at age 28 years**

| Age | Sand-dune | Dry |
|---|---|---|
| 5-10 | 0.60 | 0.72 |
| 10-15 | 0.78 | 0.81 |
| 15-20 | 0.87 | 0.88 |
| 20-25 | 0.93 | 0.94 |

## REFERENCES

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