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Effect of Thinning History on the 300 Index Growth Model Projections

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EXECUTIVE SUMMARY

The 300 Index growth model [1] requires the user to initiate the model with estimates of productivity either as an index or stand measurement. If the measurement is taken after stand tending, the user also needs to specify these historic silvicultural operations. This historical information includes the initial stocking, the stand age and post-thin stocking at each thinning, and the stand age, pruned height and number of stems pruned in each pruning lift.

The requirement to specify historical silvicultural information can sometimes cause problems, as such information may not always be readily available especially at the individual plot level.

The objective of this study is to analyse and report on the sensitivity and level of error in volume predictions produced by the 300 Index growth model when an incomplete or erroneous forest management history is used.

The key conclusions of this analysis regarding the importance of accurately specifying thinning history when using the 300 Index Growth Model are:

- For stands measured at about age 10 years, specifying the timing and intensity of a previous thinning accurately is not critical except on high productivity sites when the thinning occurred from an initial stocking greater than 800 stems/ha within two years of the measurement.

- For stands measured at about age 15 years, specifying the timing and intensity of a previous thinning accurately is important if the thinning occurred after age 10 years on high productivity sites, and after age 12 years on medium productivity sites, especially when the initial stocking was greater than 800 stems/ha. Specifying the precise timing and intensity of thinnings is less important on low productivity sites, and when thinning occurred prior to age 10 years on high productivity sites and 12 years on medium productivity sites.

- For stands measured at about age 24 years, specifying the timing and intensity of a previous thinning accurately is important only if the thinning occurred after age 15 years on higher productivity sites.

An ‘expert system’ which allows users to run the 300 Index model when historical data are missing is described in FFR report R035 [2]. It is intended to implement this system in FORECASTER shortly.

INTRODUCTION

The 300 Index model [(1)] predicts growth of radiata pine and is intended to be used nationally in New Zealand. Both stand-level and individual-tree versions of the model are available. As with other growth models, the 300 Index model generally uses a starting measurement at a known stand age to initiate a prediction run. For the stand-level model, this starting measurement consists of the stand-level variables stocking, mean top height (MTH) and basal area (BA), while the individual-tree version uses a list of tree measurements of diameters and heights. As an alternative to a starting measurement, users can supply the model with measures of site productivity in the form of a 300 Index and Site Index. The model also requires the user to specify information on any silvicultural operations (e.g., thinnings) made subsequent to the measurement age. Unlike most other growth models, the 300 Index model requires information detailing significant aspects of the stand history prior to the measurement. This historical information includes the initial stocking, the stand age and post-thin stocking at each thinning, and the stand age, pruned height and number of stems pruned in each pruning lift.

The requirement to specify historical silvicultural information can sometimes cause problems, as such information may not always be readily available, especially at the individual plot level. A new module has recently been developed which allows the user to specify the stand history at different levels of detail depending on the available information [(2)]. This module uses whatever information is supplied by the user, and then fills in missing elements in the history that are required by the model. In effect, this new module allows a user to provide any level of information, ranging from a very complete history where this is available, to very limited information. However, better model predictions will be produced if more accurate and detailed information on the previous stand history is provided to the model. In general, the more remote in the past and less severe an operation, the less is the prediction error likely to be. However, the sensitivity of the model to errors in the key parameters of stand history is currently unclear. To clarify this issue, this report presents the results of a sensitivity analysis on the effects of stand history errors on 300 Index model predictions.

METHODS

The sensitivity analysis was performed by systematically varying elements of the silviculture in simulated runs over a 30-year rotation. The aim of this analysis was to demonstrate the size of errors that can occur if assumptions have to be made on past management without accurate knowledge of timing and level of an operation. The analysis covers the sensitivity of the model to the timing and intensity of thinning. It examines only single-thin regimes – examining multiple thinnings would have been too complex for this study. It also does not address the issue of timing and intensity of pruning. However, as the numbers of stems pruned and final pruned heights are generally easily determined in a measurement plot, uncertainty over the pruning history is probably less of an issue than uncertainty over the thinning history of a stand.

Three levels of site productivity were used in the sensitivity analysis, representing typical low, medium and high levels of site productivity (Table 1). The sensitivity of the model was examined for three measurement ages, namely soon after silviculture (age 10), at mid-rotation (age 15), and at pre-harvest (age 24). The analysis was also performed for a wide range of final crop stocking levels, namely 200, 400, 600, and 800 stems/ha.

Table 1: Site productivity levels, defined by values of the 300Index and Site index.

Site productivity	300 Index Value	Site index Value
Low	20	20
Medium	30	30
High	40	35

To obtain suitable starting values for the simulation runs, growth predictions at ages 10, 15 and 24 years were made for the four regimes shown in Table 2, replicated across the three site productivity levels. This resulted in the 54 stand predictions shown in Table 3, each consisting of an age, stocking, MTH and BA. These were used as “measurement” starting values in all further scenario runs.

Table 2: Four standard regimes with various initial stockings and thinning intensity that were used with three levels of site productivity to estimate measurements at age 10, 15 and 24 years.

Regime	Initial stocking (stems/ha)	Thinning (remaining stems/ha)	Time of thinning
1	600	200	Age 7
2	800	400	Age 7
3	1200	600	Age 7
4	1200	800	Age 7

Table 3: Estimated values of stocking, MTH, and basal area at three stand ages for each standard regime across three productivity levels.

Productivity	Standard regime	Age 10			Age 15			Age 24		
		stems /ha	MTH	BA	stems /ha	MTH	BA	stems /ha	MTH	BA
Low	1	200	9.3	8.2	199	15.0	21.3	197	23.3	53.3
	2	399	9.3	15.0	397	15.0	35.4	385	23.3	64.5
	3	599	9.3	21.5	592	15.0	47.7	553	23.3	79.9
	4	798	9.3	27.2	782	15.0	57.7	696	23.3	90.5
Medium	1	200	15.0	16.0	199	23.1	32.0	196	34.6	52.0
	2	399	15.0	26.9	395	23.1	46.9	380	34.6	68.6
	3	399	15.0	26.9	395	23.1	46.9	380	34.6	68.6
	4	794	15.0	43.9	767	23.1	66.7	679	34.6	86.8
High	1	200	18.0	27.1	199	27.2	47.0	196	40.3	66.0
	2	399	18.0	41.3	394	27.2	62.7	381	40.3	80.9
	3	596	18.0	51.6	583	27.2	73.3	547	40.3	90.6
	4	792	18.0	60.6	765	27.2	80.5	697	40.3	95.9

For each starting value, the timing and intensity of thinning was then varied systematically. The number of potential combinations of thinning histories was potentially very large. This number was restricted to a reasonable level by simulating only realistic and likely combinations.

The timing of thinning was varied in relation to the measurement event to alter the time-span between the thinning and the measurement. Thinning time was altered in relation to measurement time according to Table 4. Thinning intensity and initial stocking were varied in relation to each other, resulting in 13 different combinations of initial stocking and thinning that covered a wide range of potential regimes. Table 5 shows the combinations of initial stocking and thinning intensities used as scenarios in this study.

Table 4: Thinning ages used in simulations in relation to the timing of measurements.

Measurement age	Thinning ages
10	5, 6, 7, 8, 9
15	5, 7, 9, 12, 14
24	5, 7, 9, 12, 14, 18

Table 5: Initial stockings and associated thinning intensities used in the management scenarios.

Initial stocking	Thinning intensity			
	1	2	3	4
1600	800	600	400	200
1200	800	600	400	200
800	600	400	200	
600	400	200		

These various combinations of thinning timing and intensity were modelled for low, medium and high productivity site levels. Several hundred combinations of measurement time, thinning time and initial stocking across the three productivity levels were modelled and the output of those runs was compared with the results of the relevant standard regime that supplied the measurement data for the different measurement times. The effect of varying the thinning history was judged using the predicted stem volume at age 30 years (m^3/ha).

RESULTS

The results of the sensitivity analysis are summarised in Figures 1-12. Considerable information is contained in these figures and care must be taken in interpreting the results. Note that each individual chart shows the predicted volumes at age 30 years for one of the starting values shown in Table 3. For example, Fig. 1(a) corresponds to the first measurement in Table 3, which consists of a stand measured at age 10 years at a stocking of 200 stems/ha on a low productivity site. The lines on the chart show the effects of varying the thinning history on the stand volume predicted at age 30 years for that particular measurement. Each line represents a different initial stocking or thinning intensity. The predicted volume is plotted against the age of thinning. When the lines are horizontal, the implication is that the timing of thinning has little effect on the predicted volume.

For example, Fig. 1(a) shows that on a low productivity site, in a stand measured at age 10 years at a stocking of 200 stems/ha, timing and intensity of any thinning prior to the measurement has minimal effect on final volume. Fig 1(c) shows that on a high productivity site, a stand measured at 10 years and a stocking of 200 stems/ha shows minimal sensitivity to previous thinning for initial stockings less than 800 stems/ha. At initial stockings greater than 800 stems/ha thinned later than age 8 years, there is a noticeable difference in the final volume compared with stands thinned earlier or at lower initial stockings which have the same measured stocking, MTH and BA.

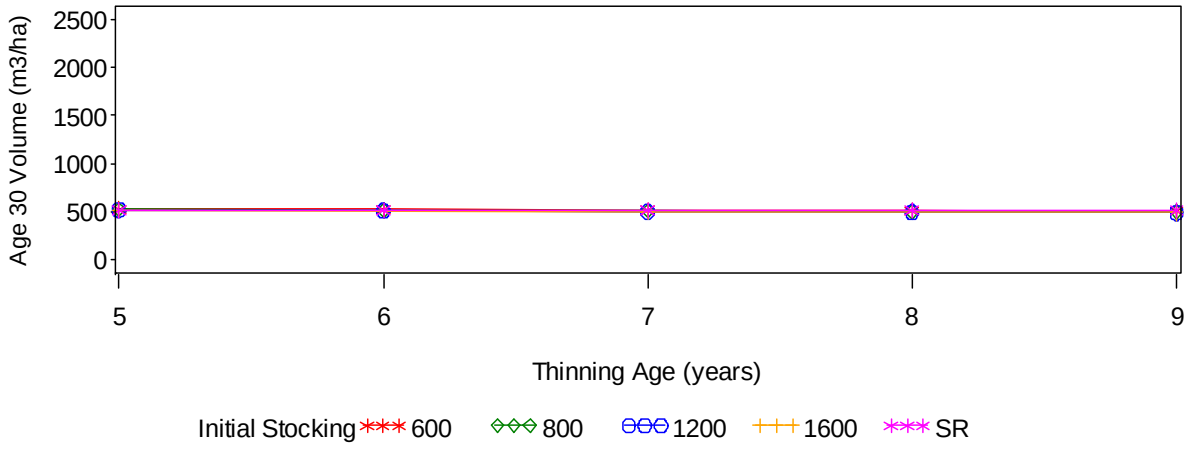
A number of general trends are clearly visible in Figs. 1-12. Firstly, the greatest sensitivity to thinning history occurs on the more productive sites. Secondly, when thinnings occur more than five years prior to a measurement, the precise timing and intensity of the thinning is generally not critical and has little influence on the final predicted volume.

More specifically, thinning events that have the greatest effect on predicted final volume, and where their precise definition in terms of both timing and intensity is therefore most critical, are those that were performed within one to four years of a mid-rotation inventory (age 15 years) especially on highly productivity sites.

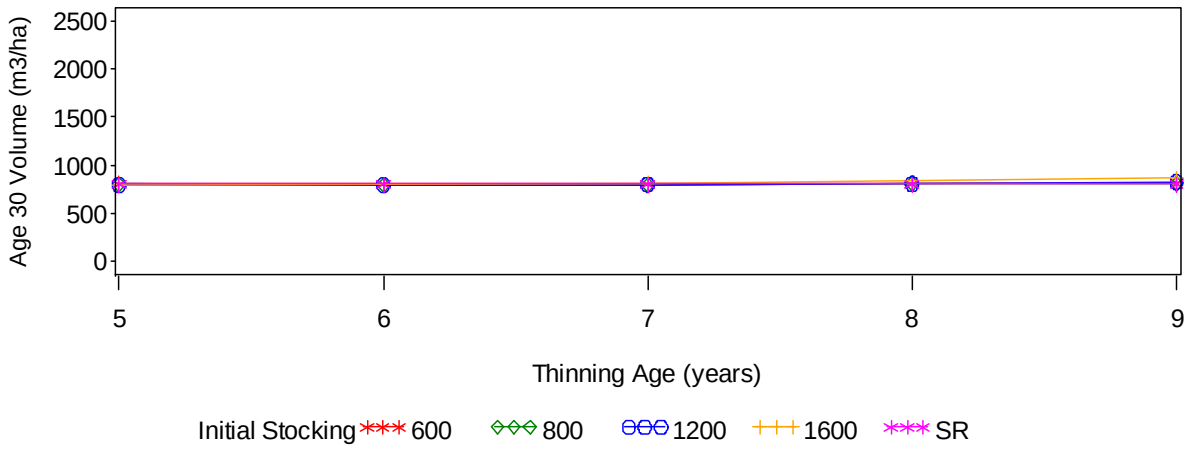
For pre-harvest inventories performed at about age 24 years, the precise definition of the timing and intensity of thinning is of little importance except for thinnings that occurred after age 15 years on medium to high productivity sites.

Finally, for early measurements made at around age 10 years, the timing and intensity of previous thinnings is of little importance except on high productivity sites when initial stockings are greater than 800 stems/ha and the thinning occurs after age 8 years.

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

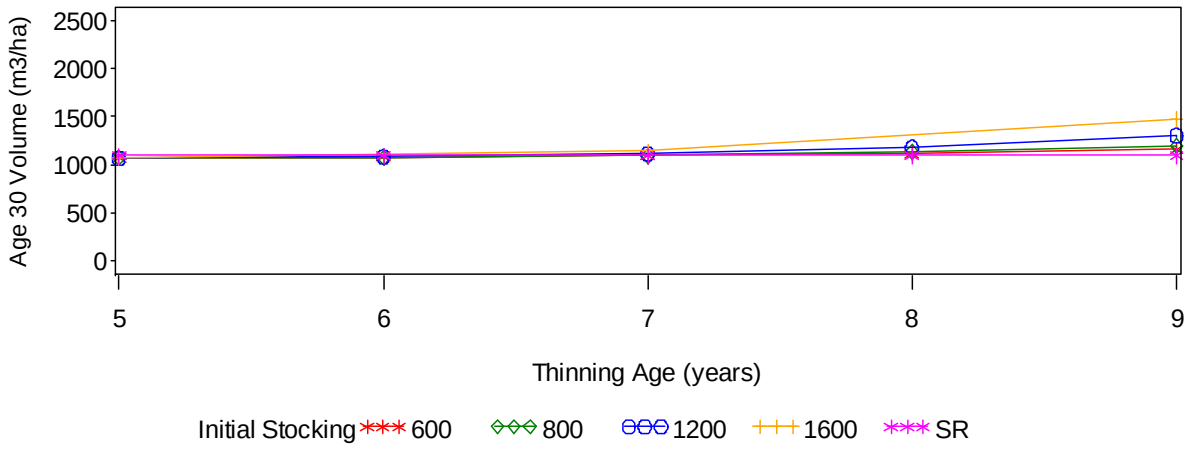
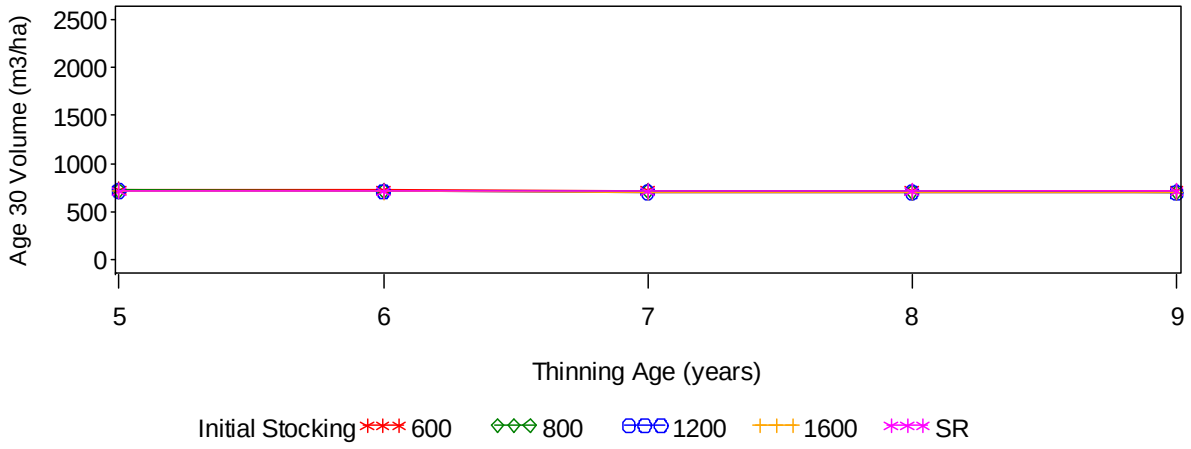


Figure 1. Predicted volume at age 30 years using age 10 starting measurement and post-thin stocking of 200 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



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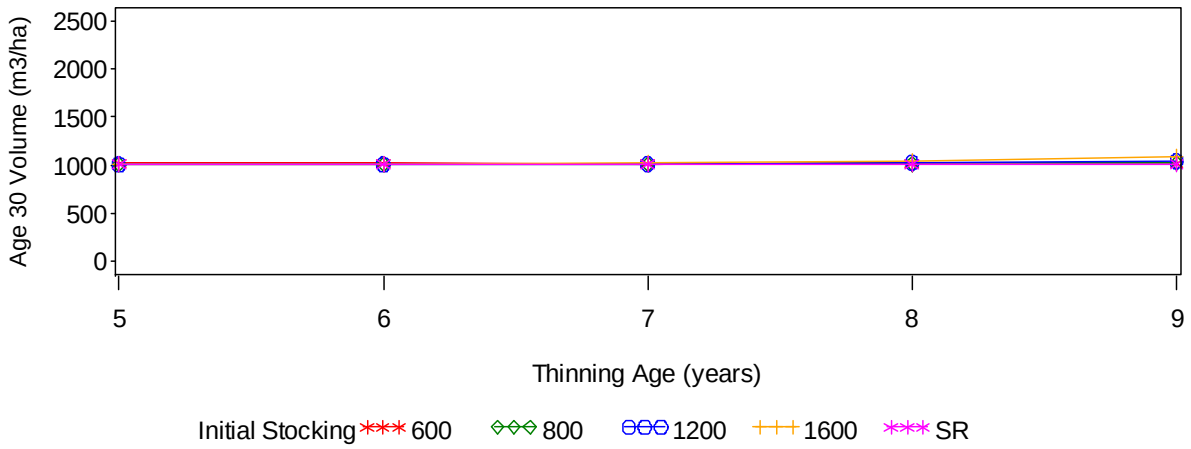


(c) High productivity site

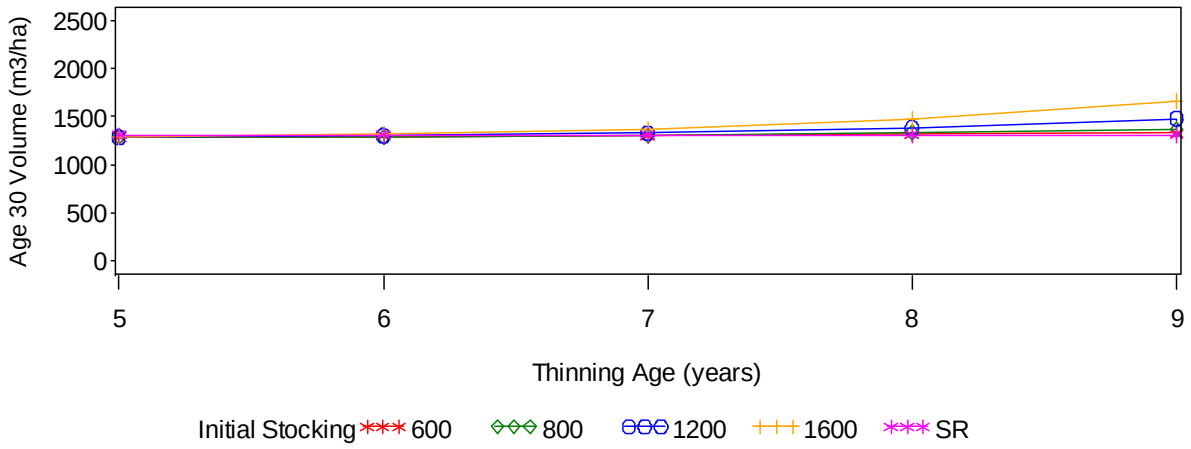
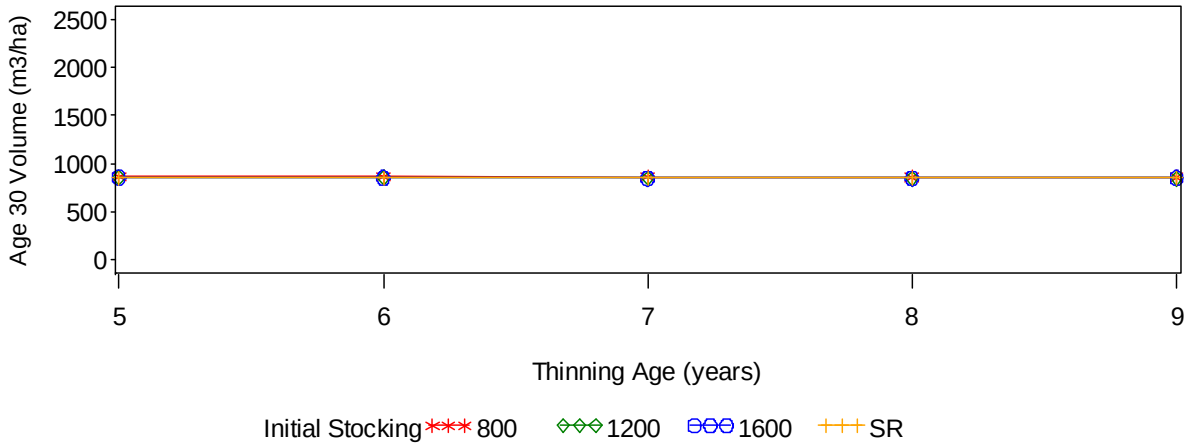
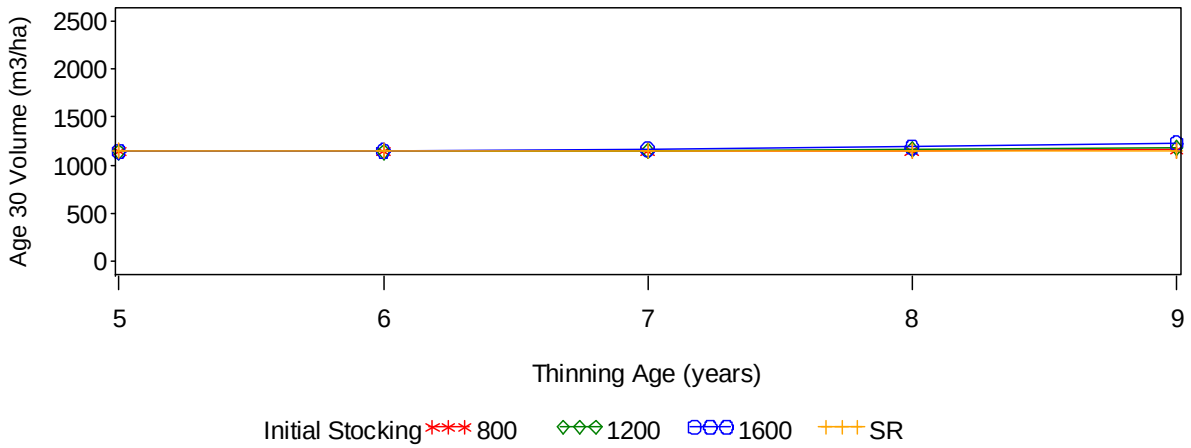


Figure 2. Predicted volume at age 30 years using age 10 starting measurement and post-thin stocking of 400 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

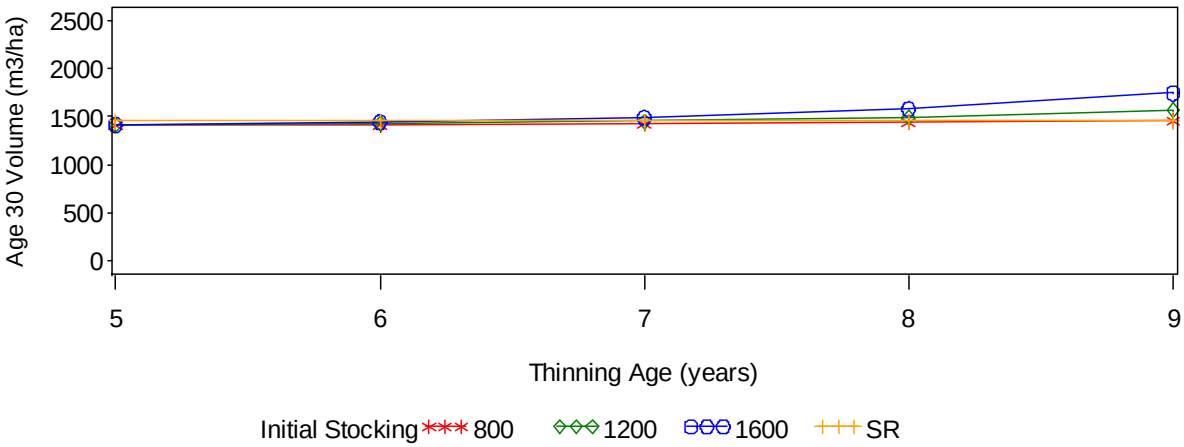
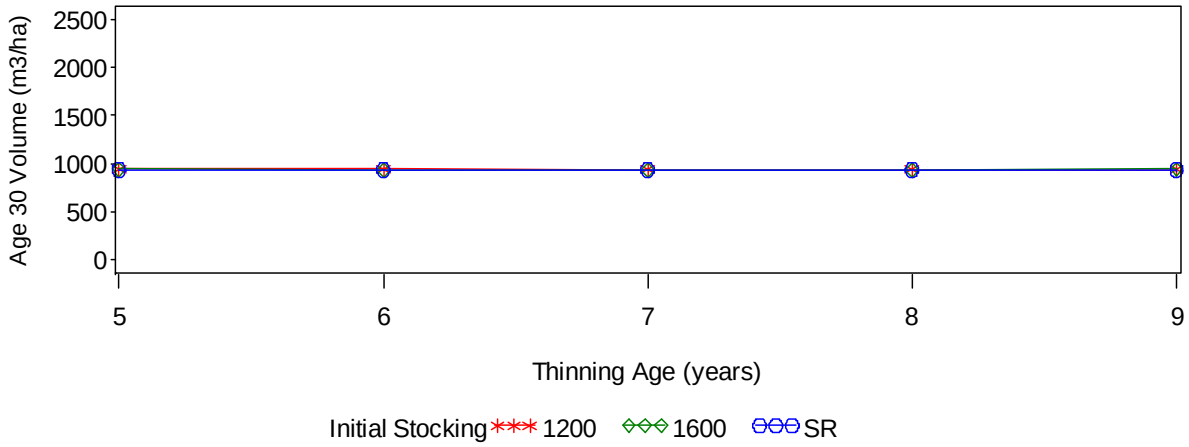
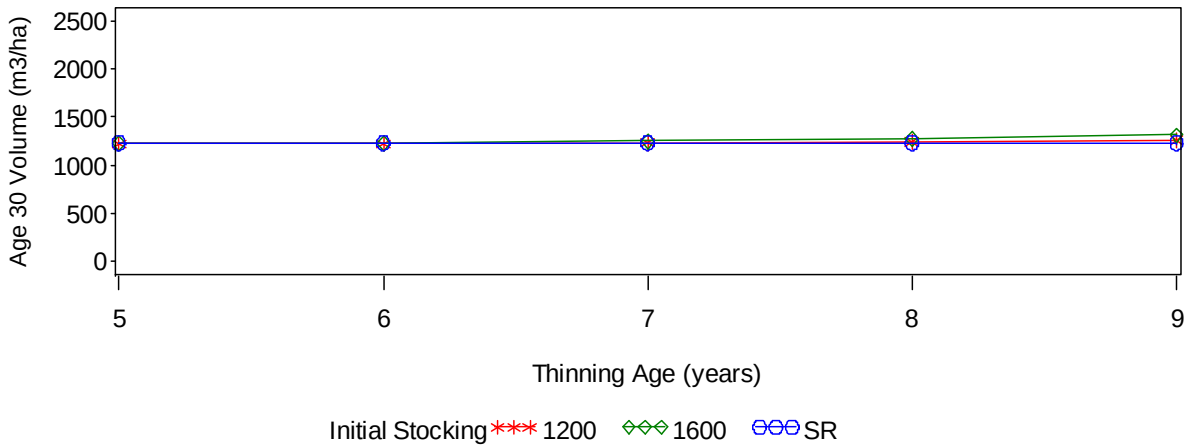


Figure 3. Predicted volume at age 30 years using age 10 starting measurement and post-thin stocking of 600 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

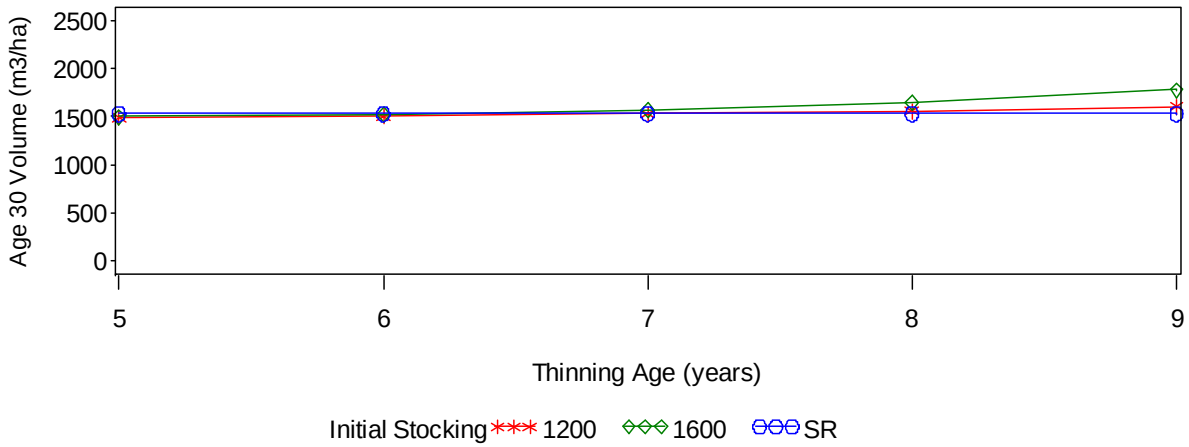
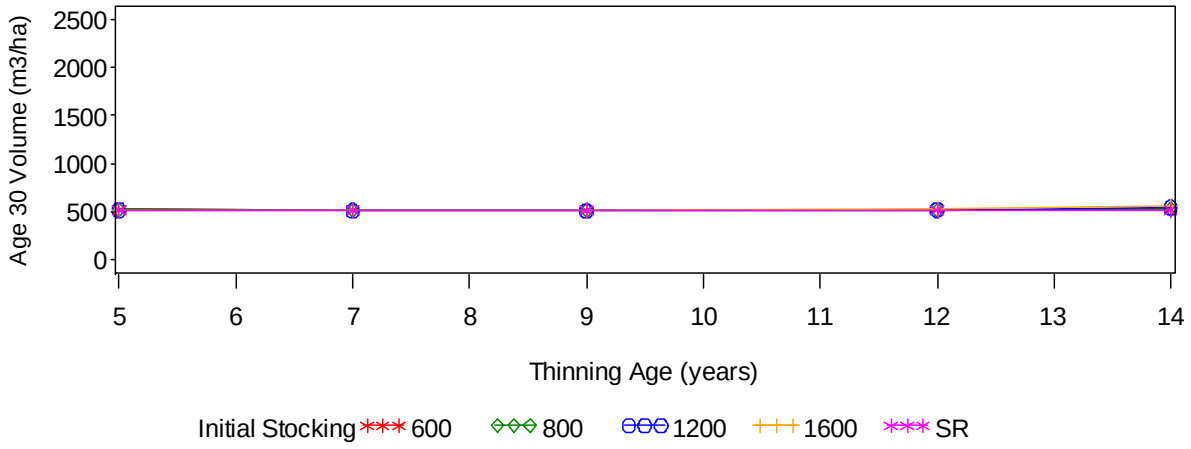


Figure 4. Predicted volume at age 30 years using age 10 starting measurement and post-thin stocking of 800 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



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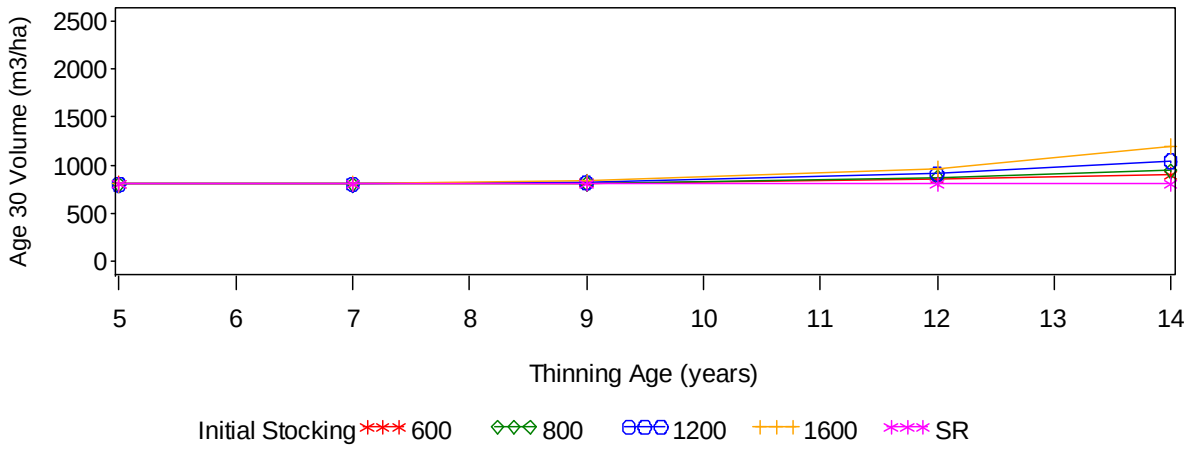


(c) High productivity site

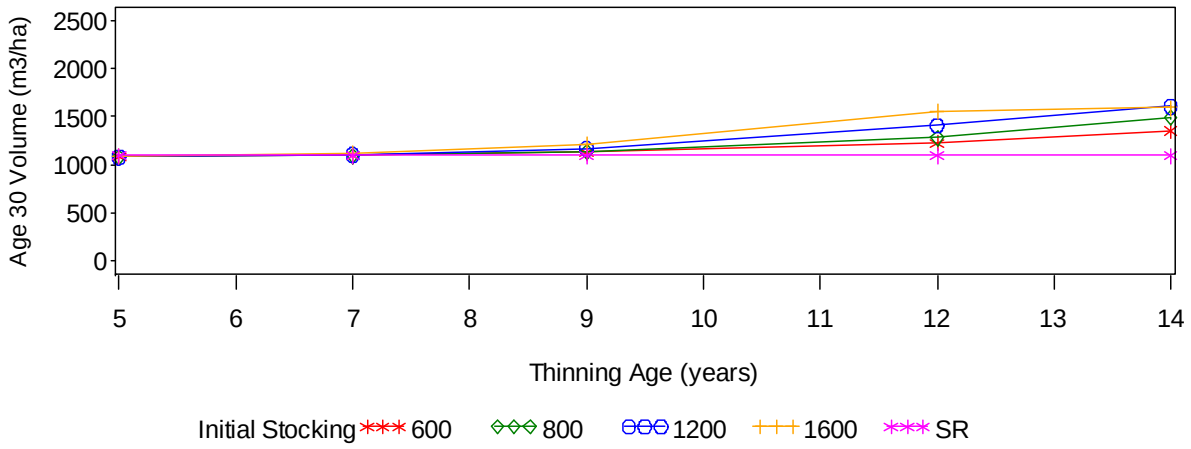
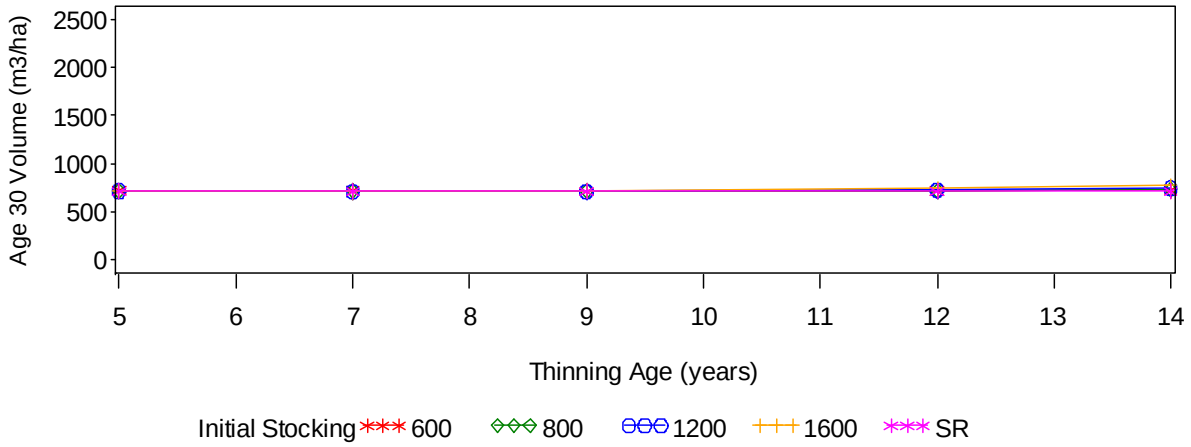
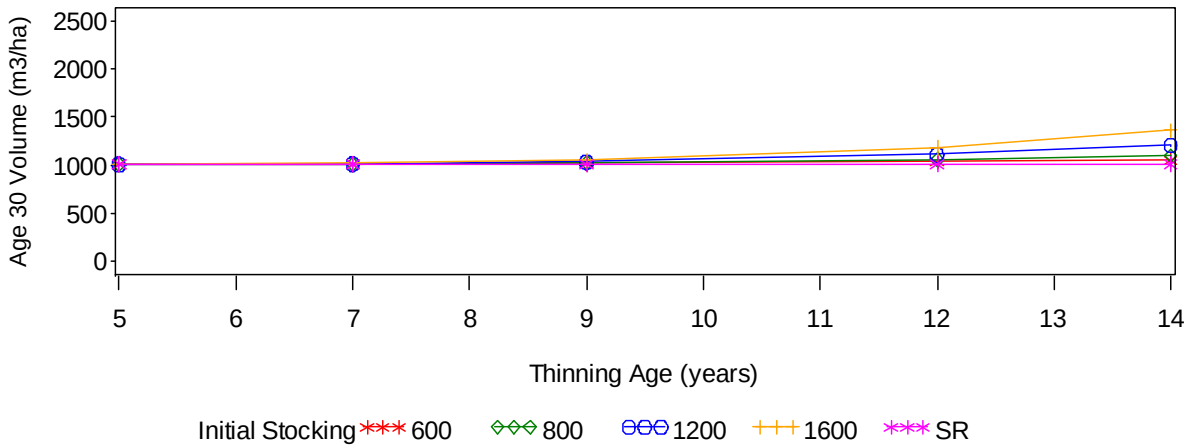


Figure 5. Predicted volume at age 30 years using age 15 starting measurement and post-thin stocking of 200 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

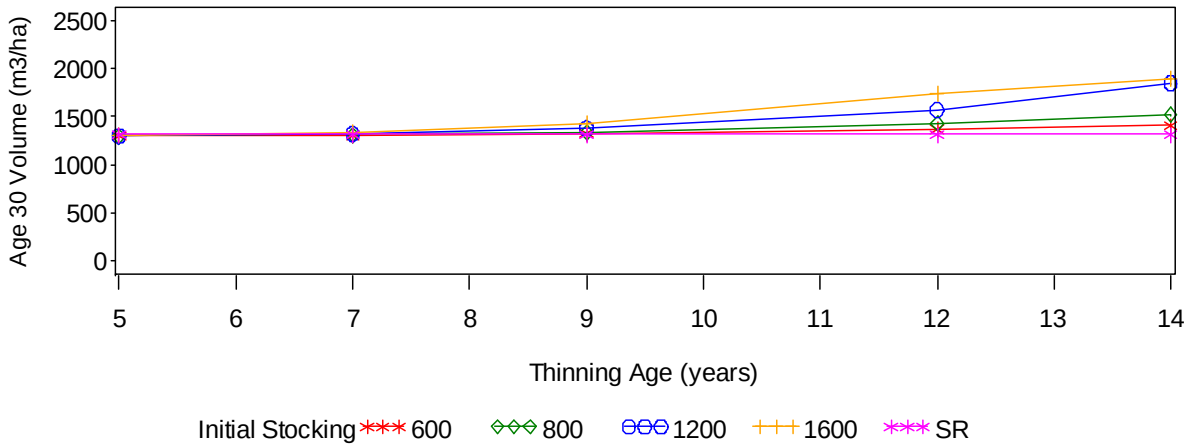
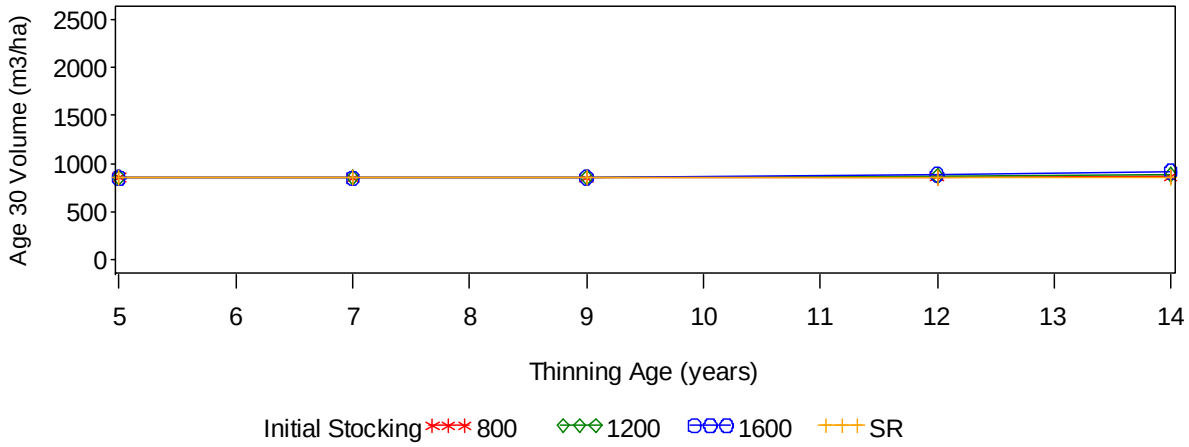
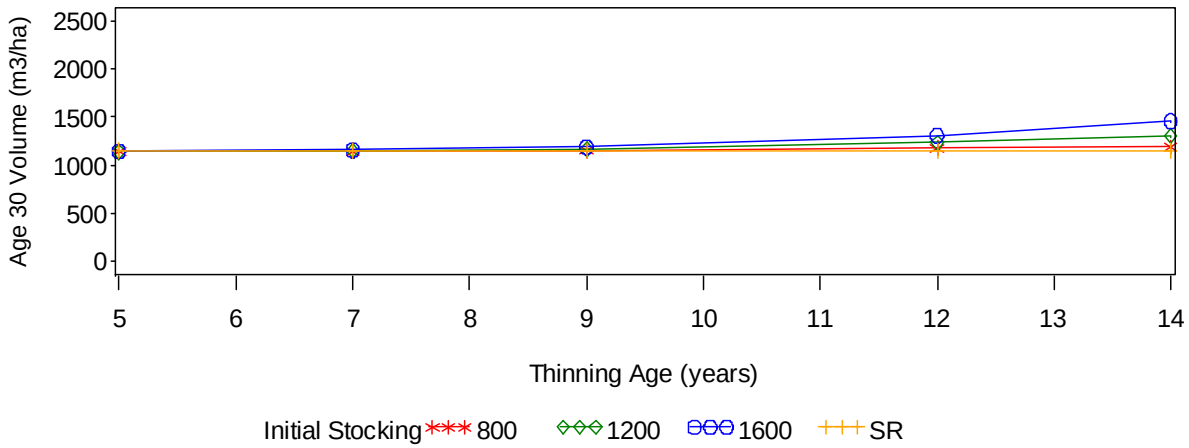


Figure 6. Predicted volume at age 30 years using age 15 starting measurement and post-thin stocking of 400 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

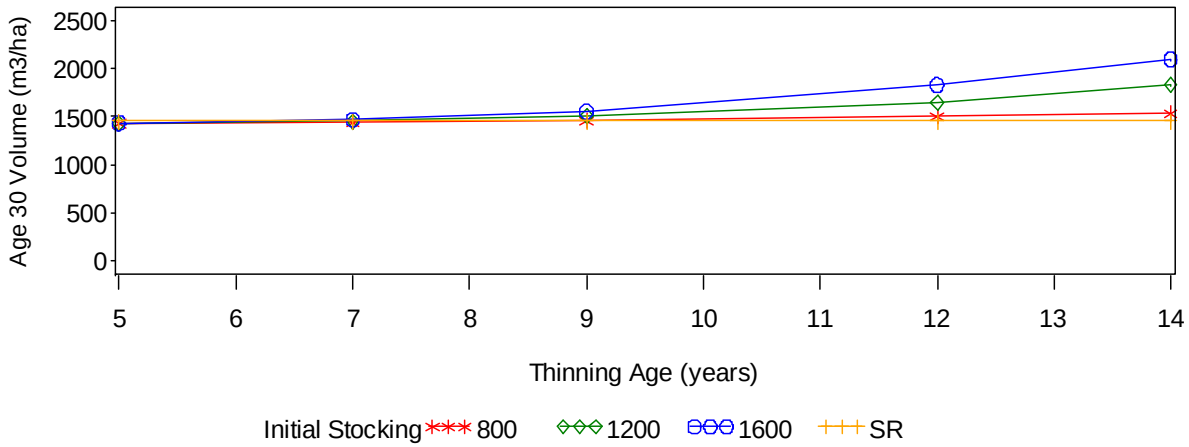
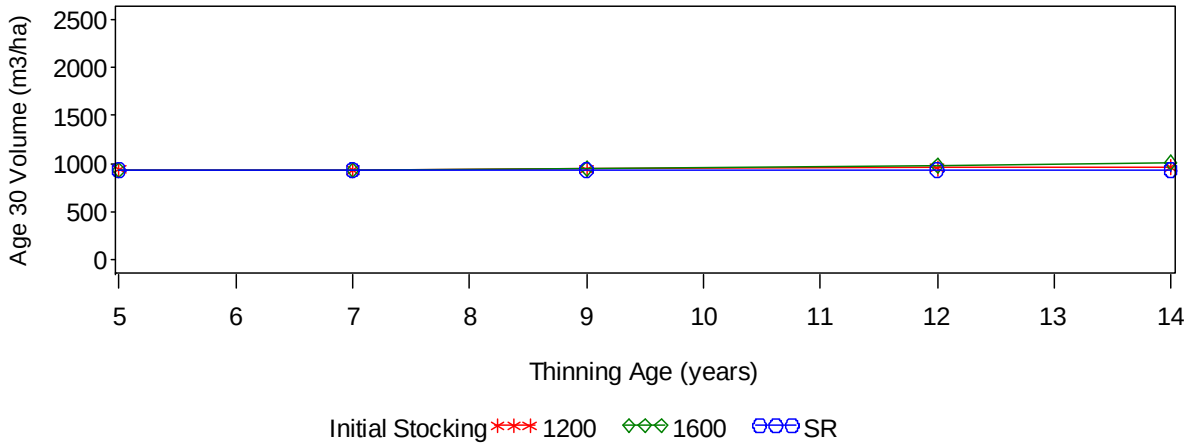
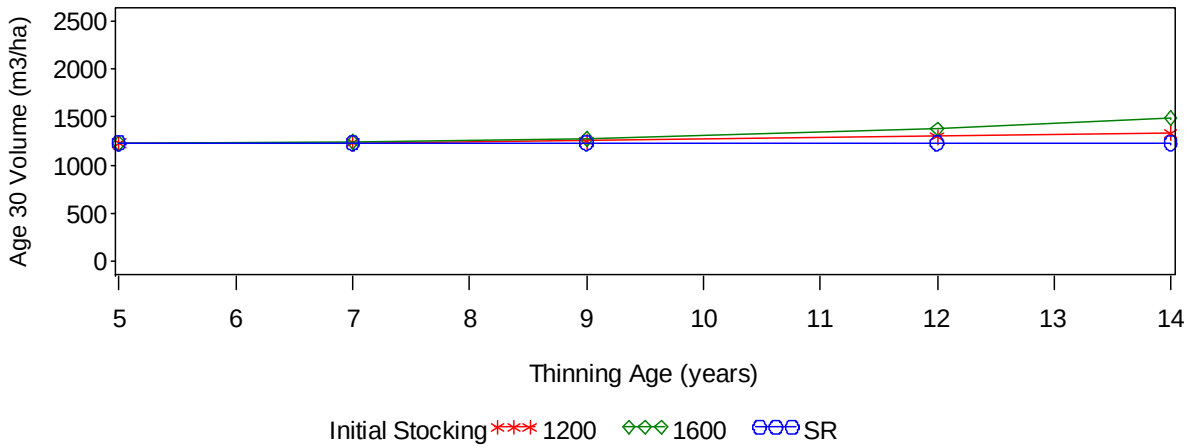


Figure 7. Predicted volume at age 30 years using age 15 starting measurement and post-thin stocking of 600 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

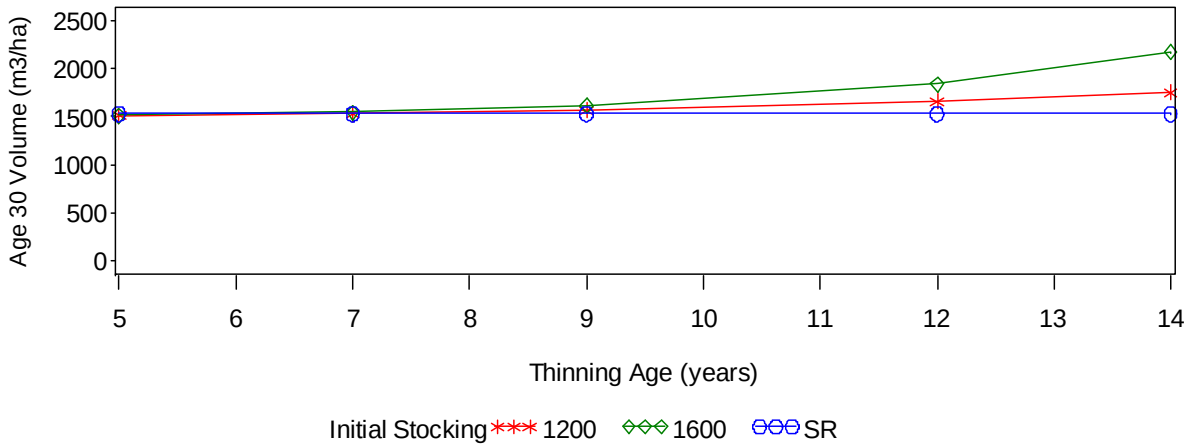
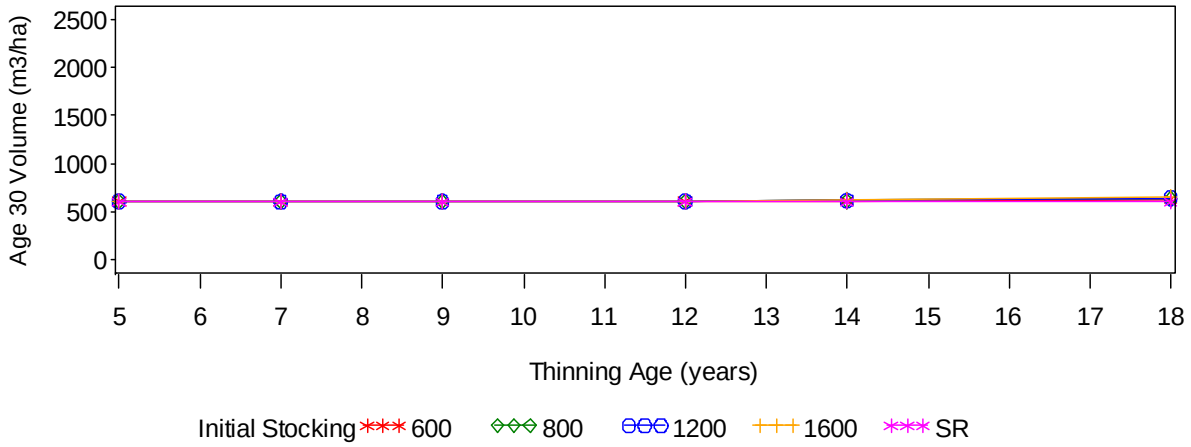
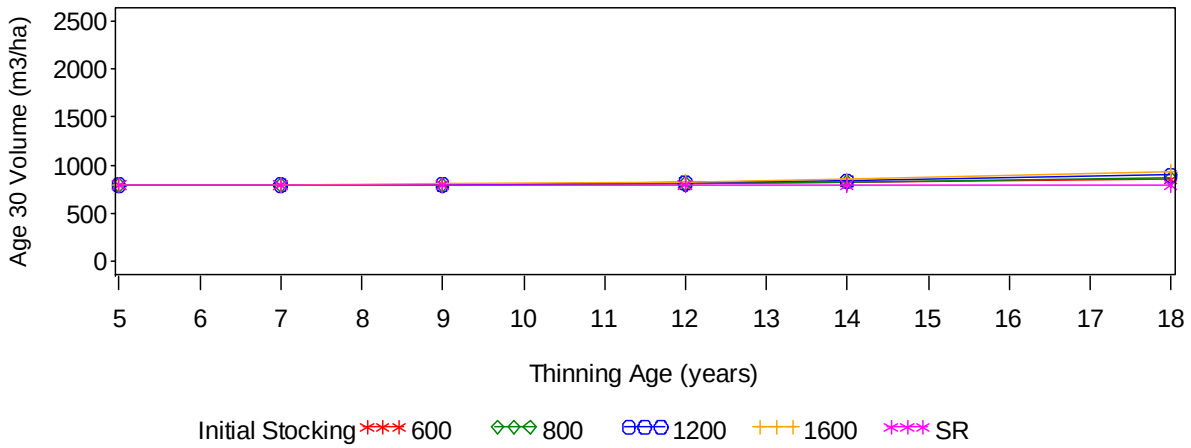


Figure 8. Predicted volume at age 30 years using age 15 starting measurement and post-thin stocking of 800 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

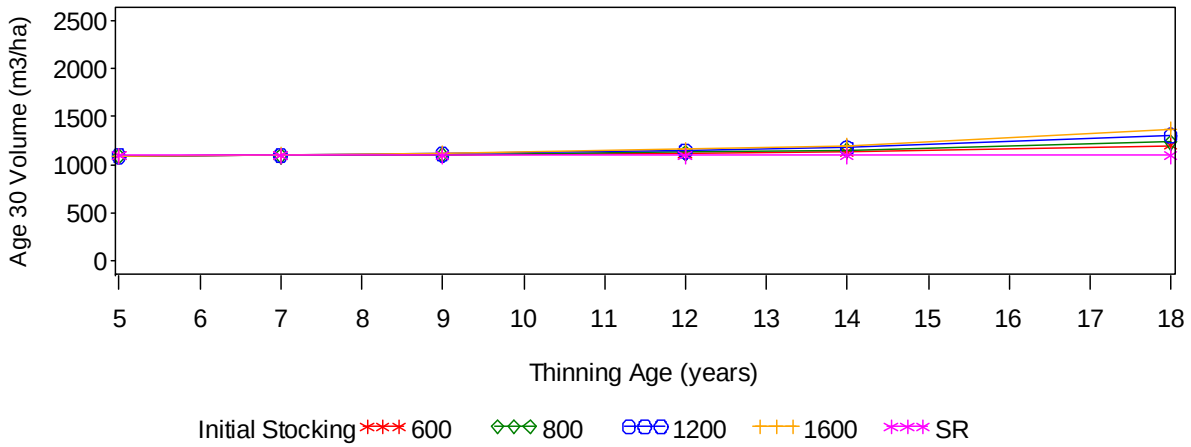
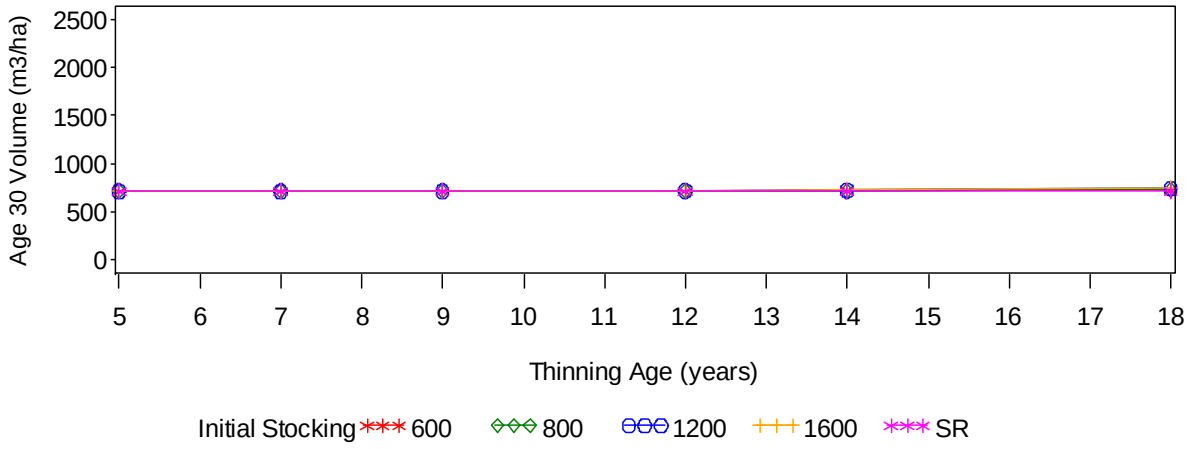
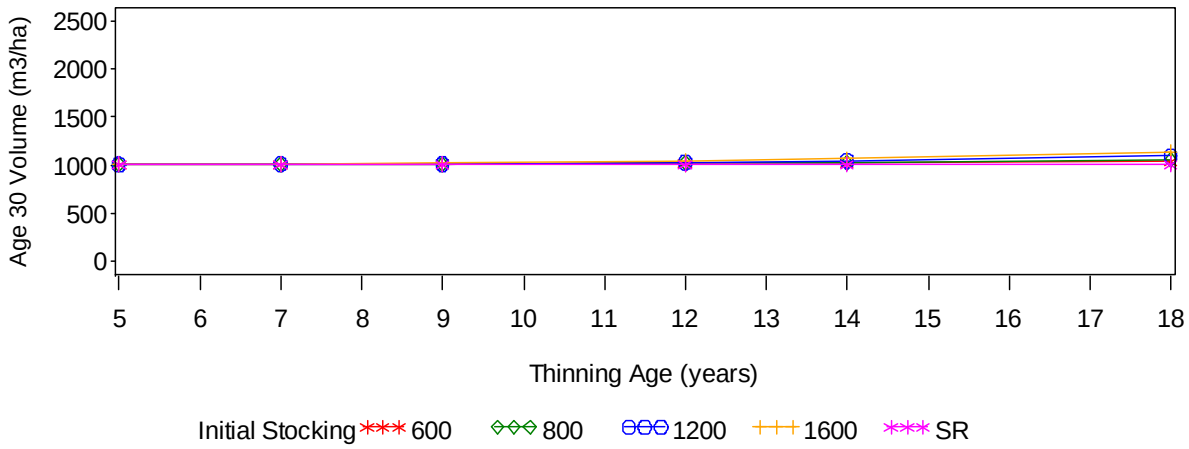


Figure 9. Predicted volume at age 30 years using age 24 starting measurement and post-thin stocking of 200 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

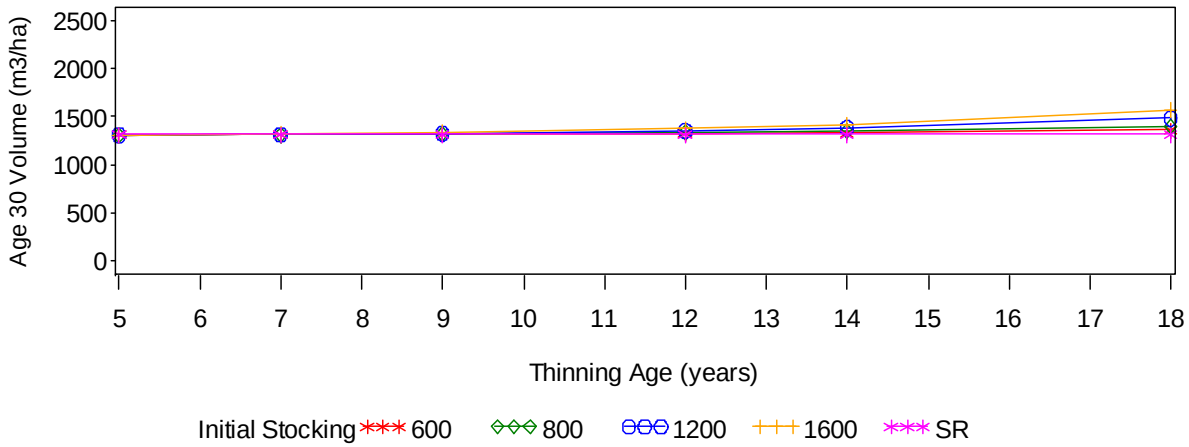
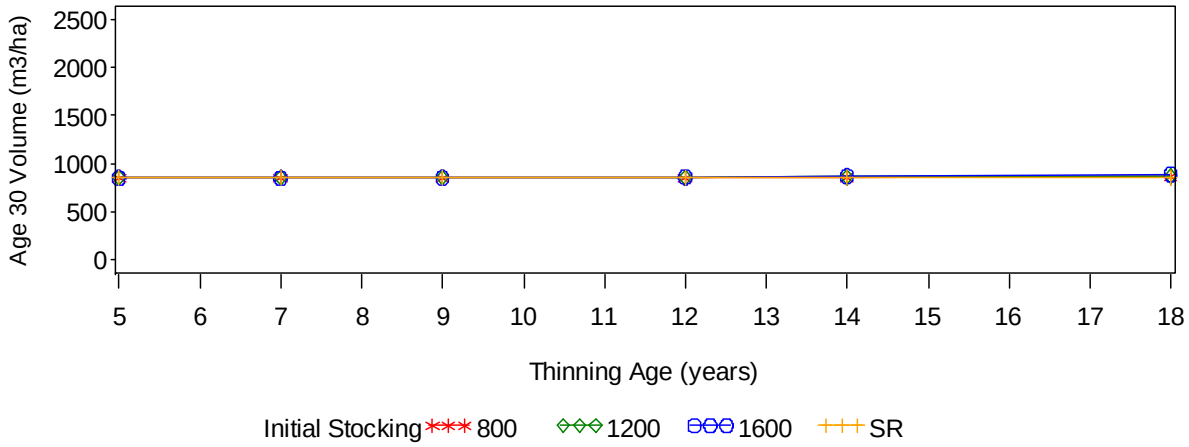
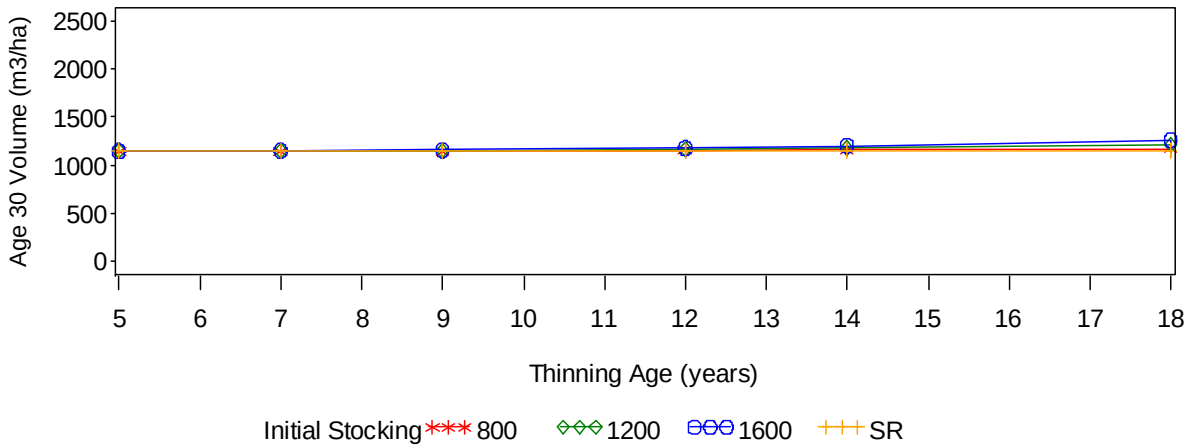


Figure 10. Predicted volume at age 30 years using age 34 starting measurement and post-thin stocking of 400 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

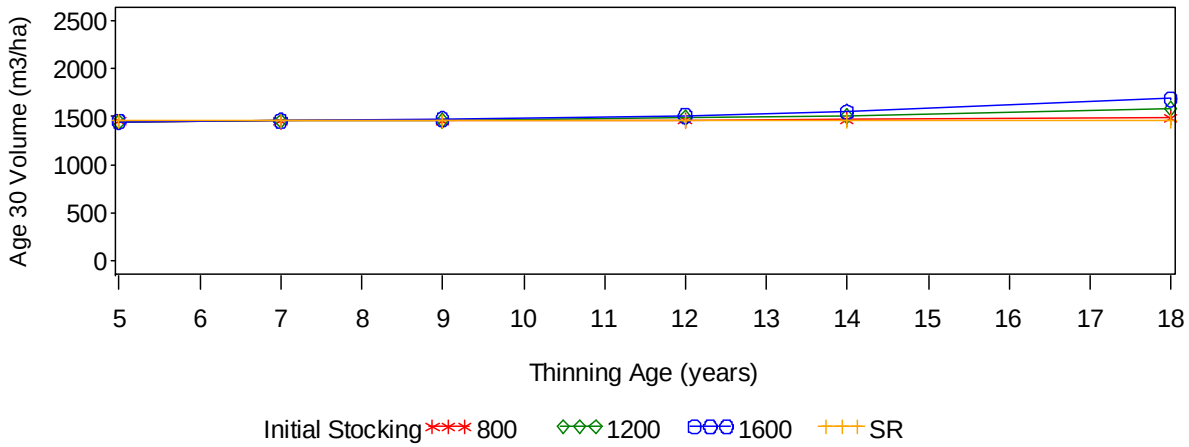
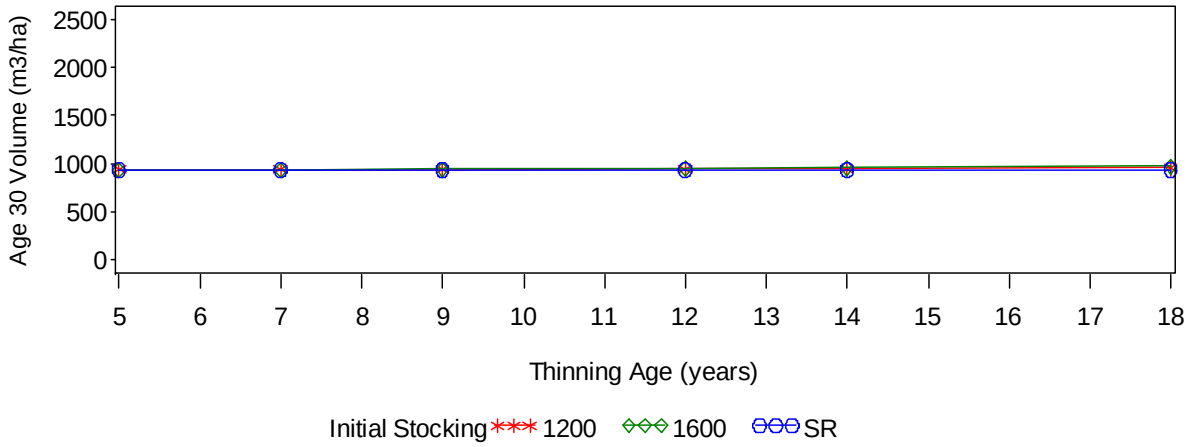
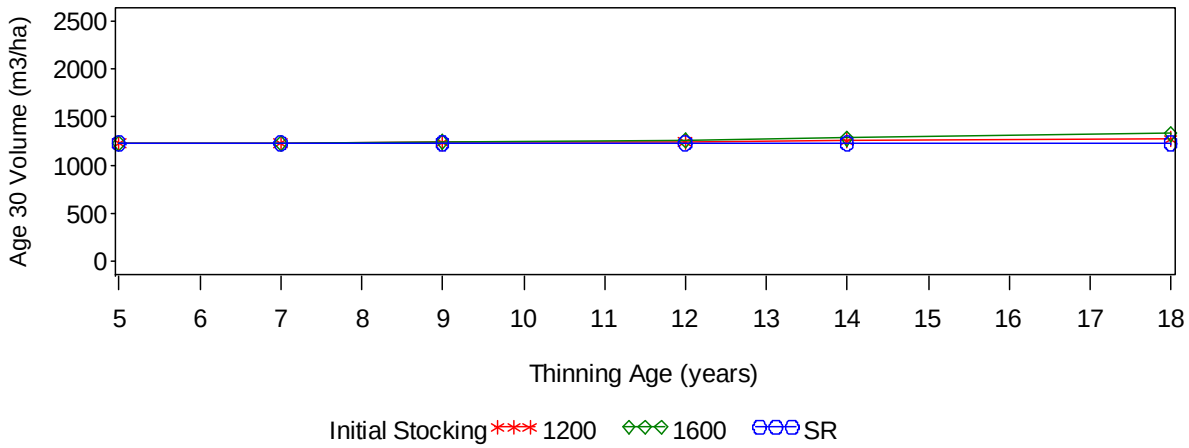


Figure 11. Predicted volume at age 30 years using age 24 starting measurement and post-thin stocking of 600 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

(a) Low productivity site



(b) Medium productivity site



(c) High productivity site

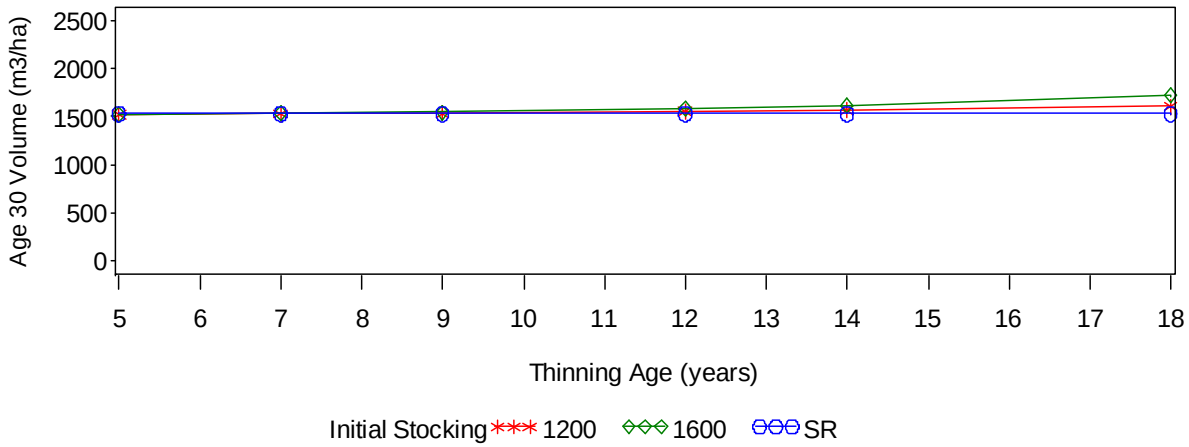


Figure 12. Predicted volume at age 30 years using age 24 starting measurement and post-thin stocking of 800 stems/ha. Predictions are shown for (a) low, (b) medium and (c) high productivity sites, for a range of initial stockings and thinning ages, and for the standard regime (SR).

CONCLUSIONS

The following points summarise the key conclusions of this analysis concerning the importance of accurately specifying thinning history when using the 300 Index growth model:

- For stands measured at about age 10 years, specifying the timing and intensity of a previous thinning accurately is not critical except on high productivity sites when the thinning occurred from an initial stocking greater than 800 stems/ha within two years of the measurement.

- For stands measured at about age 15 years, specifying the timing and intensity of a previous thinning accurately is important if the thinning occurred after age 10 years on high productivity sites, and after age 12 years on medium productivity sites, especially when the initial stocking was greater than 800 stems/ha. Specifying the precise timing and intensity of thinnings is less important on low productivity sites, and when thinning occurred prior to age 10 years on high productivity sites and 12 years on medium productivity sites.

For stands measured at about age 24 years, specifying the timing and intensity of a previous thinning accurately is important only if the thinning occurred after age 15 years on higher productivity sites.

An ‘expert system’ which allows users to run the 300 Index model when history data is missing is described in FFR report R035[(2)]. It is intended to implement this system in FORECASTER shortly.

REFERENCES

1. Kimberley, M. O., West, G.G., Dean, M. G., R. Knowles, R. L. 2005. The 300 Index - a volume productivity index for radiata pine. New Zealand. Journal of Forestry 50: 13-18.

2. Kimberley, M. O. 2011. Procedures to allow for incomplete stand histories when running the 300 Index Growth Model. FFR Report No. R035.