NZ FRI PROJECT RECORD

NO. 3926

HAWKES BAY GROWTH MODEL DOCUMENTATION

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REPORT NO. 33 APRIL 1994

Note : This is an unpublished report and must not be cited as a literature reference.

FRI/INDUSTRY RESEARCH COOPERATIVES

EXECUTIVE SUMMARY

The Hawkes Bay growth model was developed in 1982 by the Forest Research Institute. Although not formally published, the model was subjected to considerable testing and validation both within FRI and by the Resource Inventory Group of the New Zealand Forest Service. This report contains a summary of the data used to construct the model and the results of some of the validation exercises, including comparisons with other growth models available at that time.

HAWKES BAY GROWTH MODEL
(NAPIRAD 1983)

Introduction

The Hawkes Bay growth model was developed in 1982 as one of a series of regional stand growth models based on the methodology proposed by Garcia (1979, 1983, 1984). The methodology consists of a set of differential equations which describe changes in stand variables such as basal area and stocking over time. Maximum likelihood estimators are used to both estimate parameters and evaluate differences between different model formulations. This methodology has subsequently been used to develop models for other regions throughout New Zealand (and overseas) and for species other than *P.radiata*.

Data

Data for the model was selected from those forests immediately in the Hawkes Bay region: Wharerata, Patunamu, Mohaka, Esk, Kaweka and Gwavas Forests (refer Table 1). The data itself is from measurements of Permanent Sample Plots, growth plots and experimental trials stored on the then New Zealand Forest Service Permanent Sample Plot system, administered by the Forest Research Institute.

Table 1: Hawkes Bay growth model data base

Forest	Area (ha)	Plots (#)	Age (years)		Site index (m)		Basal area (m^2/ha)		Stocking (stems/ha)		Top height (m)	
			min	max	min	max	min	max	min	max	min	max
Wharerata	4601	24	5.0	17.8	25.0	35.0	2.31	68.24	193	988	4.9	29.8
Patunamu	3801	16	4.8	28.8	29.8	38.5	3.66	50.50	138	944	7.8	47.0
Mohaka	9781	31	6.8	22.9	28.1	35.0	3.06	74.88	99	2026	9.9	36.6
Esk	3236	78	4.1	29.2	23.1	35.9	0.65	87.94	158	2772	3.6	42.4
Kaweka	5381	11	8.9	16.9	20.6	25.9	6.48	39.60	198	395	8.3	20.2
Gwavas	5644	47	5.2	28.0	23.0	33.1	3.09	90.27	128	2551	5.1	40.7

Very little data was available from unthinned stands or those with high final crop stockings. Similarly, the lack of experimental data describing the effects of thinning and pruning means that the fourth state variable included in the model represents the confounded effect of the two.

Testing and Validation

Initial testing of the model was carried out by graphical comparisons of model predictions and actual data. In addition, an examination of the residual error for each of the major variables was conducted and these results are presented in Table 2.

Table 2: Errors

(Mean projection period = 2.2 years)

	Mean[1]	EMS[2]
Basal area (m^2/ha)	-0.0024	1.978
Stocking (stems/ha)	3.8	32.15
Top height (m)	-0.0035	0.853
Mean Dbh (cm)	-0.0028	0.889
Average spacing (m)	-0.0001	0.005
Basal area * height (m3/ha)	-1.38	61.04

[1] Predicted - Actual
[2] Error Mean Square

Further testing of the model was carried out the New Zealand Forest Service Resource Inventory Group (Leitch, 1982, 83: R.I.G. File Notes 9/0/1), with particular emphasis on the new models performance in comparison to it's predecessor in Hawkes Bay, KGM1, the Kaingaroa growth model. (Copies of these reports are enclosed).

The model was also tested against data from Mangatu and Ruatoria (to the North) and Ngaumu Forest (south). Unfortunately **very** little data was available from both Ruatoria and Mangatu in 1982 and testing was limited. Indications were that height growth is modelled well in both forests, and basal area and stocking (mortality) in Mangatu but not in Ruatoria, where these variables appeared to be over-predicted. It should be possible to evaluate the model more thoroughly with the additional 10-12 years of measurements since 1982.

Discussion

Much of the validation centered on comparisons between the new model and KGM1 in response to an anticipated wood shortage in the region and doubts about forecasts based on the Kaingaroa model. For stockings less than 500 stems/ha, the new model predicted a volume increase of 5-10% for the 'average' site, with higher mortality and increased mean tree size. Conversely, at high stockings Napirad predicts considerably higher volumes and much less mortality than the Kaingaroa model. The model also predicts much higher yields from the poorer sites in Kaweka.

It was difficult to confirm the accuracy of predictions for Kaweka, and those for high stockings, given the paucity of data in these areas. It should now, however, be possible to examine these predictions in more detail if necessary.

Leitch (1983) concluded that the new models performance was superior to that of the Kaingaroa growth model and other alternatives for Hawkes Bay, especially after thinning. This is particularly significant given the number and severity of silvicutural treatments then practised in the region.

References

Garcia, O. 1979: Modelling stand development with stochastic differential equations. Pp.315-33 in Elliott, D.A.(Ed.) "Mensuration for Management Planing of Exotic Forest Plantations", New Zealand Forest Service, Forest Research Institute Symposium No.20.

--------- 1983: A stochastic differential equation for the height growth of forest stands. Biometrics 39:1059-72.

--------- 1984: New class of growth models for even-aged stands: Pinus radiata in Golden Downs Forest. New Zealand Journal of Forestry Science 14:65-88.

Leitch, J.V. 1982: Hawkes Bay growth model - Napirad. NZFS Resource Inventory Group File Note 9/0/1. (Unpublished)

----------- 1983: Napirad vs the Kaingaroa growth model. NZFS Resource Inventory Group File Note 9/0/1. (Unpublished)

New Zealand Forest Service

RECEIVED - 9 DEC 1982 RECORDS Forest Research Institute ROTORUA

Date: 8 December 1982 My ref: 9/0/1 JVL:WAI Your ref:

From: RESOURCE INVENTORY GROUP, ROTORUA

To: DIRECTOR PRODUCTION FORESTRY DIVISION, F.R.I. ROTORUA

SUBJECT: HAWKES BAY GROWTH MODEL - NAPIRAD

FILE

BRING UP / / lett.

Attention: Murray Lawrence

Introduction

This note contains impressions of NAPIRAD gained by comparing its performance with:

* A subset of Hawkes Bay PSP's used in previous KGM & BEEK validation work

* IFS yield tables for Hawke's Bay based on KGM2

* IFS yield tables for Kaingaroa Forest based on KGM1

The exercise was rather brief, and aimed at giving some "feel" for NAPIRAD relative to the Kaingaroa model.

Results may be summarised as induating better performance of NAPIRAD in Hawkes Bay relative to KGM; especially following thinning. The performance of NAPIRAD at Kaingaroa did not appear to be vastly different from KGM1; however NAPIRAD'S seemingly improved thinning function may be of utility for modelling heavy early thinnings at Kaingaroa.

Methodology and more detailed results are presented below.

Method

Accessable Hawkes Bay PSP plots together with IFS regional planning yield tables were compared with NAPIRAD run from the same starting values.

In the case of PSP's this included thinning where appropriate. Comparisons were limited to top height, basal area and stocking to avoid possible tree volume table inconsistences with PSP's and lack of total stem volumes with IFS data.

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M. Lawrence			

Results

The following tables summarise the results.

Table	Contents
1	Top height/age equation comparisions for site index 28. Note: These equations have been commonly used throughout the region.
2	IFS data from Kaingaroa Forest standard regimes (KGM1).
3	Hawkes Bay KGM1/2 runs with PSP or IFS starting values.

Discussion - KGM vs NAPIRAD

Top height

The small differences, about 5% at age 50, exibited at Kaingaroa (Table 2) are what would be expected with the differing asymptotic values involved - 56.5 at Kaingaroa and 64.1m - Hawkes Bay respectively. Generally speaking, as can be seen from Table 1, height differences amongst models are small, and unlikely to be of overriding importance. Overall, NAPIRAD performs best for the Hawkes Bay cases examined. (Tables 2 and 4) - as one would hope, and expect.

Stocking

NAPIRAD has more severe mortality trends than KGM and this is no doubt a consequence of differing silviculture/environment interactions between Kaingaroa and Hawkes Bay. One anamolous plot in Gwavas is not handled at all well by either model and reasons for the discrepancy are not easy to find. NAPIRAD tends to behave better than KGM following thinnings - an important point.

Basal area

Considering the Kaingaroa data (Table 2) first, basal area trends are virtually opposite to the top height ones; that is, initial over-prediction tending to under-prediction by age 50.

However, NAPIRAD basal area predictions are good in the Hawkes Bay set (excepting the anomolous Gwavas plot mentioned above). Again NAPIRAD behaviour following thinning appears superior to KGM.

Conclusion

Bearing in mind ad hoc nature* of data selection for the comparisons, the overall conclusion is that NAPIRAD appears to behave in a superior fashion to KGM, especially in Hawkes Bay and should be implemented without delay.

J. V. Leitch
for J. W. Shirley
O/C Resource Inventory Group

*Vindicating comments made by Oscar Garcia which may be summarised as suggesting this type of exercise being 'a pig in a poke'. One's intuitive feeling is that the model is a lot better than the sample results indicate.

Table 1: HEIGHT MODEL COMPARISON FOR SI28

AGE	GOULDING VOLCANIC	T/B VOLCANIC	T/B NELSON NELSON	GARCIA KANG	NAPI RAD
5	4.3	4.4	5.8	5.3	5.7
10	12.5	12.2	13.7	13.2	13.5
15	21.0	20.4	21.3	21.1	21.1
20	28.7	28.0	28.0	28.0	28.0
25	35.0	34.6	33.7	33.9	34.0
30	40.0	40.1	38.4	38.7	39.2
35	43.9	44.6	42.3	42.5	43.5

Table 2: KAINGAROA - KGM1 VS NAPIRAD GROWTH PREDICTIONS

DATA SOURCE & REFERENCE	AGE	TOP-HEIGHT (M)			STOCKING (S/HA)			BASAL AREA (M^2/HA)		
	YR	KGM1	NAPI	%DIF	KGM1	NAPI	%DIF	KGM1	NAPI	%DIF
Kaingaroa SI 29	20	29.4	29.3	-	335	334	-	36.7	37.3*	-
BOP 1982 resource survey	25	35.8	35.4	1.1	332	326	-1.8	47.3	50.4	6.6
2 thinnings to waste	30	40.8	40.5	0.7	325	318	-2.1	56.6	60.5	6.9
	35	44.6	44.8	0.4	317	310	-2.2	64.9	68.0	4.8
	40	47.5	48.4	1.9	310	301	-2.9	72.8	73.5	1.0
	50	51.2	53.7	4.9	299	284	-5.0	87.7	80.1	-8.7
Kaingaroa SI 31	25	37.4	37.4	-	508	508	-	52.9	52.9	-
BOP 1982 resource survey	30	42.2	42.5	0.7	476	490	2.9	61.1	64.6	5.7
1 waste thin	35	45.9	46.8	2.0	448	472	5.3	68.3	73.2	7.1
	40	48.6	50.2	3.3	426	453	6.3	75.1	79.4	5.7
	50	51.9	55.2	6.4	396	417	5.3	88.3	86.7	-1.8
Kaingaroa SI 30	25	37.0	37.0	-	206	-	-	34.6	34.6	-
BOP 1982 resource survey	30	41.9	42.0	0.2	205	202	-1.4	43.8	45.4	-6.0
Extraction thin	35	45.6	46.2	1.3	204	198	-2.9	52.3	53.9	3.1
	40	48.3	49.6	2.7	202	193	-4.5	60.5	60.4	-0.2
	50	51.8	54.7	5.6	200	184	-8.0	76.3	68.7	-9.9

*Discrepancy due to rounding of input ages (program)

Table 3: HAWKES BAY - KGM VS NAPIRAD GROWTH PREDICTIONS

DATA SOURCE & REFERENCE	AGE	TOP-HEIGHT (M)			STOCKING (S/HA)			BASAL AREA (M^2/HA)		
	YR	KGM2	NAPI	%DIFF	KGM2	NAPI	%DIFF	KGM2	NAPI	%DIFF
Mohaka SI 31.6	18	28.5	28.5	-	161	161	-	26.4	26.4	-
IFS/Old crop unprun.	20	31.6	31.3	-0.9	161	160	-0.6	31.0	31.7	2.2
	30	44.5	42.7	-4.0	160	155	-3.1	50.5	51.7	2.4
	40	52.7	50.4	-4.4	159	148	-6.9	67.0	62.5	-6.7
Esk SI 30	22	32.8	32.8	-	240	240	-	48.1	48.1	-
IFS/Norm board	30	42.2	41.6	-1.4	238	232	-2.5	64.2	62.7	-2.3
	35	46.6	45.8	-1.7	235	226	-3.8	72.9	68.5	-6.0
	40	50.0	49.4	-1.2	235	220	-6.4	81.1	72.5	-10.6
Esk SI 28	7.2	8.9*	-	-	2079*	2079	-	23.6*	22.6	-
(E78)	9.2	13.3	12.1	-9.0	2079	2057	-1.0	38.8	38.8	0
PSP 1150015002	10.0	14.1	13.6	-3.5	2079/545	2044/545	1.7/0	15.8	15.3	-3.2
	10.5	14.2	15.2	7.0	545/474	543/474	-0.4/0	14.1	16.3	15.6
	12.1	16.7	16.8	0.6	474	473	0	21.1	20.1	-4.7
	13.5	18.5	19.8	7.0	474/198	474/198	0	12.2	13.5	10.6
	15.5	21.3	22.8	7.0	198	197	0.5	18.7	18.7	0

*PSP not KGM2

Cont.....

Table 3 cont.

DATA SOURCE & REFERENCE	AGE	TOP-HEIGHT (M) PSP	KGM	%DIF	NAPI	%DIF	STOCKING (S/HA) PSP	KGM	%DIF	NAPI	%DIF	BASAL AREA (M^2/HA) PSP	KGM	%DIF	NAPI	%DIF
Mohaka	8.7	13.0	-	-	-	-	1474	-	-	-	-	28.4	-	-	-	-
SI 30	10.0	14.7	17.5	-	15.5	5.4	248	-	-	248	-	10.2	10.2	0	7.7	-2.4
KGM1	10.7	16.6	19.7	-	17.2	3.6	99	99	0	99	0	5.0	6.1	22	4.6	-8.0
	13.7	21.6	25.8	-	22.2	2.8	99	99	0	99	0	10.3	-	27	10.4	1.0
	16.8	25.9	29.5	-	26.9	3.9	99	99	0	98	-1.0	17.4	-	-	17.2	-1.2
Gwav.	13.7	19.3	19.0	-1.6	-	-	691	-	-	-	-	42.1	-	-	-	-
SI 26	15.7	22.1	22.0	-0.5	22.2	0.5	603	691	14.6	685	13.6	45.4	48.3	6.4	49.6	9.2
SI 276 NAPI	18.7	26.5	26.0	-1.2	26.3	-0.8	573	678	18.3	674	17.6	51.0	56.5	10.8	59.1	15.9
KGM2 Nelson T/B	21.7	27.8	28.0	0.7	30.1	8.2	524	668	27.5	662	26.3	56.4	63.7	12.9	66.9	18.6
Gwav.	22	34.0	-	-	-	-	692	-	-	-	-	62.0	-	-	-	-
SI 30	24	36.0	-	-	36.4	1.1	208	208	0	208	0	31.0	26.8	-13.5	28.2	-9.0
SI 31.4 NAPI	27	38.0	-	-	39.8	4.7	208	208	0	206	1.0	38.0	32.4	-14.7	36.0	-5.2
KGM2	30	39.0	-	-	42.8	9.7	208	208	0	203	-2.4	44.0	37.9	-13.9	42.7	-2.9
Gwav.	20	27.0	-	-	-	-	237	-	-	-	-	32.0	-	-	-	-
SI 26	22	30.0	-	-	29.5	1.7	128	128	0	128	0	21.4	22.3	4.2	22.0	2.8
SI 27 NAPI	23	31.0	-	-	30.7	1.0	128	128	0	128	0	23.5	24.0	2.1	24.1	2.6
KGM2	26	32.0	-	-	34.0	6.2	128	118	0	127	0.8	29.5	29.8	1.0	30.2	2.4
	28	35.0	-	-	36.1	3.1	128	118	0	126	-1.6	33.1	33.5	1.2	33.9	2.4

FS E15

New Zealand Forest Service

Date: 4.2.83 My ref: 9/0/1 JVL:WI Your ref: Telephone:

From: RESOURCE INVENTORY GROUP, ROTORUA

To: FOREST RESEARCH INSTITUTE, ROTORUA

SUBJECT: NAPIRAD VS THE KAINGAROA GROWTH MODEL

Mr Lawrence.
C. Goulding

Attention: Murray Lawrence

Introduction

This note presents comparisons of Kaingaroa and Napirad growth model outputs for standard Kaingaroa and Hawkes Bay silvicultural regimes. As there has been some surprise with the apparent severity of Garcia model mortality predictions, emphasis here is on this aspect, although where appropriate, other outputs of managerial significance, such as total stem volume (TSV), are also considered.

The results and conclusions may be summarised as follows:

1. For Kaingaroa regimes, relatively high final crop stockings, over 370 spha, the Kaingaroa model predicts more severe mortality than Napirad; but Napirad predicts more TSV.

2. For Hawkes Bay regimes, heavy early thinnings - less than 300 spha- the converse is true, i.e. Napirad mortality is more severe than Kaingaroa model predictions. TSV predictions differ less with Napirad slightly over predicting at age 30, but under predicting at age 40, relative to the Kaingaroa model.

3. An outcome of this work has been to ascertain that Garcia mortality prediction include normal wind damage - which markedly increases their credence.

4. Certainly for the Hawkes Bay regimes, evidence tends to favour Napirad; that is, Garcia-type mortality and TSV predictions; which indicate earlier clearfelling because of larger piece sizes. This conclusion is of managerial significance and needs to be followed up.

Method

Kaingaroa, KGM1 or KGM2 as appropriate, and NAPIRAD models were run through a series of standard regimes. Details of the regimes are shown on Tables 1 and 2. Additional information is presented below.

Regime Name (SI)	Brief Details	Source/Notes
GWAVAS (28.5)	Thinned to 275 age 10	D. Lowry
KAWEKA (22.4)	Thinned to 275 age 9	D. Lowry
MOHAKA (30)	Thinned to 237 age 10	D. Lowry
KAINGAROA 1 (32.2)	Thinned to 370 age 9	C. Mountfort
KAINGAROA 2 (27.7)	Thinned to 600 age 8	C. Mountfort
KAINGAROA 3 (33.0)	Thinned to 510 age 9	C. Mountfort
FENTON (30.0)	Thinned to 200 age 10	Derived from Manley&Knowles
FENTON CONT (30.0)	Fenton grown on > age 40	NZJ for V.25.
HIGH STOCKING (30)	1500 spha no treatment	

The last two regimes were added to gauge mortality behaviour in the models, both regimes being grown on to extinction.

Results

Complete output for representative years are presented in Tables 1 and 2. However, note that Fenton-continued (from age 40) and the High-stocking regime results are appended.

All percentages are relative to the Kaingaroa growth model values - not because it is necessarily "right" but simply as it pre-dates Napirad and people are presumably familiar with Kaingaroa model idiosyncrasies.

Kaweka results appear inconclusive, and as this forest hardly featured in Napirad model development they are not considered further.

Top height trends appear reasonably consistent - with some divergence past age 30 due to differing asymptotic values. However, these height differences are not likely to markedly affect volumetic comparisons (though, in KGM's case mortality will become constant upon reaching asymptotic top height).

Basal area behaviour, see Tables 1 and 2, appear closely correlated with regimes, especially past age 30. Thus heavy early thinning or Hawkes Bay regimes show Napirad predicting higher basal areas until age 30, thereafter Kaingaroa model predictions exceed Napirad's. Outputs for high final crop stockings exhibited by Kaingaroa regimes, show KGM basal area predictions consistently below Napirad ones.

Table 1: NAPIRAD VS STANDARD HAWKES BAY REGIMES

AGE	TOP-HT		BASAL AR		STOCK		TSV		REGIME NOTES
	NAPI	KGM2	NAPI	KGM2	NAPI	KGM2	NAPI	KGM2	GWAVAS
10	13.8	14.0	13.1	13.1	275	275	65	65	Age 6 thin to 600
20	28.5	28.5	45.1	40.7	67	275	427	389	Age 9 thin to 275
30	39.7	38.9	64.3	61.9	257	273	834	795	a=.4977,b=.3175
40	47.7	45.9	74.1	79.4	244	265	1146	1196	T/B NELSON KGM2
10	10.3	11.9	13.6	13.6	300	300	51	58	KAWEKA
20	22.4	22.4	43.0	39.4	294	300	323	273	Age 6 thin to 600
30	32.7	29.6	61.6	62.1	286	300	663	547	Age 9 thin to 275
40	40.8	34.2	72.2	83.1	276	299	912	830	a=1.165,b=.2580
									T/B AUCK.SAND KGM2
10	14.7	13.4	13.5	13.5	237	237	70	66	MOHAKA
20	30.0	30.0	45.3	42.3	230	237	449	418	Age 5 thin to 600
30	41.3	42.2	63.3	62.9	221	235	856	853	Age 8 thin to 237
40	49.2	50.0	72.6	79.5	211	228	1156	1266	a=.8142,b=.3023
									T/B VOLC.PLAT KGM2

Mortality values, for representative ages, have been plotted on Graph 1. This plot also shows percentage differences in stocking, between models, relative to KGM, at age 40.

These mortality trends are ordered by final crop stocking, the two age 40 extremes being:

1. -8.6% Napirad mortality over prediction in the Fenton regime; and

2. +7.9% Napirad mortality under prediction in the Kaingaroa 2 regime;

with other regimes slotting neatly inbetween.

Because forest managers are interested in volumes and this is how growth models are ultimately judged, volumetric comparisons at ages 30 and 40 are presented in Table 3.

Napirad tends to over predict volumes around age 30 in all cases; the magnitude of the over prediction being greatest in Kaingaroa regimes. By age 40 these Napirad TSV prediction trends have reversed to under prediction for Hawkes Bay/Fenton regimes. However, for Kaingaroa regimes the over prediction has increased.

Implications of these results will be discussed in the next section.

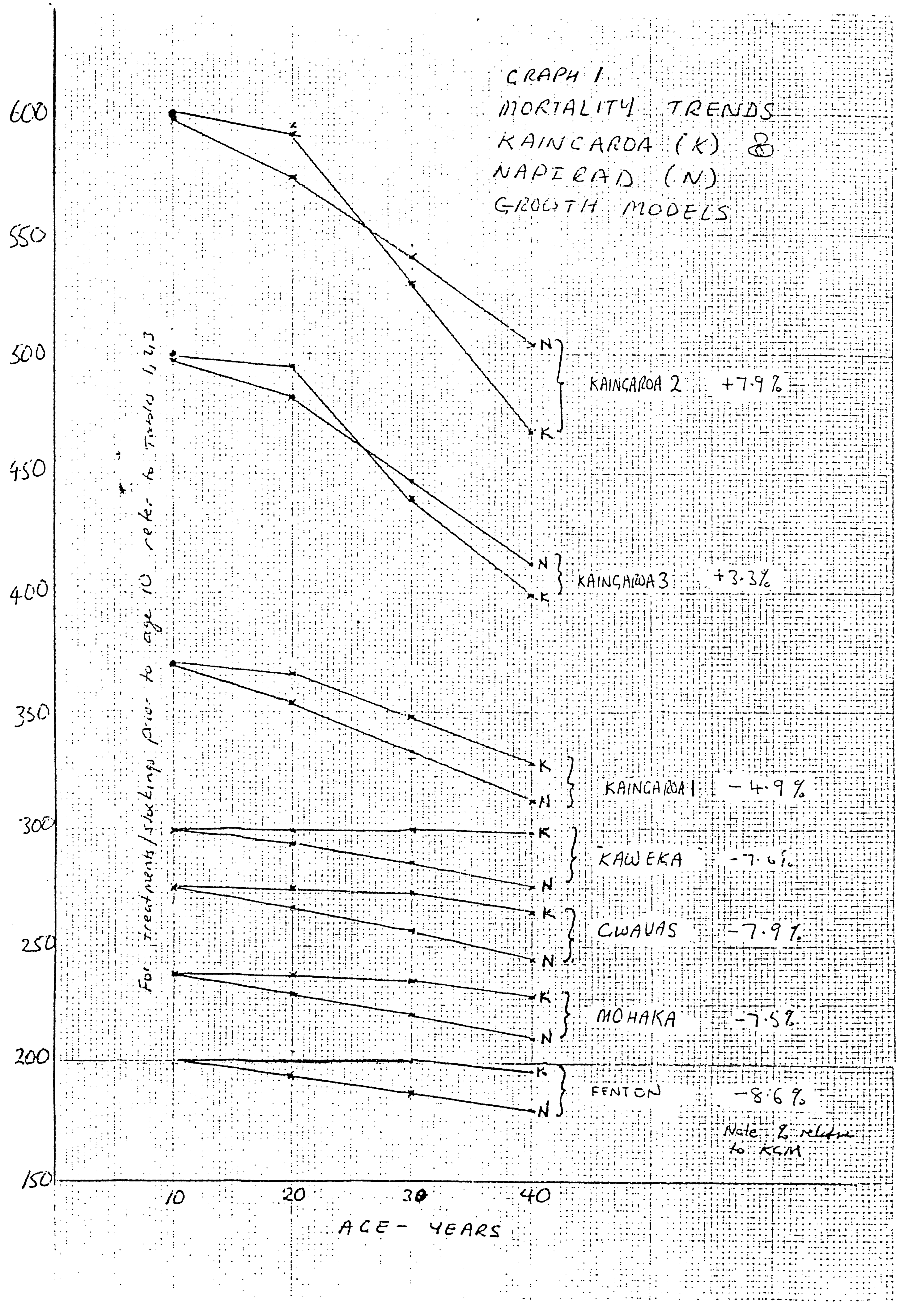
GRAPH 1
MORTALITY TRENDS
KAINGAROA (K) &
NAPIER AD (N)
GROWTH MODELS
KAINGAROA 2 +7.9%
KAINGAROA 3 +3.3%
KAINGAROA 1 -4.9%
KAWEKA -7.6%
GWAVAS -7.9%
MOHAKA -7.5%
FENTON -8.6%
Note % relative to KGM
For treatments/stockings prior to age 10 refer to Tables 1, 2, 3
600
550
500
450
400
350
300
250
200
150
10
20
30
40
AGE - YEARS

Table 2: NAPIRAD VS STANDARD KANG & FENTON REGIMES

AGE	TOP-HT		BASAL AR		STOCK		TSV		REGIME NOTES
	NAPI	KGM1	NAPI	KGM1	NAPI	KGM1	NAPI	KGM1	
6	8.8	7.0	9.0	9.0	1730	1730	41	27	KAINGAROA
6			4.2	4.5	600	600	18	13	Standard regime
9	14.3	12.8	15.5	16.2	595	600	82	76	Age 6 thin to 600
9			10.5	11.9	370	370	56	56	Age 9 thin to 370
10	16.2	14.8	14.2	15.5	369	370	82	82	a=.9, b=.3
20	32.2	32.2	50.5	44.9	354	368	538	474	
30	43.6	43.2	70.9	64.3	333	348	1010	892	
40	51.2	49.2	80.5	80.1	312	328	1337	1255	
8	10.2	8.6	9.0	9.0	1730	1730	47	32	KAINGAROA 2
8			4.4	5.0	600	600	21	25	SI 27.7
10	13.3	11.9	9.7	11.2	597	600	51	49	High stocking
20	27.7	27.7	45.0	41.4	574	592	422	382	Age 8 thin to 600
30	38.8	39.1	69.1	60.5	541	529	887	765	and leave
40	46.9	46.2	82.2	74.5	504	467	1260	1099	
9	14.8	13.3	27.0	27.0	1200	1200	131	132	KAINGAROA 3
9	14.8	13.3	13.8	14.5	510	510	76	71	Age 9 thin to 510
10	16.7	15.3	17.9	17.8	508	510	107	98	SI 30
20	33.0	33.0	56.8	47.2	482	495	623	510	
30	44.4	43.9	77.3	65.0	448	440	1123	914	a=.9, b=.3
40	51.9	49.7	86.4	79.3	412	399	1457	1254	
6	8.0	6.4	9.0	9.0	1730	1730	38	25	FENTON
6			4.4	4.9	680	680	17	14	SI 30
10	14.7	13.6	20.3	20.2	672	680	110	101	Age 6 thin to 680
10			7.4	7.7	200	200	39	38	Age 10 thin to 200
20	30.0	30.5	35.7	33.0	195	200	355	332	Similar to Manley
30	41.3	41.7	55.8	53.0	188	200	752	710	& Knowles NZJF
40	49.2	48.2	66.5	70.1	180	197	1059	1076	a=.9, b=.3

Cont. Table 3

Table 3: NAPIRAD VS KGM VOLUME PREDICTIONS

AGE	TOTAL STEM VOLUME NAPI	KGM	PERCENT* DIFFERENCE	REGIME NOTES
30	834	795	+4.9	GWAVAS
40	1146	1196	-4.2	
30	663	547	+21.2	KAWEKA
40	962	830	-15.9	
30	856	853	+0.3	MOHAKA
40	1156	1266	-8.7	
30	1010	892	+13.2	KAINGAROA 1
40	1337	1255	+6.5	
30	887	765	+15.9	KAINGAROA 2
40	1260	1099	+14.6	
30	1123	914	+22.8	KAINGAROA 3
40	1457	1254	+29.7	
30	752	710	+5.9	FENTON
40	1059	1076	-1.6	
50	1261	1416	-10.9	FENTON CONT
60	1380	1738	-20.5	
70	1446	2052	-29.5	
90	1486	2681	-44.6	(NAPI VOL PEAK)

*Relative to KGM

Discussion

The above results suggest:

1. Volumetric prediction differences for the Kaingaroa type regimes are over 10 per cent and thus will affect cutting plans and rotation lengths.

2. Gross piece size (TSV ÷ stocking) predictions differ between model predictions for the same regime, the most marked discrepancy being with Kaingaroa regimes. (Table 4).

Table 4: GROSS PIECE SIZE COMPARISON (M^3)

AGE	MOHAKA			KAINGAROA 3			FENTON		
	NAPI	KGM2	(%DIF)*	NAPI	KGM1	(%DIF)*	NAPI	KGM1	(%DIF)*
30	3.9	3.6	(8)	2.5	2.1	(19)	4.0	3.6	(13)
40	5.5	5.5	(0)	3.5	3.1	(12)	5.9	5.5	(7)

*Relative to KGM

3. The pattern in model predictions appears to be related to regimes and obviously to the model building data sets. Thus each model appears to predict adequately in areas similar to the historical data sets used for their construction - as one would hope and expect. (This fact is what saves further work in establishing which model is "right" - a task inferrable from point 1).

4. Validation of models is difficult, as the predictions are mythical average or middle values seldom found in individual plot data. Mortality trends will be the most variable in space and time because of its "globby" nature and so harder to verify with plots. (This is very likely true at Golden Downs too).

5. After examining and discussing the mortality results the general feeling is that NAPIRAD type trends may be real - especially when it is realised, that contrary to popular belief or what the video screen says:

   NORMAL WIND DAMAGE <u>IS</u> INCLUDED in Garcia type models

6. Thus, Napirad - and Garcia - mortality trends are likely to be real - it's just that we have got comfortable with the KGM/BEEK mortality predictions*. One must also remember that mortality is a "globby" process in space/time which is being modelled by a continuous function - hence the steady attrition - e.g. ca. 1 stem/yr exhibited by Napirad and GDNS81.

7. Indications (e.g. see Appendices) are that Napirad or Garcia type models behave better under extrapolation than regression based models.

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*Actually Elliott and Goulding reported during testing as KGM1 at Kaingaroa that mortality may have been under predicted in old crop stands.

Conclusion

The above model runs indicate that one can have a reasonable degree of confidence in applying each model for regimes/data reminicent of historical modeled building data. Outstide these domains Garcia type models such as Napirad appear to be the lesser of the evils, with mortality trends being perhaps uncomfortably closer to reality than most managers are prepared to admit (or BEEK/KGM predicts). An implication is being that to get final crop stockings age 30 of 200 spha, the final thinning at age 10, according to Napirad should be to ca. 230, not 200 spha (as conventional wisdom would indicate).

Clearly, Napirad requires more validation for conservative Kaingaroa type regimes, but its superiority appears sufficiently established for Hawkes Bay type regimes to permit immediate implementation.

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APPENDIX I

NAPIRAD VS KGM1 MORTALITY COMPARISON - FENTON CONTINUED

AGE	TOP-HT		BASAL AR		STOCK		TSV		REGIME NOTES
	NAPI	KGM1	NAPI	KGM1	NAPI	KGM1	NAPI	KGM1	
40	49.2	48.2	66.5	70.1	180	197	1059	1076	
50	54.4	51.7	71.8	86.3	172	195	1261	1416	
60	57.8	53.5	74.0	102.5	164	193	1380	1738	
70	60.1	54.5	74.7	119.0	156	192	1446	2052	BA Peak age 71*
80	61.5	55.0	74.6	135.9	148	192	1476	2365	
90	62.5	55.3	74.0	153.4	141	192	1486	2681	Vol Peak*
100	63.0	55.4	73.2	171.5	135	191	1483	3005	
150	64.0	55.6	68.2	272.2	108	191	1401	4782	Asymptotic ht
200	64.1	-	63.3	-	89	-	1305	-	reached at age 60*
300	64.1	-	54.6	-	64	-	1124	-	*NAPIRAD

APPENDIX 2

NAPIRAD VS KGM1 MORTALITY COMPARISON - HIGH STOCKING

AGE	TOP-HT		BASAL AR		STOCK		TSV		REGIME NOTES
	NAPI	KGM2	NAPI	KMG2	NAPI	KGM2	NAPI	KGM2	
10	14.7	13.6	23.1	23.1	1500	1500	134	115	Unthinned SI 30
20	30.1	30.5	70.4	51.8	1374	1119	726	520	Starting spha=1500
30	41.4	41.7	90.8	60.5	1228	664	1258	811	
40	49.2	48.2	99.9	69.7	1083	498	1627	1070	
50	54.4	51.7	103.5	80.8	953	432	1852	1325	
60	57.9	53.5	104.4	93.1	840	403	1976	1578	Max BA at 60*
70	60.1	54.5	104.0	106.1	743	389	2038	1830	
80	61.5	55.0	102.9	119.6	661	382	2060	2082	Max vol at 85 2060*
90	62.5	55.3	101.5	133.5	592	378	2059	2334	
100	63.1	55.4	100.0	147.5	533	376	2045	2585	*NAPI
150	64.0	55.6	92.4	218.8	339	374	1910	3843	
160	64.1	55.6	91.0	233.1	314	374	1881	4095	
200	64.1	55.6	85.5	290.5	236	374	1767	5104	
300	64.1	55.6	73.6	434.5	136	374	1516	7672	
400	64.1	55.6	63.4		89	374	1305		
500	64.1	55.6	54.7		64	374	1126		
1000	64.1	55.6	26.5		22	374	545		
2000	64.1	55.6	6.3		8	374	131		DBH = 102.6
3000	64.1	55.6	1.5		4	374	32		
4000	64.1	55.6	0.3		3	374	6		
7535	64.1	55.6	<1		1	374	<1		DBH = 14cm
9000	64.1	55.6	<<1		1	374	0		DBH = 1.5cm