THE EFFECT OF FINAL CROP STOCKING ON GROWTH ACROSS A RANGE OF SITES

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EXECUTIVE SUMMARY

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ABSTRACT

When developing the Strategy for future Silvicultural Trials (see Cooperative report No. 35) the issue of testing final crop stocking treatments on all sites was highlighted. The issue was rationalised by suggesting an analysis of existing trial data be undertaken to test if the effects of stocking are consistent across all sites.

An initial study comparing the performance of seven regional growth models at 200, 300, and 400 stems/ha indicated that there was a substantial site x stocking interaction.

Using a modelling approach, an analysis of data from 24 trials found that a site x stocking interaction was significant in a few minor instances, but is not sufficiently substantial or widespread to be of management importance. The implications are that some regional growth models may need to be scrutinised for their performance in respect to stocking, and that trials can be established with a single stocking in the knowledge that the results can most probably be extrapolated to other stockings.

As many of the trials in this study are not mature, this analysis should be repeated in the near future, with older data.

A further result of this work is the suggestion that the "300 index" (peak MAI for volume for 300 stems/ha) be used to describe the intrinsic productivity of a site. If the use of this index becomes widespread, it may enable the development of superior growth models based on environmental factors, and may be used to assess management practices in terms of sustainability.

KEYWORDS

Stocking, tree stocking, spacing, site index, site quality, site productivity

INTRODUCTION

When developing the Strategy for future Silvicultural Trials (see Cooperative report No. 35) the issue of testing final crop stocking treatments on all sites was discussed. As there were a considerable number of semi-mature final crop stocking trials in existence, it was considered prudent to analyse existing data before proceeding with further trials.

The effects of stocking on tree diameter, height, and volume are well known. At lower stockings, trees have greater diameters but are shorter. Total stand basal area and volume are lower (Garcia 1990; Maclaren *et al* 1995). Most of these effects are well modelled, in broad terms, by the STANDPAK suite of programs (Whiteside 1990), but there are several reasons for wanting to know if the effects of stocking are consistent across all sites:

1. As a check on the reliability of regional growth models.
Do they show the same behaviour across a range of stockings? If not, why not? If the behaviour of certain models conflicts with experimental data obtained from controlled and replicated final crop stocking trials, then these models may need closer scrutiny.

2. As a way to cut costs in forest research.
If various silvicultural or breeding trials could dispense with a stocking treatment, this would considerably reduce the average area required for a trial. If the effects of stocking are consistent across all sites, then it should be possible to predict tree behaviour at stockings not directly represented.

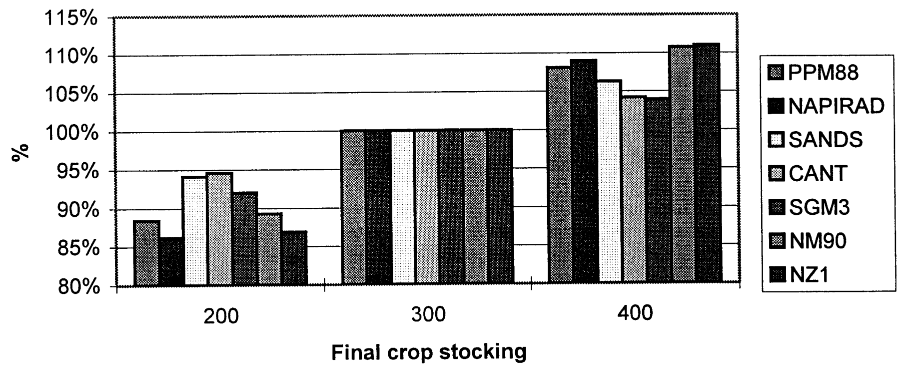
3. As a way to standardise the results from all permanent sample plots (PSPs), so that they can provide an index of site productivity.
The current situation is that plots cannot be directly compared for productivity, because there is inevitably some variation in stocking. If the stocking effect were to be "removed", and the huge PSP database (c. 10 000 plots) linked with environmental variables such as temperature, rainfall, exposure, soil depth, etc., it may be possible to determine the reasons behind the relative performance of different sites. This may lead to further developments: the ability to manipulate sites so as to approach their optimum conditions, the ability to predict growth for sites where no forest data exists, the ability to increase the precision of existing growth models, and to assess the long-term sustainability of management practices.

METHODS and RESULTS

1. Checking the existing growth models.

Seven growth models (six regional and one national) were run within STANDPAK at 200, 300 and 400 stems/ha using a site index of 28 m. Total standing volumes at age 30 of the 200 and 400 stocking were then expressed as a percentage of the 300 stocking. Figure 1 shows that these ratios are not the same for each regional growth model. This implies *either* that some of the growth models contain flaws that result in an ability to reflect the precise effects of stocking, *or* that stocking effects do genuinely alter with different region.

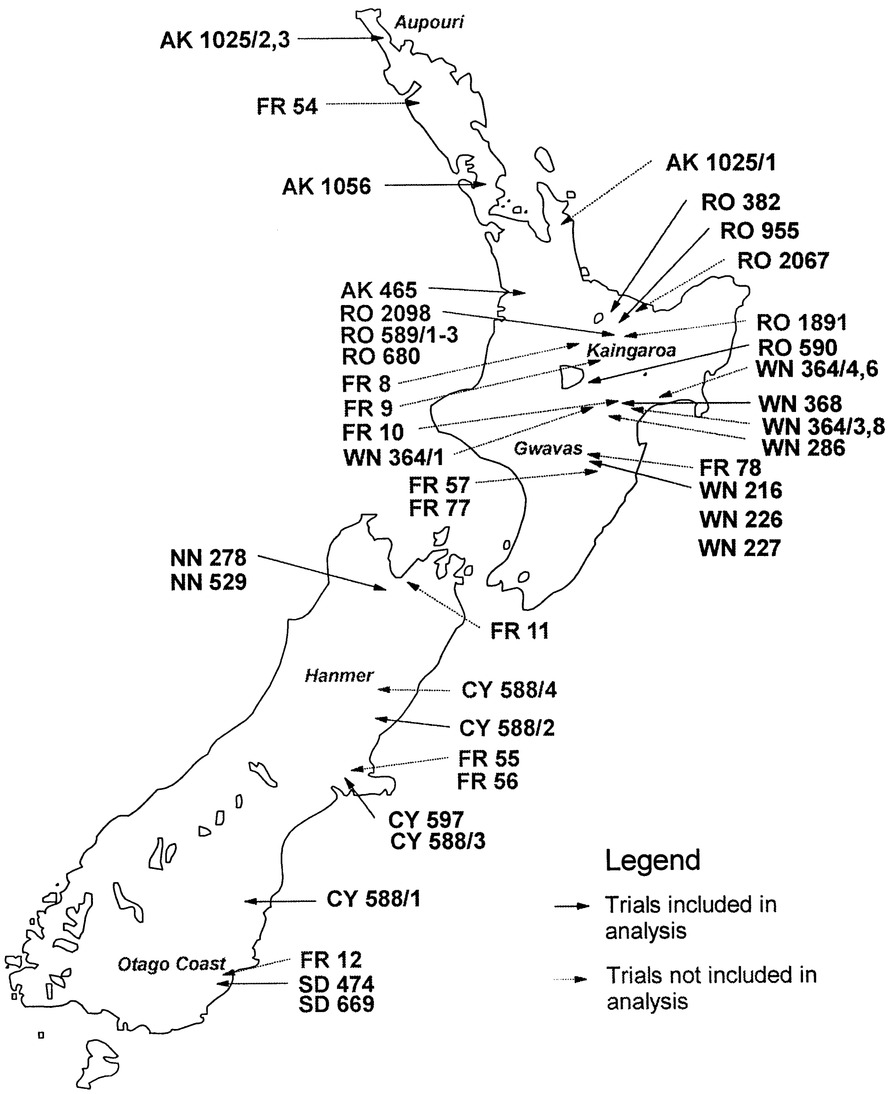
Figure 1: Proportion of Total Standing Volume of 300 stems/ha for seven regional growth models



2. **Examining the trial data for a stocking-site interaction**

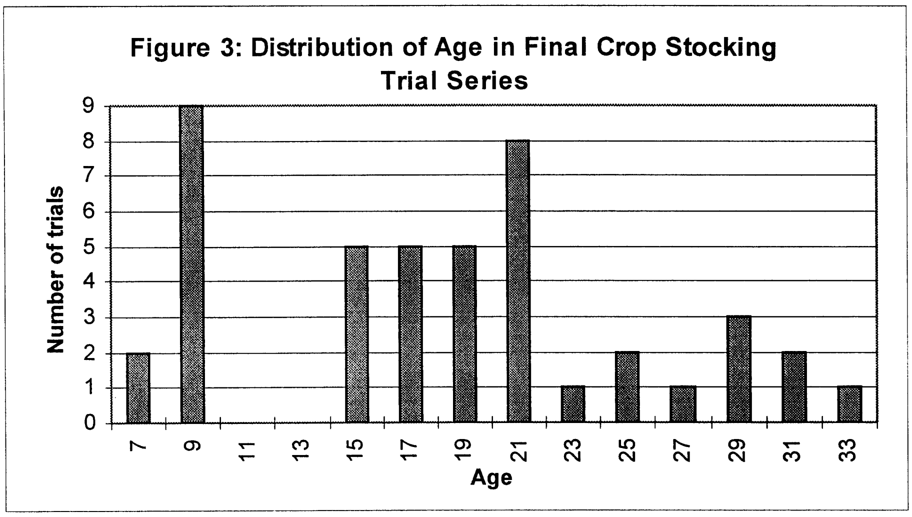
In order to determine which of the two options above is correct, some 45 trials were identified that gave a fair comparison of final crop stocking on the same site. These trials are located nationwide, as per Figure 2:

Figure 2: Location of Final Crop Stocking Trials



The first stage of the modelling was to define what was the minimum tree age required at measurement before this approach was reliable. This was tested by removing the oldest data one year at a time and examining the confidence intervals of the coefficients. The minimum age proved to be 18 years. Trials that did not have measurements at 18 years or older were discarded from the data set. This left 24 trials suitable for this analysis.

The distribution of age at the last measurement for above trials is given in Figure 3:



This shows that, of the 45 trials, only 24 are aged 18 or more.

Modelling Maximum MAI

To examine the data for a site x stocking interaction this investigation has taken a modelling approach. By fitting models that account for stocking to each trial and testing between coefficients the presence or absence of an interaction can be proven. Rather than modelling height, basal area, or volume growth it was decided to model an index of productivity that could be used universally for a number of purposes. Volume at age 20 and volume at 20m height was investigated but discarded because they have no biological basis. Instead Maximum Mean Annual Increment (Max MAI) (MAI = volume/age) was chosen as it represented the maximum capacity of the site to produce wood for a given stocking, and should be highly related to site and environmental factors.

A range of model formulations were selected and fitted to the data. Three were classical yield models (Schumacher, Hossfeld, Avery-Burkhart) that were reparameterised to a MAI form and a fourth was a suitable non-linear function (Reciprocal Quadratic) that can be reparameterised to provide easy estimation of asymptotic values. Results from fitting these models are given in table 1.

Table 1 : Comparison of model fit for MAI equations

Model	Residual Mean Square	R^2	No. of parameters
Schumacher	4.031	95.5	6
Hossfeld	4.186	95.3	5
Aver-Burkhart	4.938	94.4	6
Reciprocal Quadratic	4.075	95.4	5

These results and a comparison of each models performance in a spreadsheet implementation, indicated that the Schumacher equation was best.

The following gives the form of the Schumacher equation as fitted to the data:

$$MAI = A \, {}^{B}\!/_{T} \exp^{T^C - B^C / CT^C}$$

where

$$A = a1\left(1 - \exp^{a2N}\right)$$
$$B = b1 \exp^{b2N}$$
$$C = c1 + c2N$$

T = age
N = stems/ha/ 100

Figure 4 illustrates how the MAI model performs for a range of final crop stockings and age.

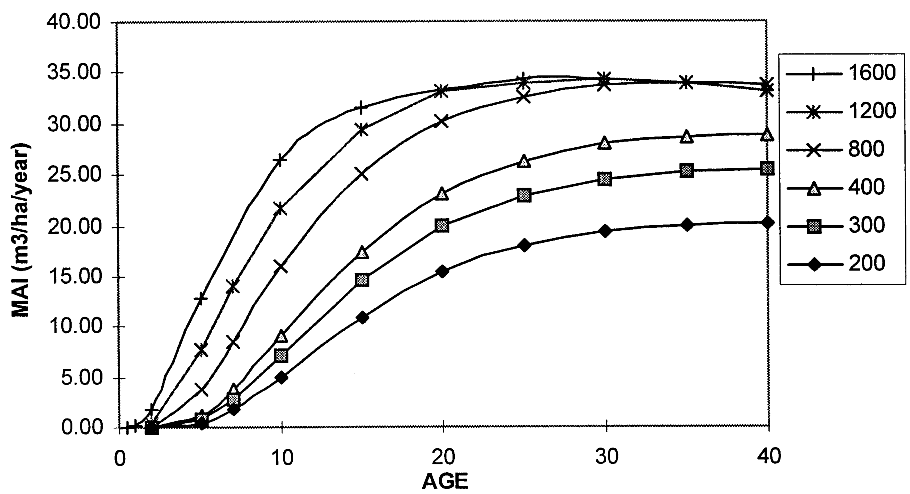
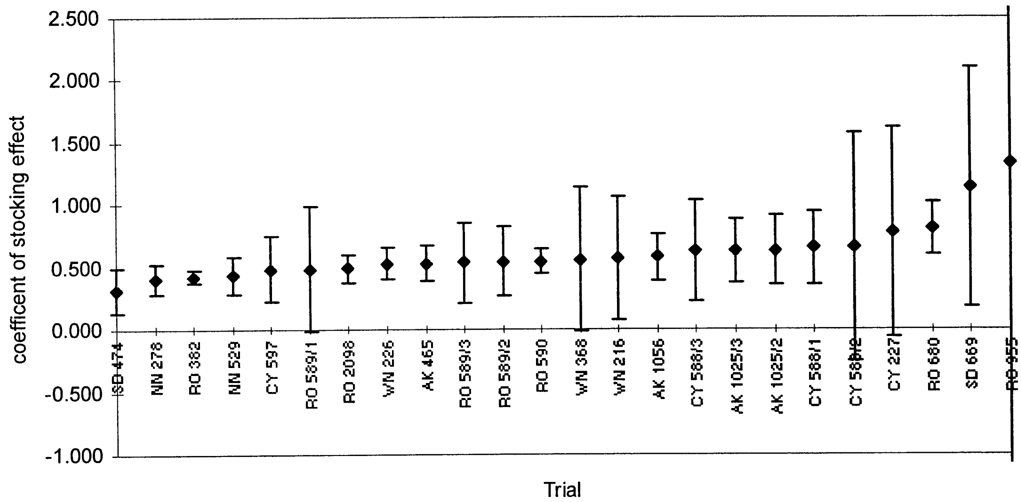


Figure 3: Model to predict MAI from age and stocking - Max MAI = 35

By fitting models to each plot and comparing with a generalised model for all trials a site x stocking interaction could be tested. This proved to be statistically significant. However when the magnitude of this interaction was examined it appeared to be of no practical importance. Figure 5 gives the coefficients and 95% confidence intervals for the effect of stocking in each trial and illustrates the overlap in coefficient estimates ie. very few are significantly different. The smaller the value of the coefficient, the greater the influence of stocking. Ranking the coefficients from small to large indicated the trials could not be clustered into logical geographic groups.

Figure 5: Coefficients and 95% confidence intervals for stocking effect on MAI



Productivity Index

Using the MAI equation, it was now possible to express all plots in terms of their likely maximum MAI at a given stocking. The stocking of 300 stems/ha was selected, being a realistic middle-of-the-range choice for modern regimes and for the range of data in the 24 trials. Table 2 lists these trials, and ranks them by the “300 Index” (ie the maximum MAI for volume that would likely have occurred at 300 stems/ha). The “300 index” is an objective and intuitive measure of the inherent properties of a site. It should be superior to “site index”, which is merely a measure of height and ignores the diameter of trees. It directly relates to the parameter of greatest interest—stem volume growth—rather than to a surrogate. It remains to be seen whether such an index correlates well with measurable site variables such as temperature, rainfall, exposure and soil depth.

Table 2: Trials included in the analysis ranked by 300 Index

Trial	Location	Maximum MAI	300 Index
RO 382	Tikitere	53.33	40.60
AK 465	Whatawhata	50.73	38.62
WN 216	Gwavas - cpt 30	45.55	34.68
RO 955	Tarawera	42.32	32.22
RO 589/3	Kaingaroa - cpt 1354 Nth Bdry	40.64	30.94
WN 368	Awahahonu -cpt 36	40.49	30.82
RO 2098	Kaingaroa -cpt 327	40.11	30.54
RO 590	Waimihia -cpt 789-Waitahanui	39.12	29.78
WN 227	Ngaumu cpt 110	36.82	28.03
RO 589/2	Kaingaroa - cpt 917 -Goudies	34.11	25.97
RO 680	Kaingaroa - cpt 1119	30.44	23.17
SD 669	Otago Coast cpt 169	30.12	22.93
CY 588/1	Waimate cpt 5	29.8	22.69
WN 226	Gwavas - cpt 217	29.79	22.68
AK 1025/3	Aupouri - cpt 70	27.85	21.20
SD 474	Otago Coast - cpt 157-Akatore	26.88	20.46
NN 278	GoldenDowns - cpt 113	26.53	20.20
NN 529	Golden Downs cpt 345	26.22	19.96
AK 1025/2	Aupouri - cpt 69	26.03	19.82
RO 589/1	Kaingaroa cpt 890 -Matea	25.47	19.39
AK 1056	Woodhill - cpt 225,230,231	24.12	18.36
CY 588/3	Okuku cpt 402	24.07	18.32
CY 597	Eyrewell - cpt 32	14.87	11.32
CY 588/2	Balmoral - cpt 29	10.87	8.28

CONCLUSIONS

A comparison of regional growth models indicated that there was a substantial site x stocking interaction. However a comparison of trial data found that this interaction was significant in only a few minor instances, but is not sufficiently substantial or widespread to be of management importance. The implications are that some regional growth models may need to be scrutinised for their performance in respect to stocking, and that trials can be established with a single stocking in the knowledge that the results may be extrapolated to other stockings.

A further result suggestibly this work is that the “300 index” (peak MAI for volume for 300 stems/ha) be used to describe the intrinsic productivity of a site. If the use of this index becomes widespread, it may enable the development of superior growth models based on environmental factors, and may be used to assess management practices in terms of sustainability.

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