FRI PROJECT REPORT
NO. 1732

EVALUATION OF THE PERFORMANCE OF GROWTH MODELS FOR KAINGAROA

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REPORT NO. 7 DECEMBER 1987

Note : Confidential to Participants of Stand Growth Modelling Programme

: This material is unpublished and must not be cited as a literature reference

FRI/INDUSTRY RESEARCH COOPERATIVES

EXECUTIVE SUMMARY

This report is the result of work performed by Cooperative members to assistin the validation of the interim growth model for P.Radiata on the Pumice Plateau, KGM3. This work was performed independently of the FRI researchers who constructed the model and consists of three articles :

Growth Model Comparisons	W.T.Hayward & B.Rawley NZFP Forests
Evaluation of the Performance of Growth Models	I.C.Jenkin Timberlands Central
Evaluation of KGM3 by Tasman Forestry Ltd	M.Colley, F.Law & D.New Tasman Forestry

There are significant differences between KGM3 and the NZFP model. This would result in different beliefs about the correct way to achieve management objectives when analysing silvicultural regimes. KGM3 predicts more volume than NZFP for higher stocked regimes. KGM3 indicates that the greater number of stems at either age 5 or 11, the greater the volume at age 30, unlike NZFP where maximum volume is attained with residual stockings of 800 and 600 stems/ha respectively.

For the regimes practised by Timberlands in the Bay of Plenty, KGM3 provides a marked improvement in basal area prediction over its predecessor KGM2. Over a range of final crop stocking regimes at age 8, errors at age 24 were confined to within +/- 7%.

At Tarawera, KGM3 possibly slightly overpredicted diameter and volume at age 24, for minimum tending regimes, in the order of 5%. The model did not appear to predict well the residual BA following thinning at age 9 for the agroforestry regime practised at Ngatira.

GROWTH MODEL COMPARISONS
KGM3: NZFP

W.J. HAYWARD
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JUNE 1987

30 June 1987

GROWTH MODEL COMPARISONS

The interim version of the Kaingaroa Growth Model (KGM3), has been made available to members of the Stand Growth Modelling Co-operative. This model has interest to NZFP because of the site similarities between the forest that this model is applicable to and the forests owned by NZFP in the Kinleith region.

This paper describes some of the simple comparison tests undertaken using the interim KGM3 model and the NZFP Growth Model, looking particularly at differences in estimated yield and a brief summary of the consequences.

1. Comparison of Growth Model Projections with Kinleith PSP Data

Subsets of Kinleith cutover PSP's were formed, each subset having a similar tending history. An average starting point was calculated for each subset from the plot data and these values of basal area, height, stocking and site index were used as the initial Growth Model input values.

Figures 1-4 illustrate the growth model projections compared with the development of basal area in individual plots.

On the basis of examining these figures:

a. Unthinned regime. The NZFP model is more plausible than KGM3.

b. For the intermediate stocking range ie. 300-600 both models appear equally plausible however, KGM3 consistently predicts greater yields. This, coupled with the problems associated with yield estimates at higher stockings would suggest caution when viewing yield predictions in this range.

c. At less than 250 st/ha both models would appear to be over optimistic.

2. The Self Thinning Rule

It has been observed that in natural communities there is for any population density, an upper limit to the size of individual organisms. During the development of such communities, as this upper limit is approached, mortality sets in. After the onset of mortality the relationship between surviving population density and individual size can be described by a simple rule:

$$\ln(w) = K - 3/2 \ln(P)$$

where w - individual size

P - density

K - constant

this relationship is called the self-thinning rule. For Kinleith forest, the self-thinning rule was defined by Drew & Flewelling (For. Sci. 1977) as:

$$\ln(w) = 10.08 - 3/2 \ln(P)$$

where w - average tree size in m

P - st/ha

Although this equation was based on first crop data, Figure 5 shows that it is still applicable to cutover PSP's established after 1940. Note that it is a measure of site and species potential but has no concept of time taken to reach a particular state. Superimposed on Figure 5 are simulations from the two Growth Models. In each case simulation is of an unthinned regime to age 40. The NZFP model behaves in a manner consistent with the self-thinning rule. KGM3 does not, but defines a new higher level of site/species potential. Further analysis reveals a significant difference in mortality between the two models (residual age 40 stockings of 403 and 846 for the NZFP and KGM3 models respectively) and this factor alone can explain some of the yield differences apparent in Figures 1-4.

3. The Effect of Initial BA and SPH on CF Volume

Figure 6 illustrates the total stem volume at age 30 against an initial BA at age 8 and an initial stocking level (ranging from 200-500 st/ha). Fundamental differences between the two models are demonstrated in this Figure. In comparison with the NZFP model, KGM3 is relatively insensitive to starting basal area but relatively sensitive to stocking level. That is, increasing the residual stocking has a significantly greater effect on Clearfell Volume than increasing the initial basal area for a given stocking.

This relationship between stocking and basal area is an important area of difference between the two models. For the NZFP model, the same basal area distributed over fewer stems will result in slightly more clearfell volume. For KGM3, less stems means less volume, irrespective of starting basal area.

4. Total Stem Volume (age 30) Against a Range of Stocking Levels at Age 5

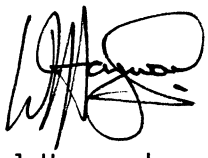
Figure 7 displays the effects of waste thinning at age 5 to a range of different stockings, from 1712 st/ha initially. Again, KGM3 indicates that the more stems left, the greater is the volume production. The NZFP model indicates that there is no point in leaving more than 800 st/ha if maximum volume is the aim.

5. Total Stem Volume (age 30 - Including Thinning Volume) Against a Range of Thinned Stocking Levels at Age 11

Again, referring to Figure 8, KGM3 favours a greater number of stems for greater volume. The NZFP model would warn against leaving more than 600 st/ha if maximum volume production was the aim.

Conclusion

This paper has demonstrated that there are significant differences in yield prediction between the interim KGM3 model and the NZFP Growth Model. These differences are important if they (a) result in different beliefs about the correct way to achieve specific long term stand management objectives or (b) result in different beliefs as to the short term availability of wood. Adoption of the KGM3 model for the Kinleith forests would undoubtably change our current philosophy on the above two counts.



W J Hayward
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B Rawley
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WJH : pf

(R002063)

Fig 1
NZFP FORESTS LIMITED

TWO GROWTH MODELS CF PSP CUTOVER DATA

Regime - Unthinned, 34.0 m^2, 1205 St/Ha, Age 10.4, Si 29.4

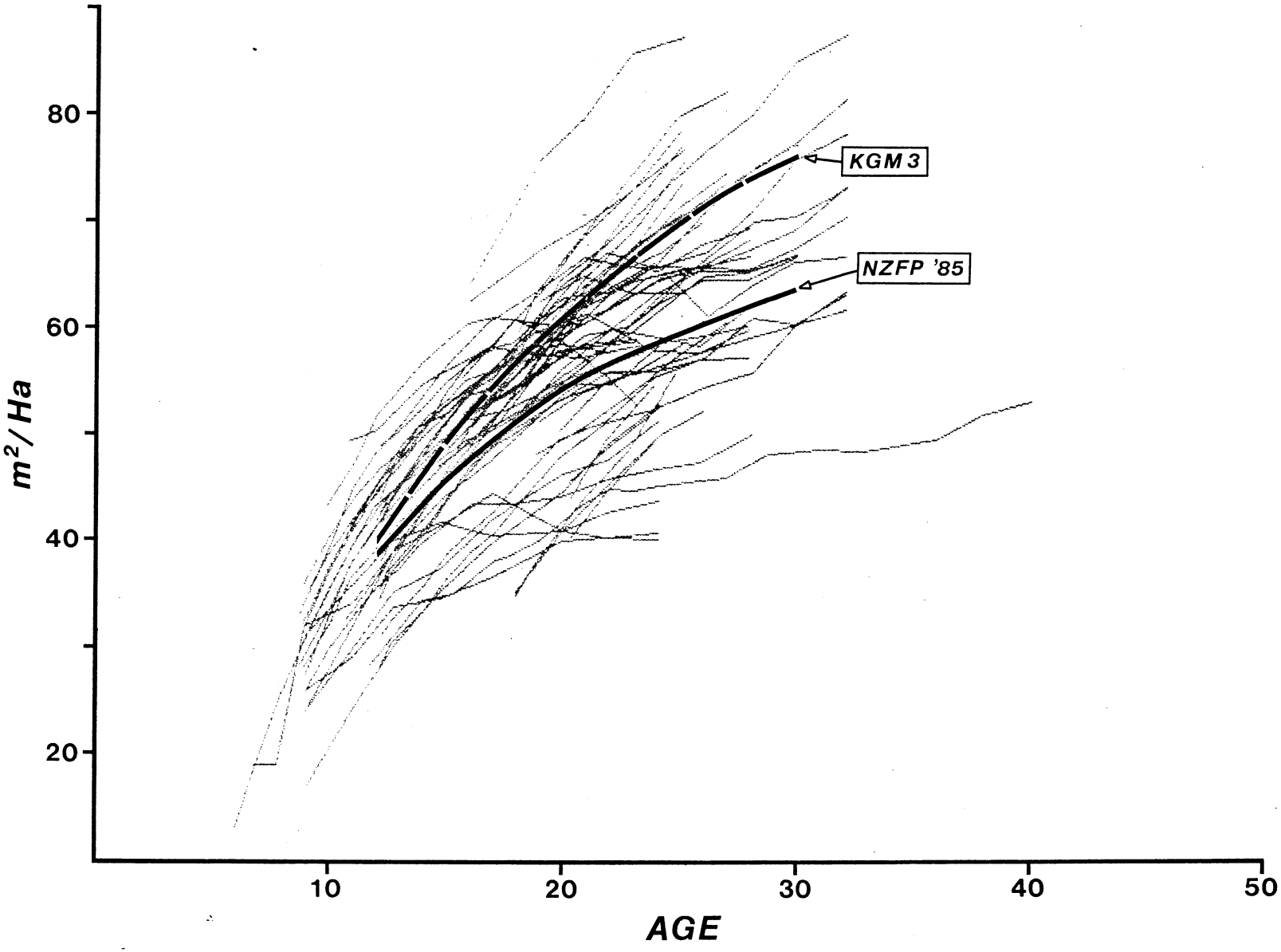


Fig 2
NZFP FORESTS LIMITED

TWO GROWTH MODELS CF PSP CUTOVER DATA

Regime – Thinned, 22.8 m^2, 487 St/Ha, Age 11.0, Si 33.2

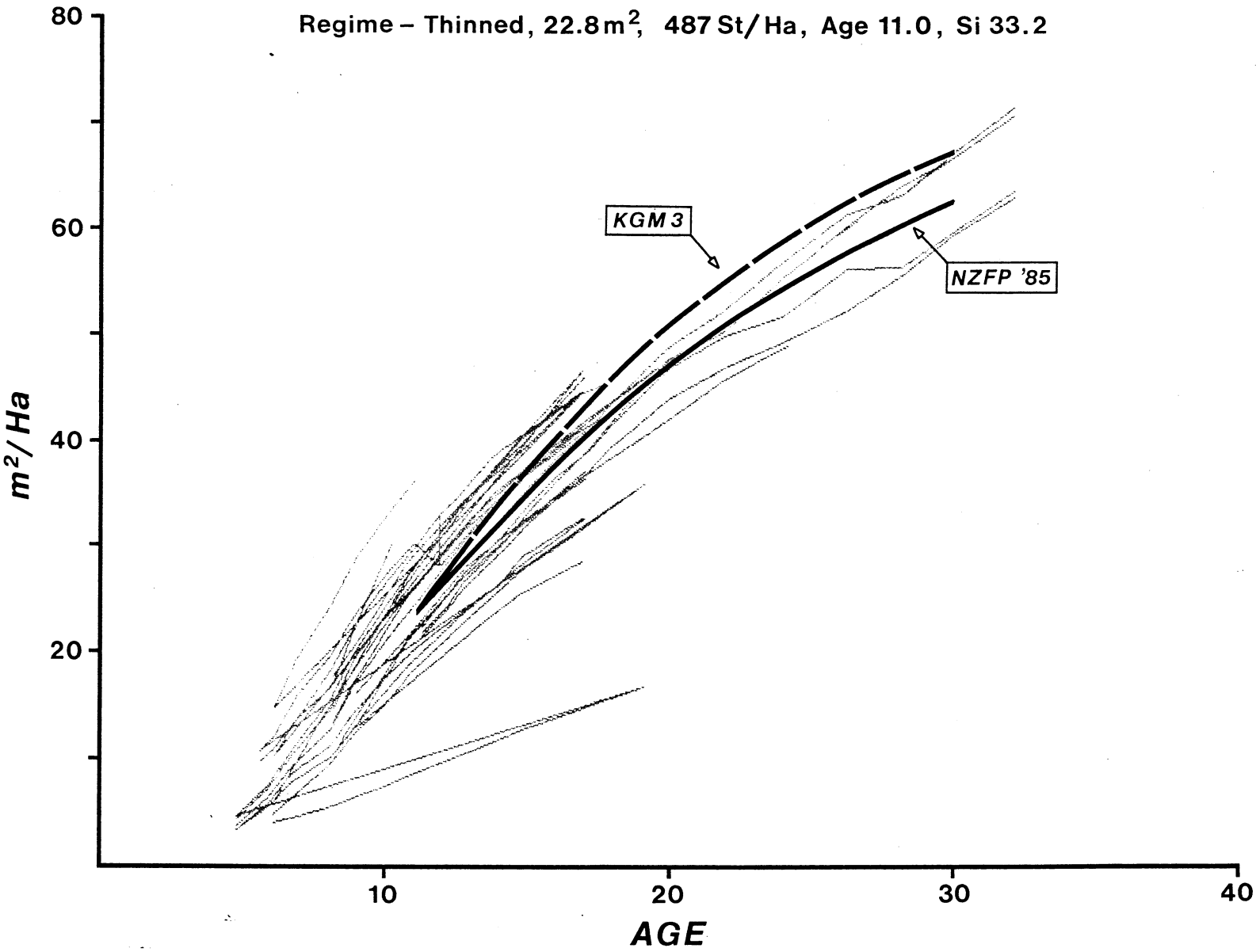


Fig 3

NZFP FORESTS LIMITED

TWO GROWTH MODELS CF PSP CUTOVER DATA

Regime – Thinned, 18.2 m^2, 369 St/Ha, Age 11.8, Si 33.2

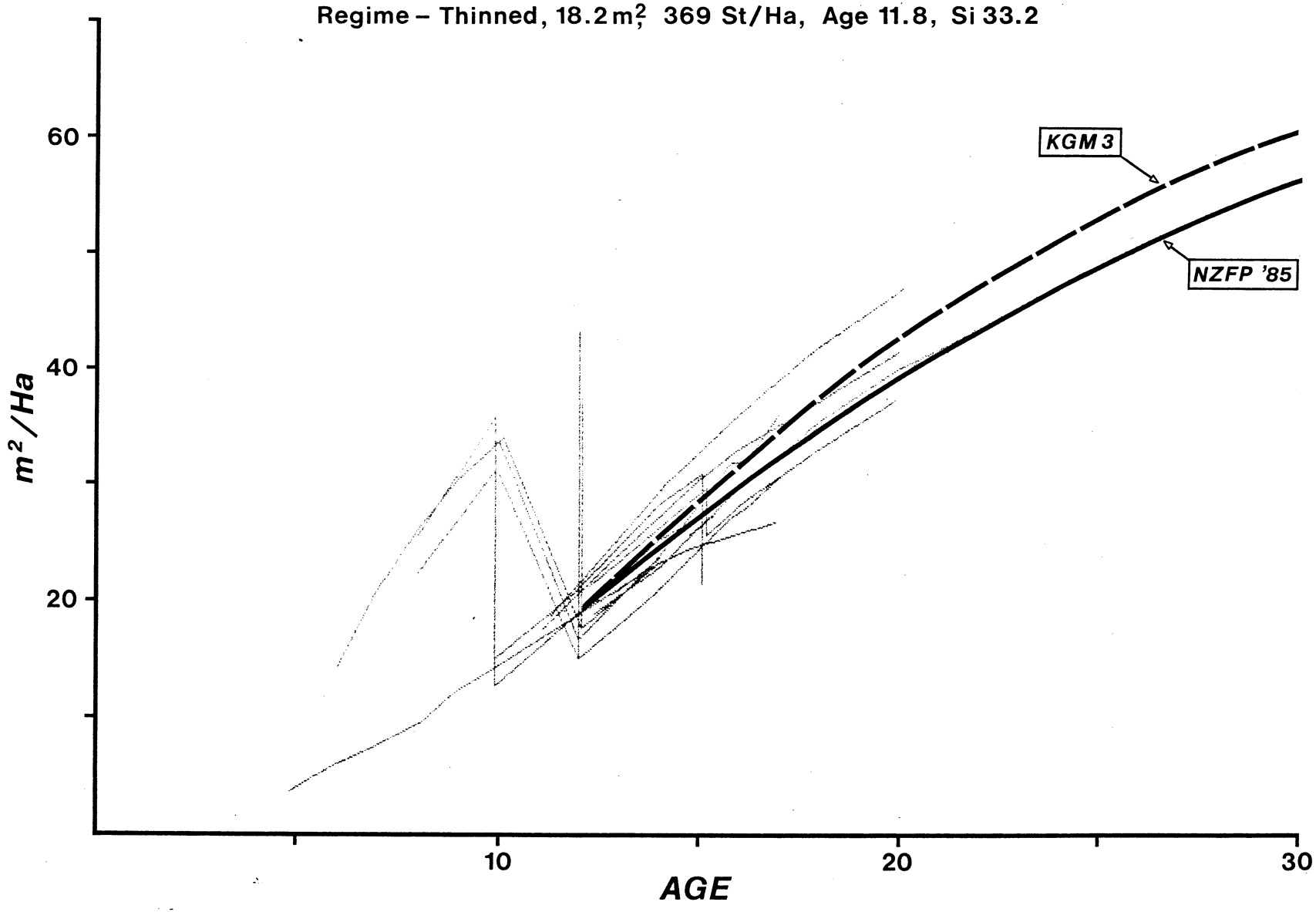


Fig 4

NZFP FORESTS LIMITED

TWO GROWTH MODELS CF PSP CUTOVER DATA

Regime – Thinned, 21.4 m^2, 244 St/Ha, Age 14.2, Si 33.2

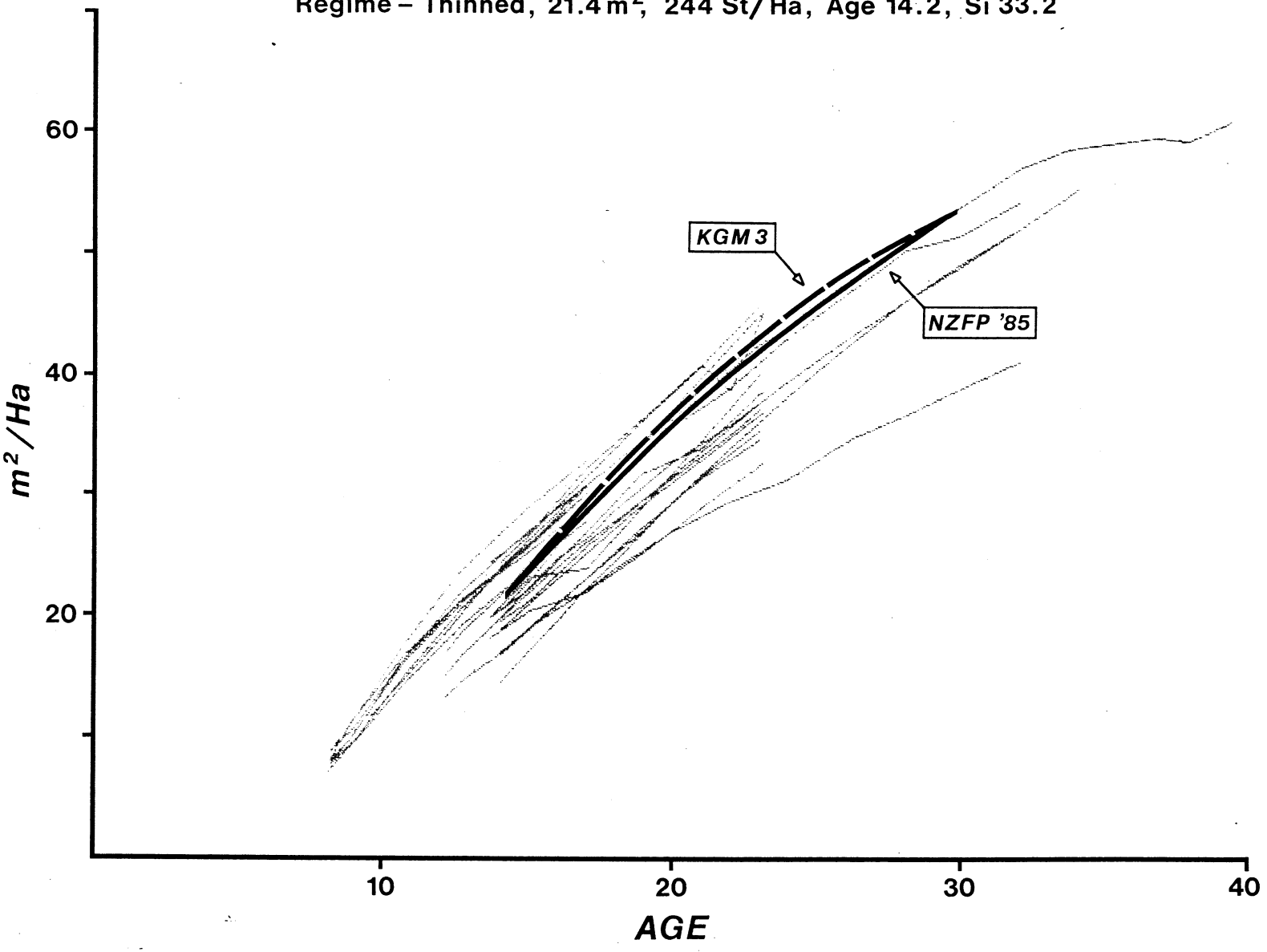


Fig 5
NZFP FORESTS LIMITED

SELF-THINNING RULE

CF GROWTH MODELS - Regime 7.0 m^2, 1712 St/Ha, Age 5.0, Si 33.2

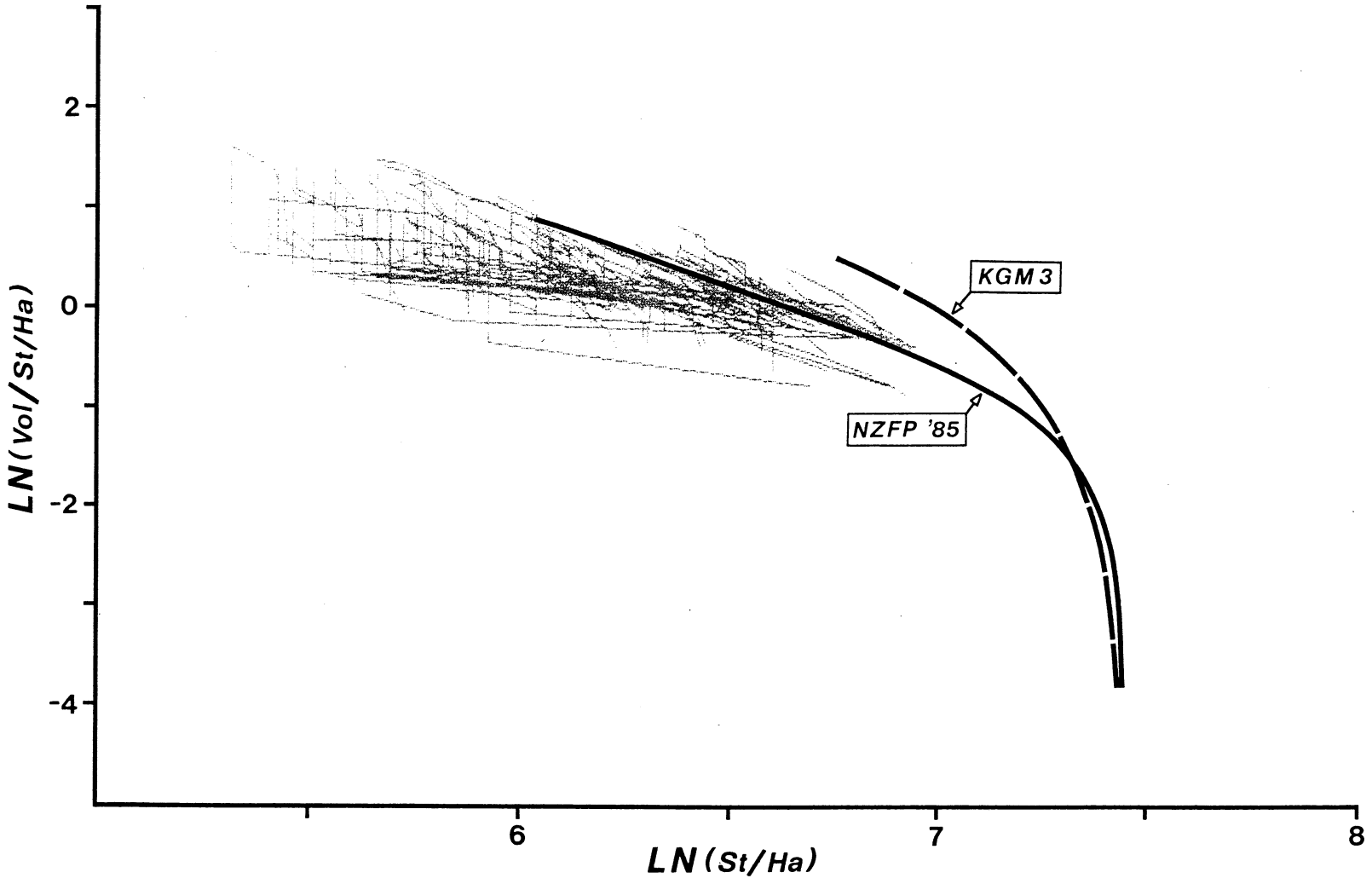


Fig 6

NZFP FORESTS LIMITED

The Effect Of Initial Basal Area & St/Ha On Clearfell Volume

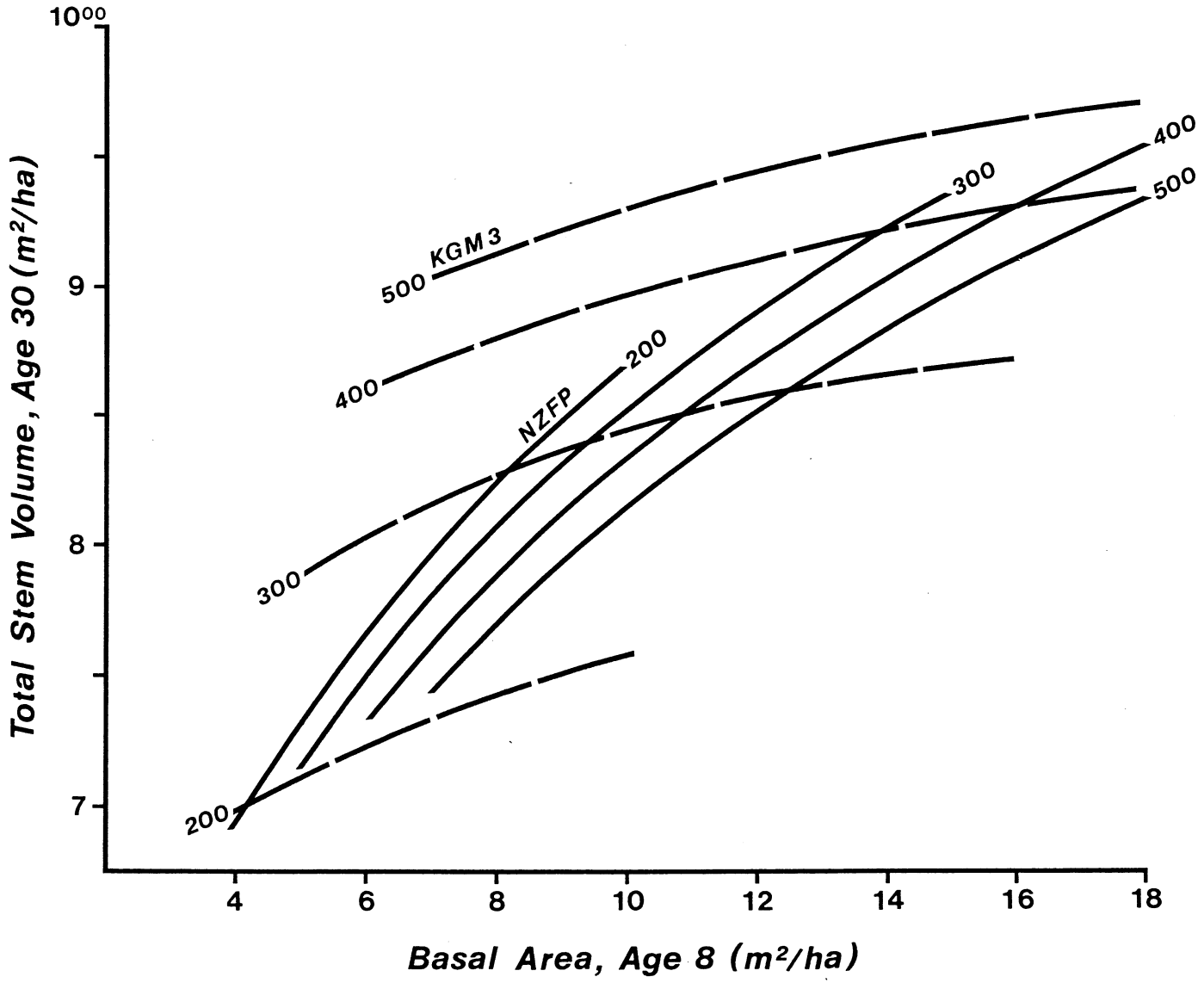


Fig 7

NZFP FORESTS LIMITED

All Waste Thinning By Sub-Routine Of Respective Model

Starting Point - Age 5.0, 1712 St/Ha, Ba 7.1m^2, Si 33.2m, H 6.0m

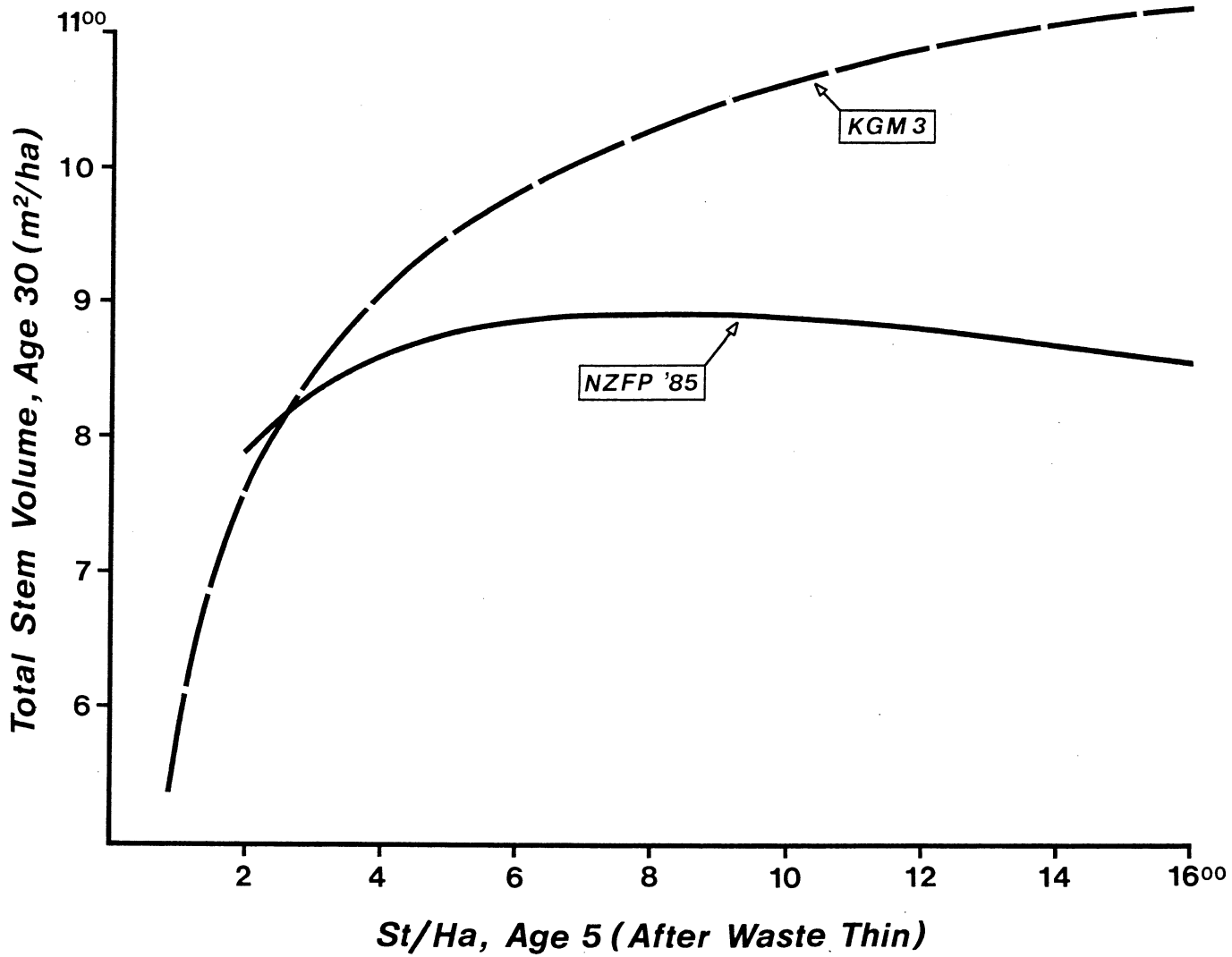
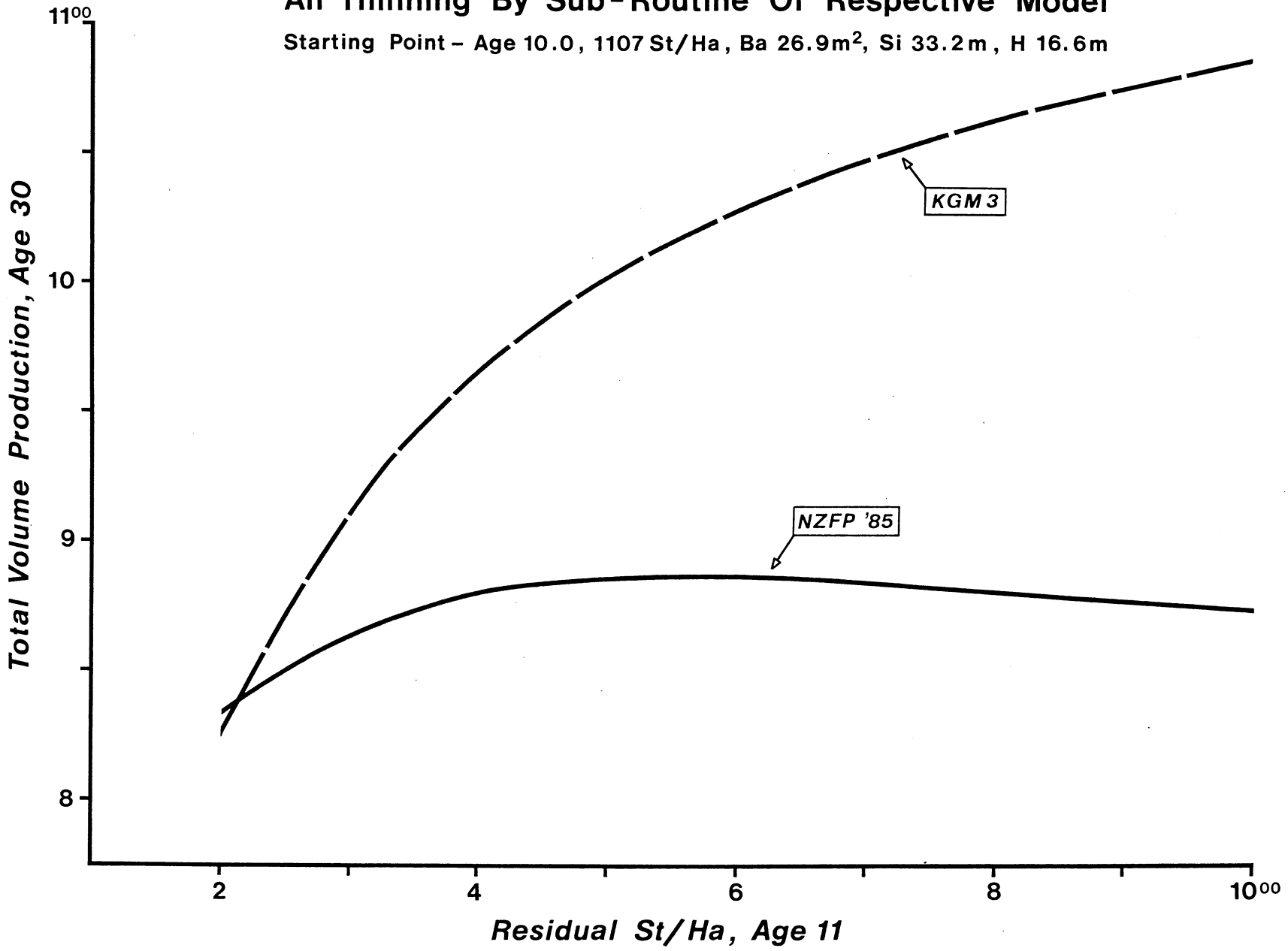


Fig 8

NZFP FORESTS LIMITED

All Thinning By Sub-Routine Of Respective Model

Starting Point – Age 10.0, 1107 St/Ha, Ba 26.9m^2, Si 33.2m, H 16.6m



EVALUATION OF THE PERFORMANCE OF GROWTH MODELS KGM3: KGM2

I.C. JENKIN

AUGUST 1987

EVALUATION OF THE PERFORMANCE OF GROWTH MODELS FOR KAINGAROA.

INTRODUCTION

This report describes the evaluation of the performance of the "Interim Stand Growth Model for Radiata Pine grown on the Central North Island Pumice Plateau" (KGM3) and the previously used model Kaingaroa Growth Model of Elliott and Goulding (KGM2).

The evaluation is based on measurements from Permanent Sample Plot 681. This trial consists of replicated plots thinned to a range of final crop stockings at an early age. This series was not included in the database for KGM3 because it is located in naturally regenerated stands. However, the trial represents sites and treatments typical of much of the resource to be felled up until the turn of the century.

Other replicated plots, differing in site and establishment were also analysed to confirm findings from the 681 series.

RESULTS

The plots analysed from the 681 series received two waste thinnings. The first at age 6 and the second, to final crop stocking, at age 8 years. The starting points for comparison were immediately following the first thinning. Measurements were made annually through to age 19, except for age 16, and finally at age 24.

Site index is in the range 31 to 35 metres.

Graphs comparing both growth models with the actual measurements are in the Appendix.

The following table shows the percentage over prediction of basal area at age 24 years for each of the thinning treatments.

MODEL	STOCKING (s/ha)				
	198	296	444	543	765
KGM2	19	5	-2	-14	-18
KGM3	7	3	1	-5	-6

These results are generally reinforced by the analysis of other replicated plots.

Nine plots in series 589 (included in the database of KGM3) thinned to 250 s/ha at age 9 years showed an overprediction of 9% by KGM2 at age 20 years. KGM3 underpredicted the basal area at age 20 years of these same plots by 4%.

A further four plots from series 681 thinned to 198 s/ha at age 8 years were also underpredicted by KGM3 at age 24 years by 4%. Thus the overprediction of basal area by KGM3 at low stockings indicated in the

above table appears to be an anomalous result.

At a final crop stocking of 117 s/ha from age 9 years the basal area at age 20 years is overpredicted by 45% by KGM2 and underpredicted by 5% by KGM3.

Previous analysis of predictions by KGM3 suggested that for low stocked stands at basal area above about 45 m2/ha basal area growth was underpredicted, just as it is at higher stockings. This is becoming apparent in the case of replicated plots from the 692 series. Growth of the mean of three plots thinned to 198 s/ha at age 20 years was simulated through to 36 years. While the differences between both models and the measurements at this age are minimal there is a trend towards underprediction from 45 m2/ha on, increasing to 19% per annunm beyond 55 m2/ha.

KGM3 consistently overpredicts mortality. This varies from as little as 1 to 2% at stockings less than 200 s/ha and basal area less than 45 m2/ha, up to 8 to 9% at stockings above 450 s/ha and basal area above 45 m2/ha.

KGM2 generally overpredicted mortality by a lesser degree than KGM3.

All the plots analysed in this report were from sites of greater than 29 m site index.The few plots from sites of lower quality that have been analysed indicate similar trends to those outlined above.

CONCLUSIONS

On the basis of these comparisons and of a range of single plot comparisons carried out previously, KGM3 provides a marked improvement in basal area prediction over KGM2 for regimes similar to those currently practised by Timberlands in the Bay of Plenty.

Generally the findings shown here confirm those in Report No. 3 of the Stand Growth Modelling Programme. Specifically for

> "...plots thinned to final crop stockings below 500 s/ha, the model predicts slightly higher mortality than in fact exists."
>
> and
>
> "...for low final crop stockings on high sites, predictions of basal area are conservative."

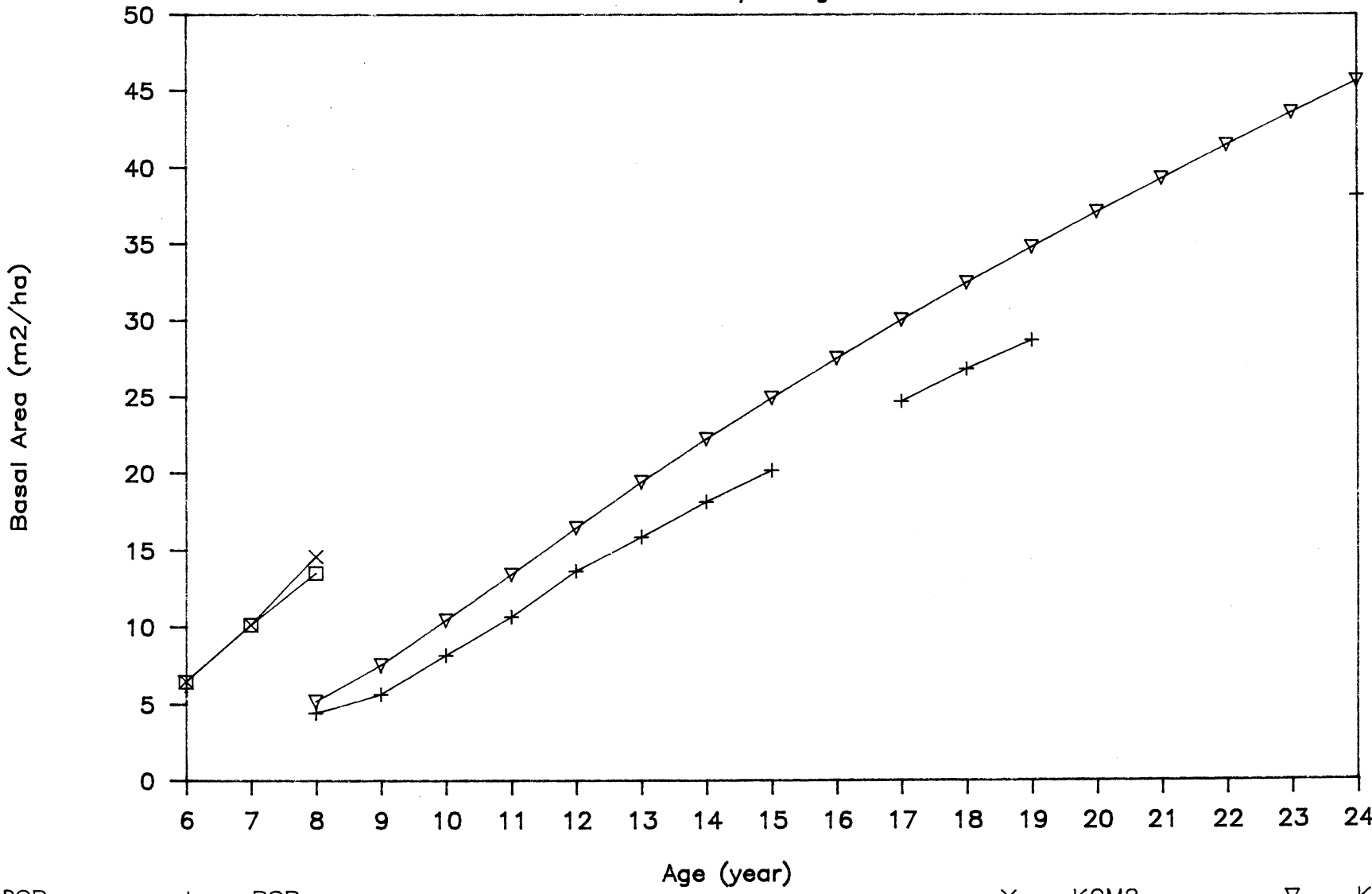
From this evaluation it would seem that mortality is overpredicted at all thinned stockings rather than just those below 500 s/ha.

The conservative prediction of basal area at low final crop stockings seems to be apparent only at higher levels of basal area. There seems little doubt that basal area is generally underpredicted beyond about 45 m2/ha on high sites. More data from stands having received a heavy early thinning and beyond 45 m2/ha basal area need to be analysed before more definite conclusions can be drawn.

I. C. Jenkin
10.8.87

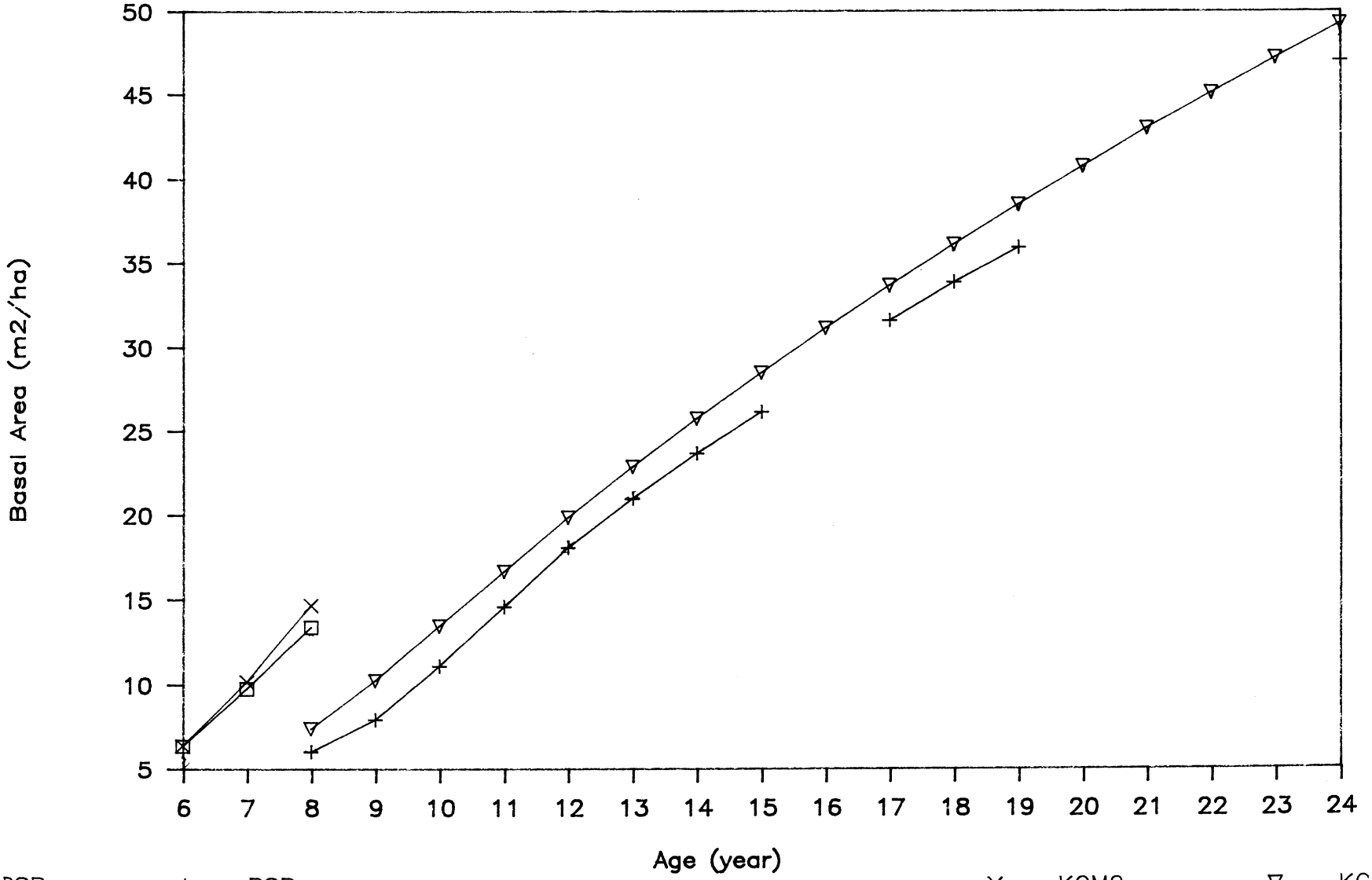
PSP 681/49 – 681/52

Thin to 198s/ha age 8



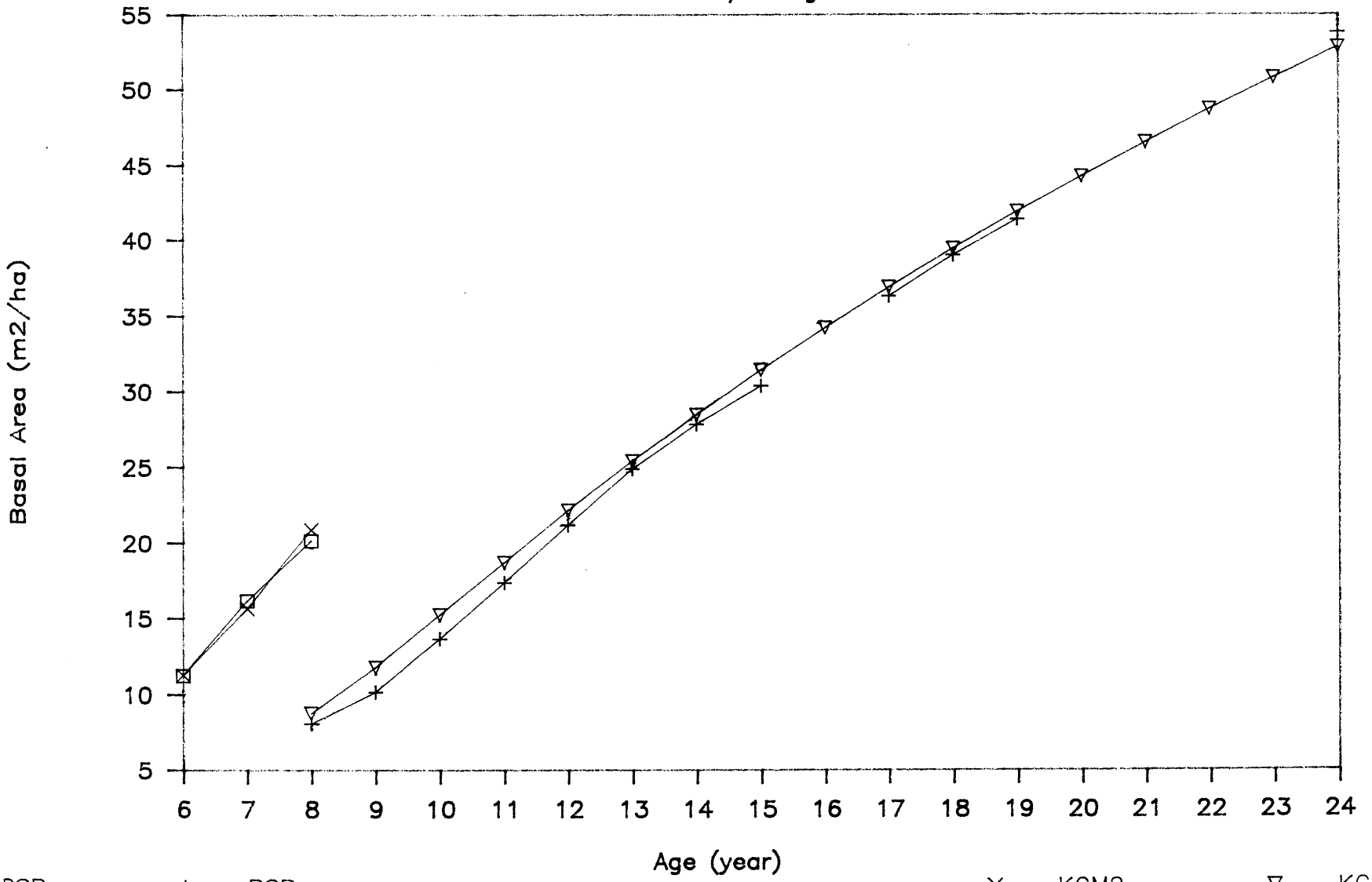
PSP 681/45 – 681/48

Thin to 296s/ha age 8



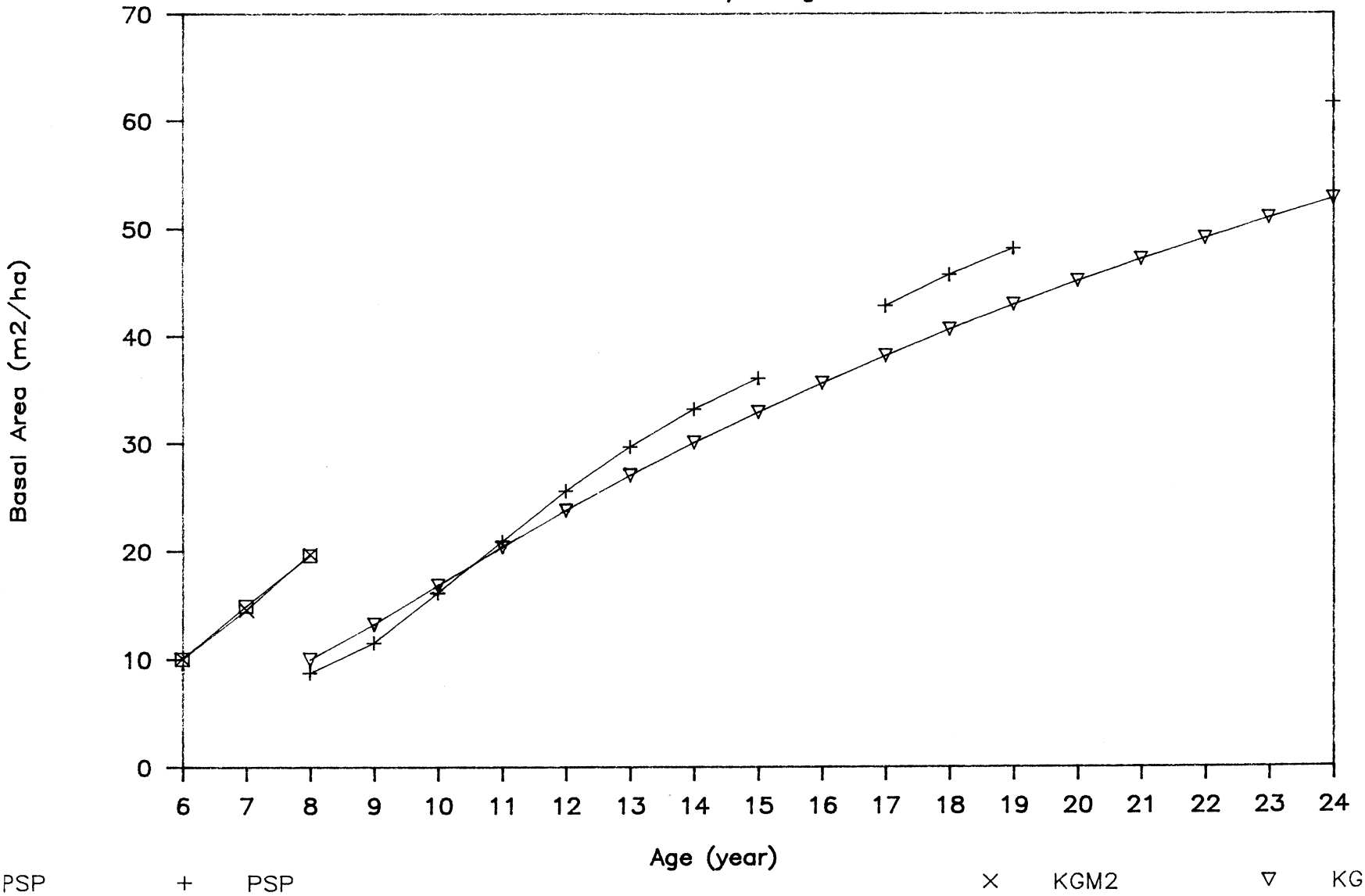
PSP 681/53 – 681/56

Thin to 444s/ha age 8



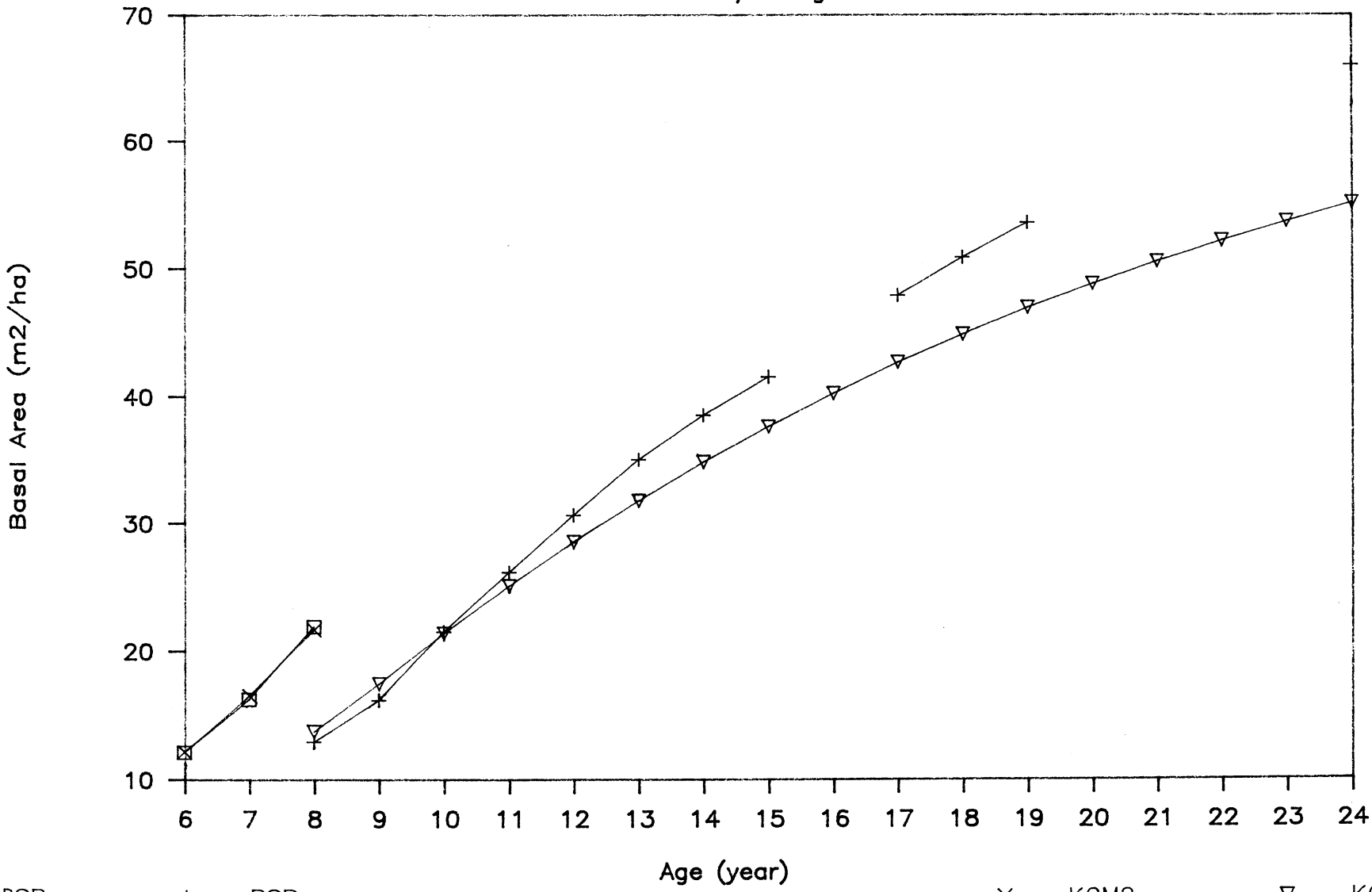
PSP 681/41 – 681/44

Thin to 543s/ha age 8



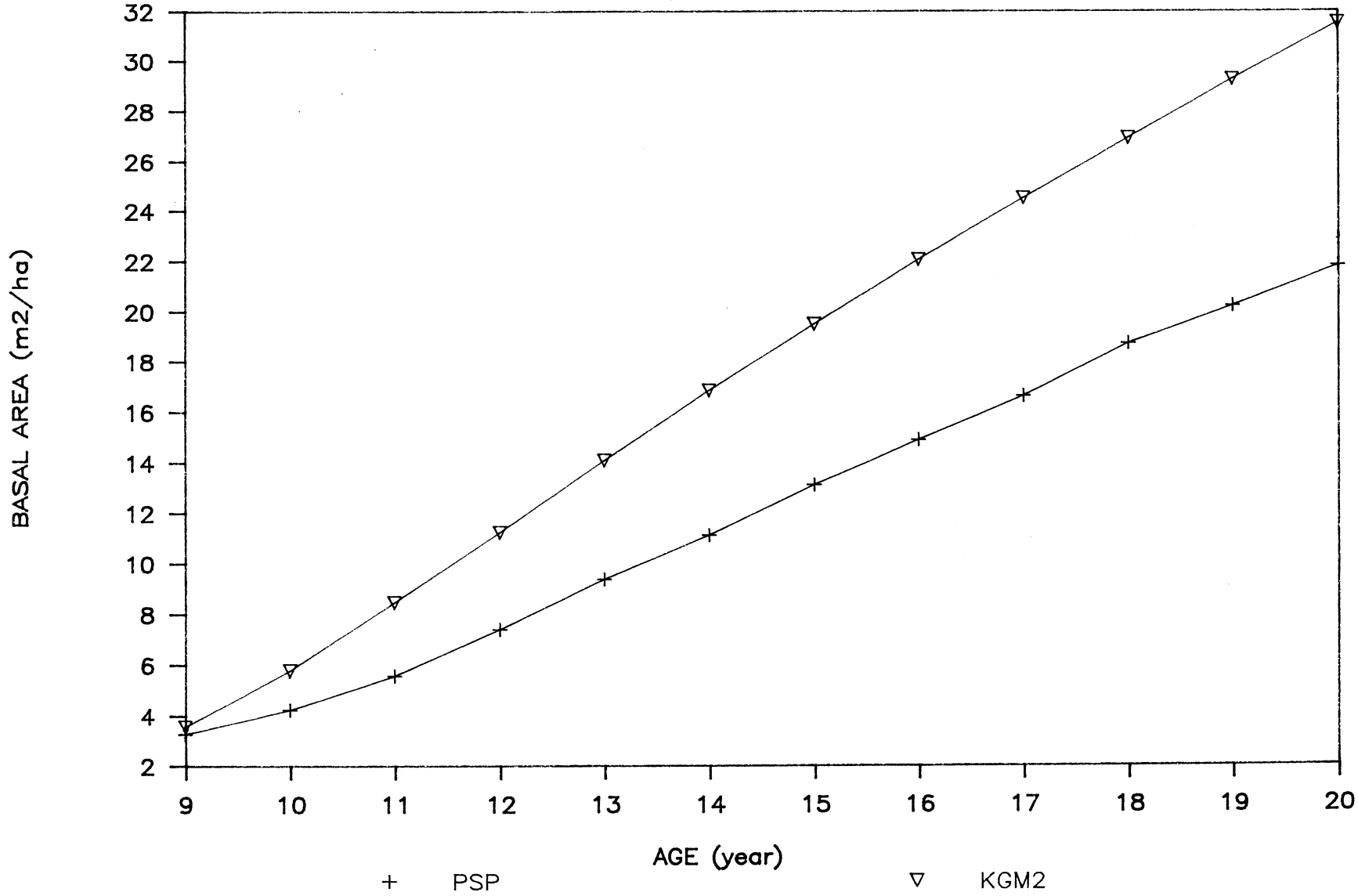
PSP 681/37 – 681/40

Thin to 716s/ha age 8



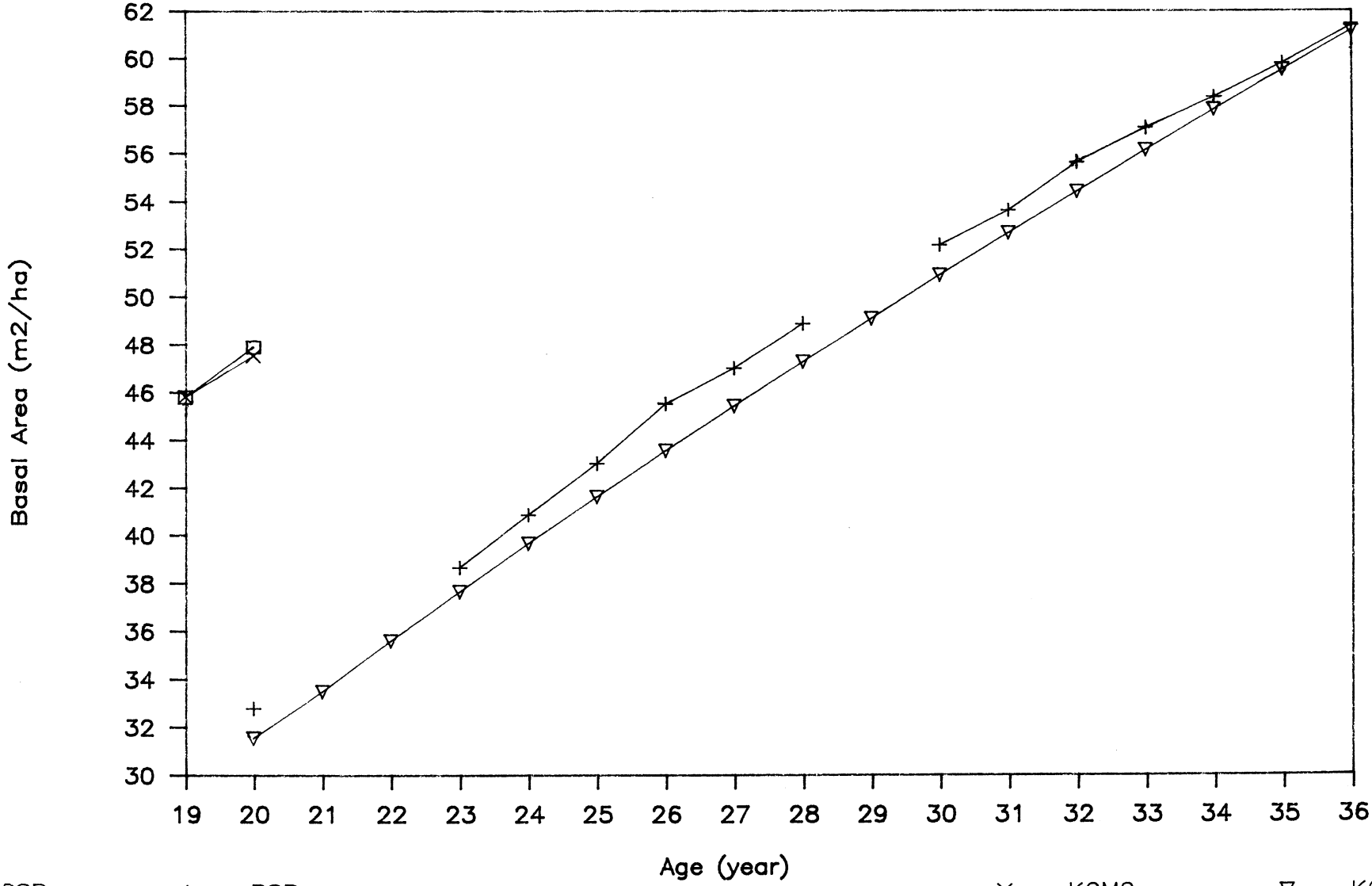
PSP 589/10,17,21,23

Thin from 313s/ha to 117s/ha age 9



PSP 692/5,/7,/8

Thin to 284s/ha age 20



EVALUATION OF KGM3 BY TASMAN FORESTRY LTD

M. COLLEY
F. LAW
D. NEW

NOVEMBER 1987

Evaluation of KGM3 by Tasman Forestry Limited

November 1987

1.0 Background

Unlike other major participants in the growth modelling co-operative, Tasman Forestry for many historical reasons does not have an extensive data base of permanent sample plots. Instead TFL have relied on over 75 active PSP's spread throughout its New Zealand estate and on four well designed silvicultural response trials to test the regime 'robustness' and site quality influences of currently available growth models. The trials are as follows:

Trial	Location & Site Quality	Trial Objectives	Age Span of Measurements
1. FRI Tarawera Trial (R.James)	SI 34 High BA incr site	Initial Spacing/ Response to thinning	6-24
2. FRI Ngatira Trial (L.Knowes)	SI 33 Agro Forestry Site	Clearwood Agro Forestry Regime	13-16
3. TFL McKee Road Trial	SI 31 N.Kaingaroa Site	Clearwood Production Thinning Regimes	5-11
4. TFL Kainui Forest	Moutere Soil Deficient site SI 27	Clearwood Regimes on low productivity sites	6-9

2.0 Objectives of Evaluation

TFL's primary objectives in validating the effectiveness of KGM3 must focus on two management level goals:

a) does the model provide over a period of years a reasonable prediction of basal area increment for regimes.

i) planted at stocking between 1 000 - 2 000 sph.
ii) unpruned regimes thinned to final crop stockings of between 300-500sph before 20m MTH.
iii) pruned regimes thinned to final crop stockings of 200-250 between 10-18m MTH?

b) Given the geographical/site distribution of its data base does KGM3 meet these regime tests for:

- lower altitude coastal BOP sites
- former pasture sites?

Assuming that stands 12 years of age and younger are in the domain of "EARLY", then two of the above trials have data that are appropriate for evaluating KGM3. It is unfortunate that the Tarawera trial will not be a true evaluation of KGM3 because data from this trial form part of the data base that went to built KGM3. Nevertheless, it was thought worthwhile to use this trial for evaluation, and the McKee Road trial has also been used for evaluation in the expectation that at least some of the objectives listed above will be met.

3.0 Details of the Trials

All trials are current and continue to be measured annually.

Tarawera Spacing Trial

Established in 1963 in a 1963 stand, with plots being established at a variety of initial spacings from 1.3m square to 2.7m square. Some plots remained unthinned and others were thinned in one or two steps to final crop stockings of usually 380sph and occasionally 740sph. The regime is therefore a "high stocking unpruned" regime with initial stockings considerably higher than those in vogue today. A total of 24 0.6ha plots.

Ngatira Trial

Two blocks, established in 1971 and 1972 at around 750sph on pasture. Pruned more or less annually to 6 metres and thinned after each pruning with a final stocking of 200 sph at age 7-8 years. A total of 7 0.06ha plots.

McKee Road Trial

Established at age 5 in a 1976 stand. Six 1.0ha blocks with similar pruning treatment (3 lifts to 6.0m) but different thinning treatments. Thinning treatments range from 1 300 to 200sph in one step at MCH 15m to 300 to 200sph at MCH 20m. Prior to this the blocks received a first thinning from initial stocking down to a range of stockings from 300 to 1 300sph at age 5.

Following the 15m MCH thinning on half the area at age 9, the six blocks became 12 half blocks, with the other half to be thinned at MCH 20m.

4.0 Evaluation of KGM3

The following areas were concentrated on:

a) Comparing KGM3's prediction of BA following a thinning with actual BA.
b) Comparing KGM3's predication of BA increment with actual BA increment.
c) Comparing KGM3's prediction of stocking (sph) with actual stocking.

(A) BA After Thinning

Refer to Graph 1. Data came from the Tarawera spacing trial (12 plots) and from the McKee Road trial (6 plots).

There is an even scatter of points above and below the line of perfect prediction, indicating that KGM3 can be a poor predicter for single plots but a good predicter for a number of plots.

The one exception is four points where 250-300 stems/ha are removed in thinning. These points come from the McKee Road trial where thinning was done at age 9 from 500sph or 350sph to 200sph. Possibly KGM3 does not work well where fewer than 600 stems are removed in thinning. Alternatively, the explanation is that it does not work well at age 9.

This would be interesting to see how well KGM3 predicts residual BA in a 300 to 200 thinning at an age greater than 12 years.

(b) **BA Increment**

Refer to Graph 2. This plots BA increment over a period of four years from ages 13 to 16 years. The seven plots represented here were thinned to 200sph at age 7 (4 plots) and 8 (3 plots).

The trend in actual BA increment is perhaps puzzling, but individual plots follow much the same trend. (That is, the trend shown does not arise from unusual fluctuations in 1 or 2 plots).

Possibly canopy closure is occurring at around age 15.

Measurements beyond age 16 will be required to confirm any trends.

Refer to Graphs 3 and 4. Only measurements since age 12 have been shown here.

Generally KGM3 slightly over predicts BA increment in the thinned plots, but actual and predicted seem to come very close from age 23 onward, although future measurements will be needed before this can be confirmed.

Similar comments can be made for the unthinned plots.

Note that actual BA increment often has a sinusoidal fluctuation, particularly for high stockings indicating that the trend on Graph 2 may be nothing unusual.

The overall over-prediction for the thinned plots is shown below:

	Age	Actual Ba	Predicted BA	Over prediction (%)
Thinned age 9 to 379	12	23.3	23.3	
	24	54.9	55.8	+1.6
Thinned age 7 to 741	12	38.6	38.6	
	24	65.3	69.3	+6.1
Thinned age 6 to 379	12	31.3	31.3	
	24	59.3	60.6	+2.2

(c) **Stocking**

Refer to Graph 5. This shows how well KGM3 predicts future stocking over a 12 year period (Tarawera) or a 3 year period (Ngatira).

For final crop stockings less than 500sph KGM3 gives an excellent prediction.

For final crop stockings above 1000sph, KGM3 over-predicts stocking (i.e. underestimates mortality), and this over-prediction worsens as stocking increases. Our interest in this area is largely academic as very few stands in New Zealand have been, or are likely to be, grown at final crop stockings of 1 000 or more stems/ha.

5.0 Conclusion

Given that the unthinned Tarawera plots are of academic interest only, one must concentrate on the results of this evaluation for the thinned Tarawera plots (typical of NZ minimum tending regimes) and the Ngatira plots (a typical agroforestry regime).

The TFL data base is insufficient on its own to provide a full evaluation of KGM3 and one must rely on the TFL evaluation to, hopefully, form part of and confirm evaluations made elsewhere.

The tentative conclusions to be drawn from the TFL evaluation are:

(i) For minimum tending regimes, BA increment as predicted is reasonably in line with actual, with a small bias towards over-prediction leading to an over-estimate of BA at age 24 (from age 12) of the order of 5%.

(ii) Stocking (mortality) predictions for final crop stockings of 500 sph or fewer are good over an age range of 12 years to at least 24 years.

(iii) Combining conclusions (i) and (ii), KGM3 possibly slightly over predicts tree diameter and stand volume for minimum tending regimes. The volume over-prediction is of the order of 5%.

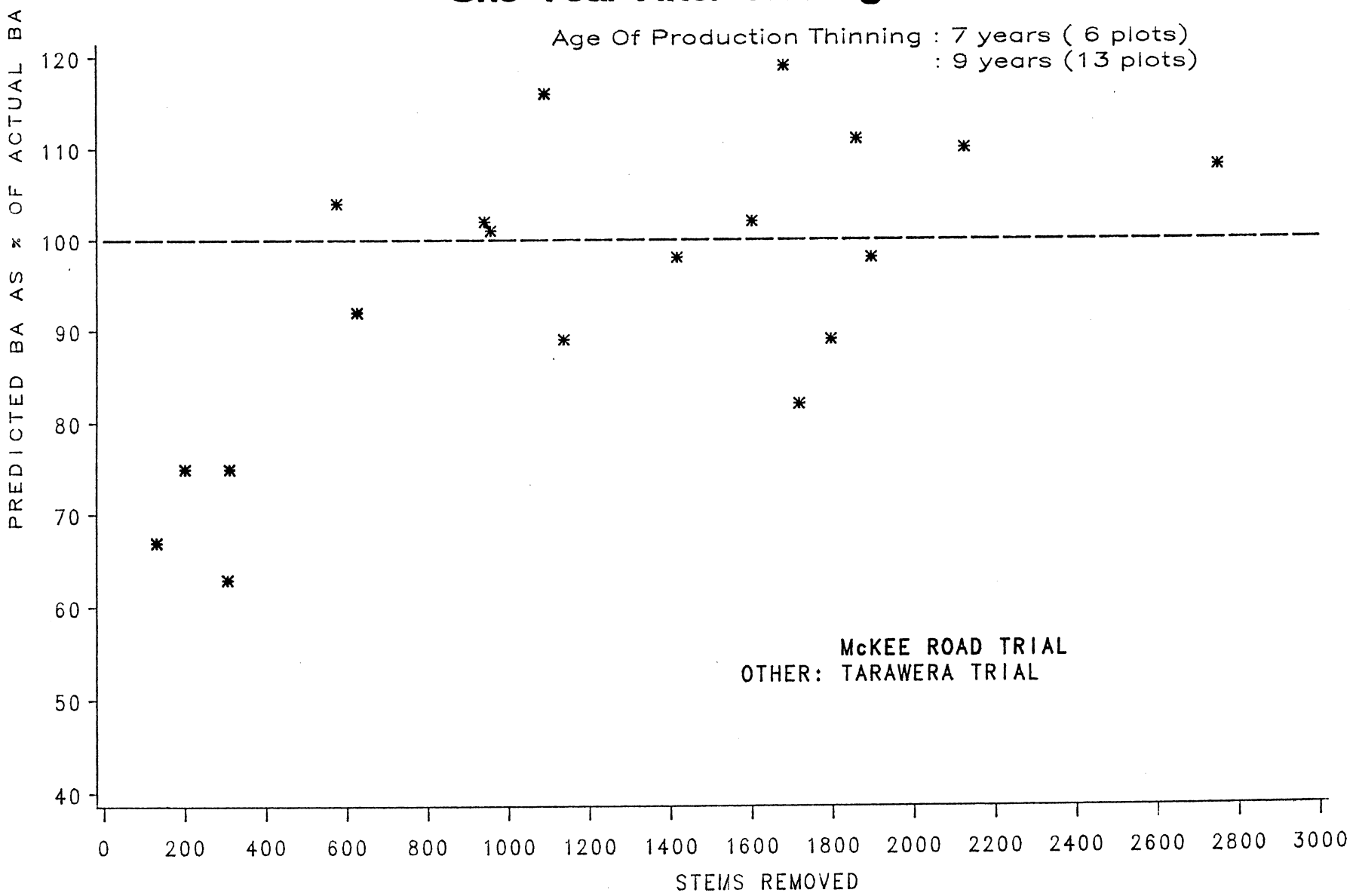
(iv) KGM3 is not a good predicter of BA following the final thinning of current pruned regimes (e.g. thin at age 9 from 500 to 250sph). This is somewhat academic as program EARLY should be better suited for predictions at this age.

Prepared by: M. Colley
F. Law
D. New

GRAPH 1

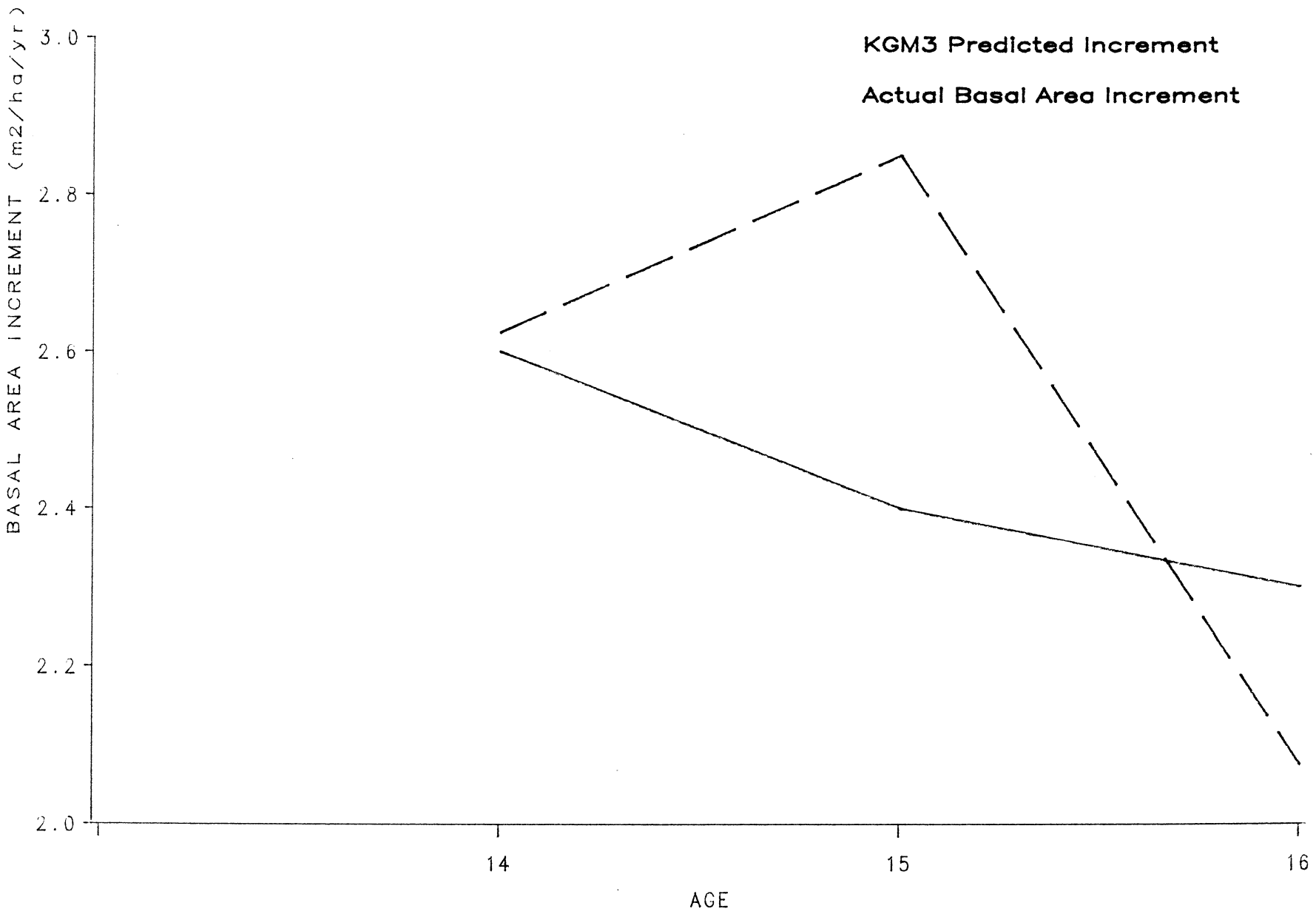
KGM3 Predicted BA as % of Actual BA

One Year After Thinning



GRAPH 2

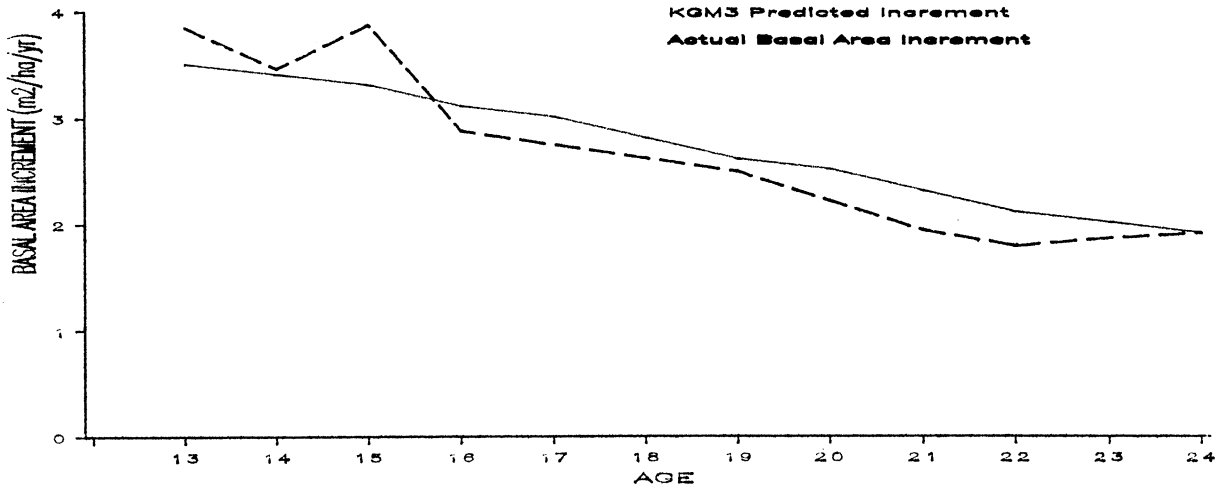
NGATIRA TRIAL



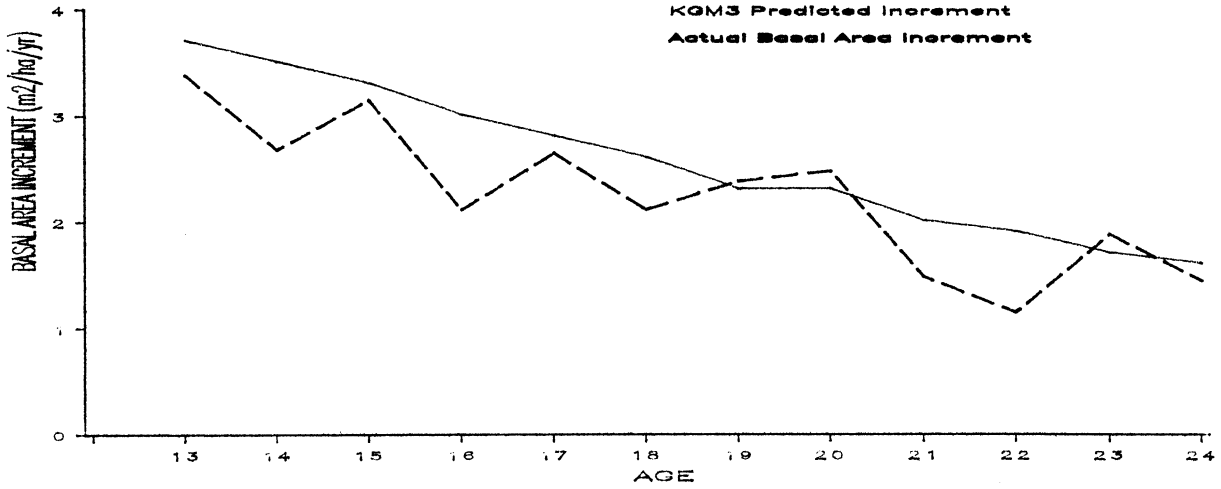
GRAPH 3

TARAWERA TRIAL : Thinned Plots

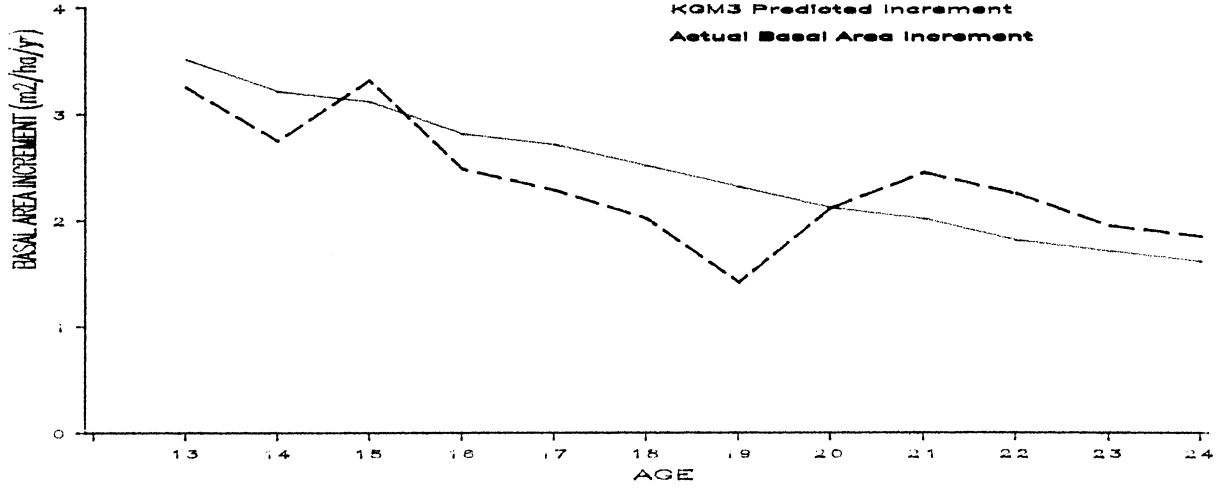
Thinned Age 9 To 379 Spha



Thinned Age 7 To 741 Spha



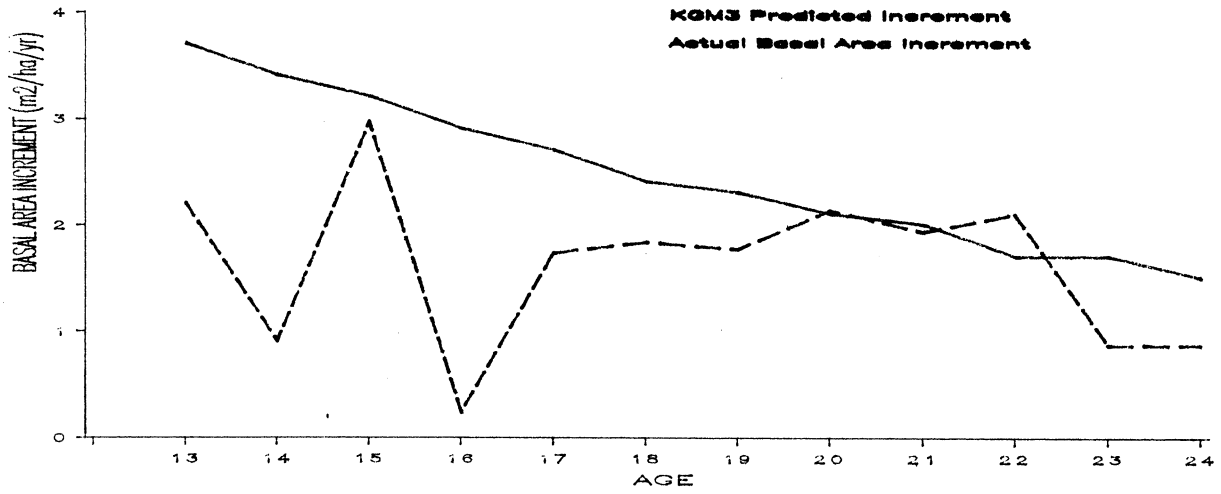
Thinned Age 6 To 379 Spha



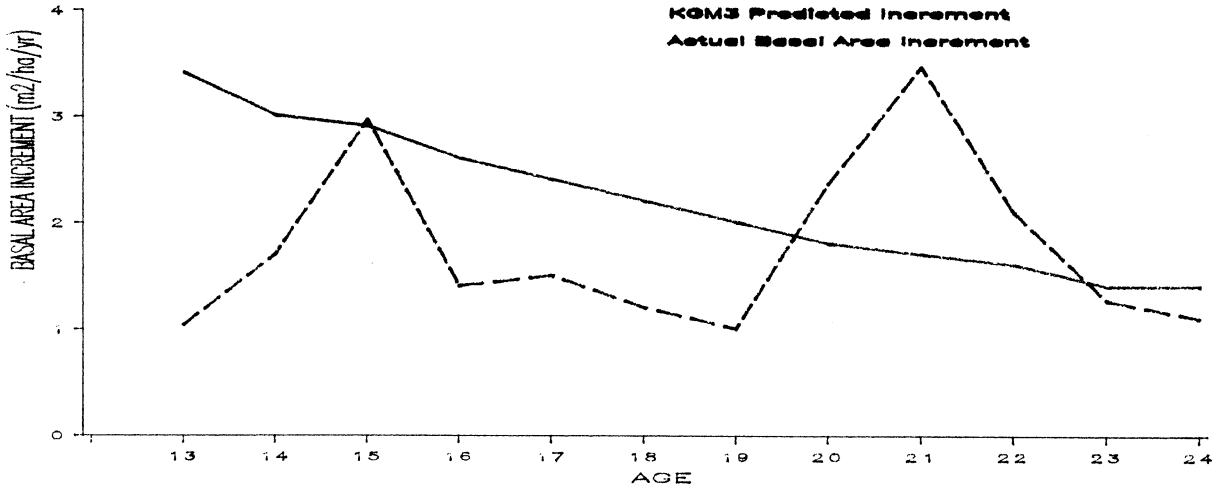
GRAPH 4

TARAWERA TRIAL : Unthinned Plots

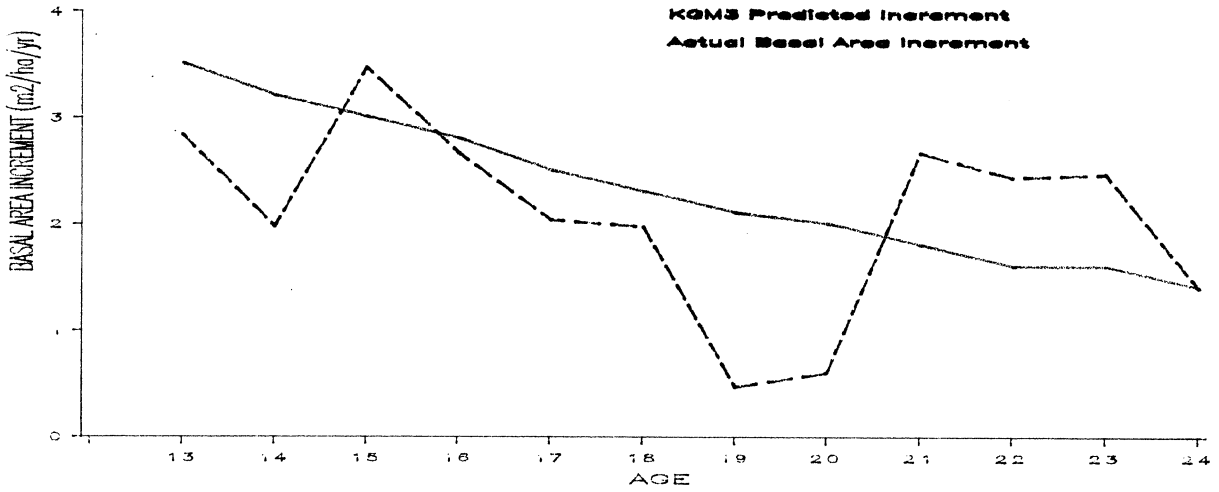
Initial Planting at 1.3 m x 1.3 m



Initial Planting at 1.8 m x 1.8 m



Initial Planting at 2.7 m x 2.7 m



GRAPH 5.

Actual Stocking Vs KGM3 Predicted Stocking