F.R.I. PROJECT RECORD
NO. 1457

MORTALITY IN THE GOLDEN DOWNS MODEL

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ABSTRACT

Mortality prediction in the Golden Downs growth model is reexamined. It is concluded that the model fits well the data available. Further analysis would require different data.

INTRODUCTION

On several occasions, users of the Golden Downs P.radiata growth model have expressed doubts about the mortality predictions. There has been concern about a possible overprediction of mortality at low stockings, and its effect on estimated piece sizes.

The conformance of the mortality predictions to the data is reexamined here. Previous analysis are reviewed, and new comparisons are presented.

DATA AND INITIAL VALIDATION

This section reviews the information on mortality presented in Garcia (1984a).

The data used in the model excluded measurements where "significant" windthrow occurred. This was defined as measurements with more than two trees recorded as windthrow since the previous measurement, or where the mean dbh of the fallen trees was greater than the mean dbh for the plot.

The mortality data used is shown in Figure 1. Figure 2 displays more clearly the data for low stockings (wide spacings), and compares the data vs the predictions. The predictions are for pairs of consecutive measurements, estimating the stocking at the second measurement given the state of the stand at the first.

In Figure 3, the predicted increment has been subtracted from the second measurement of each pair. Therefore, errors are here shown as deviations from the horizontal.

These graphs indicate that there is a reasonable amount of data available for low density stands, and illustrate the high variability typical of mortality data. It is also clear that occasional mortality is present at wide spacings.

Figures 2 and 3 show the typical pattern of errors in mortality prediction: small overpredictions most of the time, when mortality does not occur, and a few large underpredictions, when mortality actually happens. It is not easy from these graphs, however, to assess the balance between these two kinds of errors.

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In August 1984, a study was carried out to evaluate the performance of the model at stockings below 250 stems per hectare (Garcia 1984b). Special attention was paid to the mortality predictions.

Values were computed for various prediction intervals. Figure 4 reproduces the summary results. In average, there was a small mortality overprediction, not statistically significant. Note that this did not cause an overprediction of piece size, as judged by the mean tree dbh.

It may be useful to repeat here the conclusions of that study:

"There has been some concern expressed about the apparent overprediction of mortality by the model. In fact, looking at the figures in Table 1 [the full listing of data and predictions] gives the impression that the model consistently underpredicts stocking. An objective analysis of the data, however, shows no evidence of biases of any practical or statistical significance. This apparent contradiction can be explained by some characteristics of stand mortality:

"(a) Mortality is highly variable and tends to occur in "clumps": Most plots in most increment periods have no mortality at all, but sometimes considerable mortality occurs. We tend to notice more a large number of small differences in one direction than a small number of large differences in the opposite direction. All that a deterministic model can do is to predict some average expected mortality. It should be mentioned that under normal management conditions mortality is likely to be higher than predicted because plots with "heavy" wind damage (more than 2 trees or dbh larger than the mean dbh for the plot) were excluded, and because damaged experimental plots tend to be abandoned.

"(b) At these stand densities the stocking is fairly constant, and slowly varying trends are easily seen. This may be accentuated by the stockings being large integers; we do not notice as much the variations in the decimal places of the height or basal area. Also, any errors are large relative to the changes in stocking from year to year. The relative error in the change of stocking is irrelevant, however, since what we want is to predict the final values.

"It can be concluded that the performance of the model on these stands is very satisfactory, especially considering that the model attempts to cover a very wide range of treatments and stand conditions."

KIM LOWELL

In his Ph.D. thesis, Kim Lowell carried out an independent validation of the Golden Downs growth model (Lowell 1984).

Figure 5 reproduces one of his tables, with the relevant numbers highlighted. It summarises values for various prediction period lengths. MB is the mean bias, i.e., the average observed minus predicted stocking. Over-all, there is a small underprediction of mortality, not statistically significant.

ANOTHER LOOK

In an attempt to further clarify the pattern of mortality prediction errors, a number of scatter diagrams were prepared. Figure 6 displays the observed vs predicted mortalities, based on all pairs of consecutive measurements. Figures 7 and 8 show the residuals, in absolute terms and as a percentage of the predictions. The second graph in each figure expands the detail for the lower stockings.

Measurements immediately following thinnings were plotted in a different colour, to see if mortality was associated with thinning damage or sudden exposure. No particular patterns were apparent.

These graphs demonstrate the nature of the problem. Mortality has a extremely skewed distribution. With a skewed distribution, without stating the use to be made of the estimate, it is not clear what a "good" point estimator should be. The mean (unbiased)? The mode (most frequent value)? The median (the 50% point)? Something else?

There is another problem with bias as a criterion for evaluating estimators. Estimates derived by nonlinear transformations of an unbiased estimate are not unbiased for the corresponding population values. For example, the average spacing derived from an unbiased stocking estimate will be biased, and vice-versa.

In most instances the user is not interested in the mortality or stocking per se. Rather, he wants good estimates for certain related quantities, such as piece size. It is therefore more appropriate to judge the goodness of mortality estimates by looking at those quantities.

MEAN DBH, BASAL AREA, VOLUME

A good proxy for piece size is the mean dbh. Figure 9 shows no obvious bias in the dbh increment estimates. Basal area and volume increment estimates are also satisfactory (Figures 10 and 11). From this perspective at least, mortality appears to be adequately estimated.

Incidentally, figures 9 to 11 also give some idea of the variability that can be expected from the estimates. Note that the residuals include sampling and measurement errors.

WRONG DATA?

It has been shown above that the model fits well the PSP data. Obviously, it is possible for the data to be faulty. Windthrow might have been recorded as natural mortality. Present and future mortality trends might differ from those of the past. Mortality may be different in other Nelson forests outside Golden Downs. It may be pointed out, however, that similar patterns, with mortality occurring at wide spacings, are observed in data for other regions.

It is unlikely that any of these doubts could be resolved with additional sample plot data. Because of the large variability in mortality, any further studies would have to use full enumerations in large blocks of forest. One methodological problem would be the identification of windthrow. Was a tree dead before being blown down? Was it weakened and going to die anyway? Reliable dating of the mortality would be also necessary.

CONCLUSION

All the evidence indicates that the Golden Downs growth model reflects satisfactorily the mortality trends present in the data used for its development.

REFERENCES

GARCIA,O. (1984a) New class of growth models for even-aged stands: Pinus radiata in Golden Downs Forest. N.Z.J.For.Sci. 14, 65-88.

GARCIA,O. (1984b) Performance of the Golden Downs growth model on low-stocking stands. FRI Production Forestry Division, Project Record 575, August 1984.

LOWELL,K.E. (1984) Incorporation of the effects of fertilizer into an existing computer growth model for Golden Downs Forest, Nelson Region, New Zealand. University of Canterbury, Ph.D. Thesis.

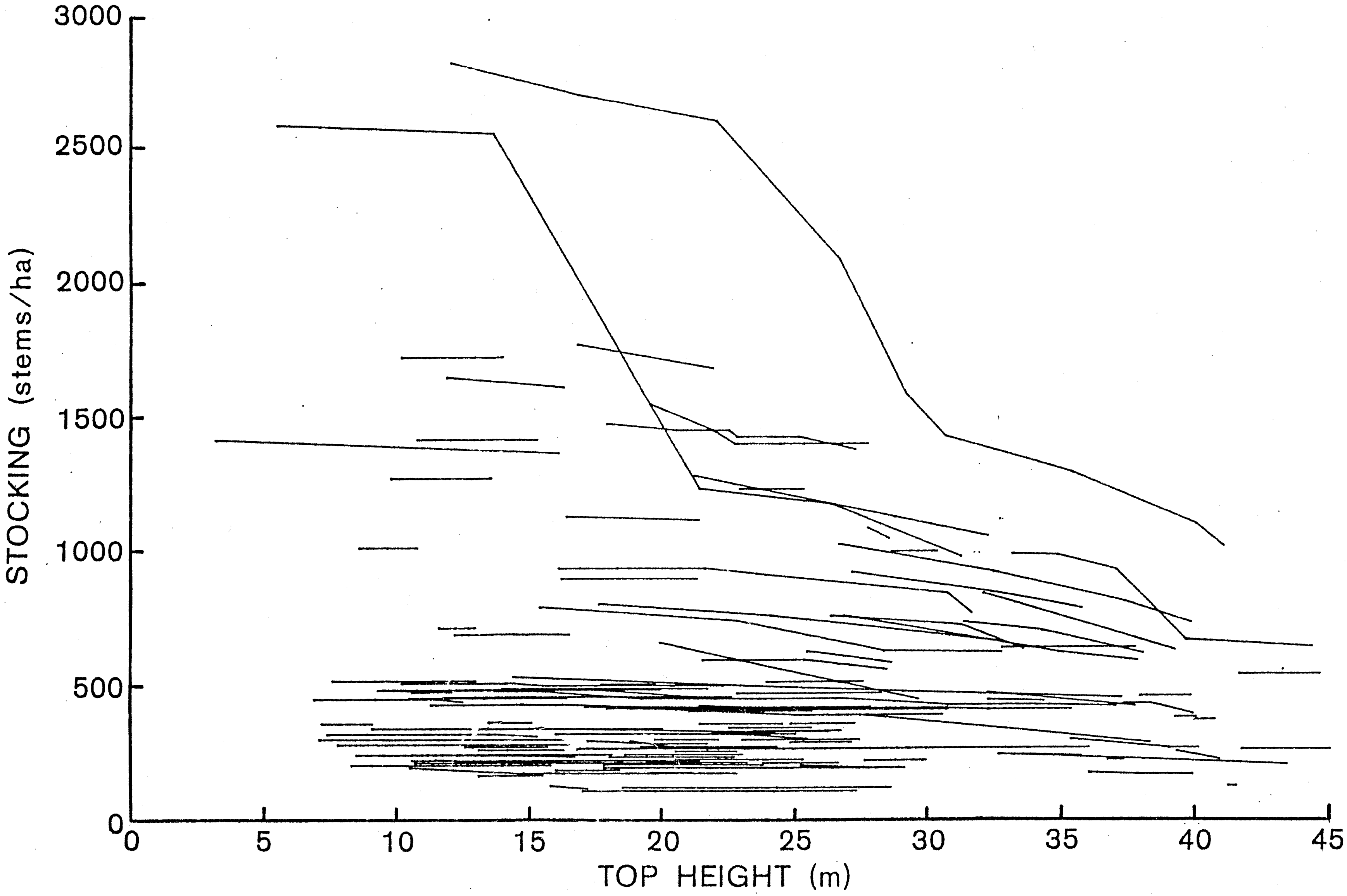
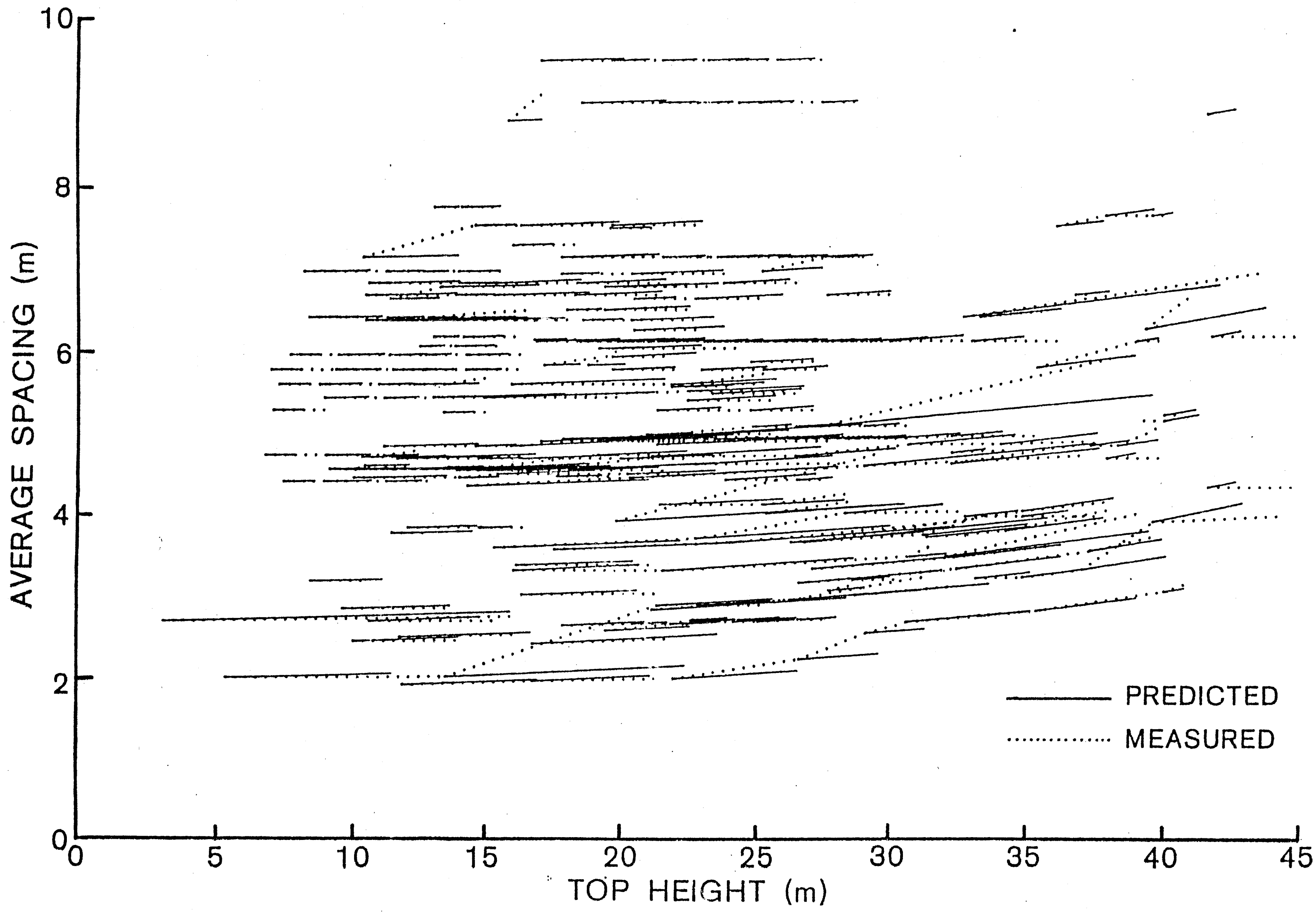
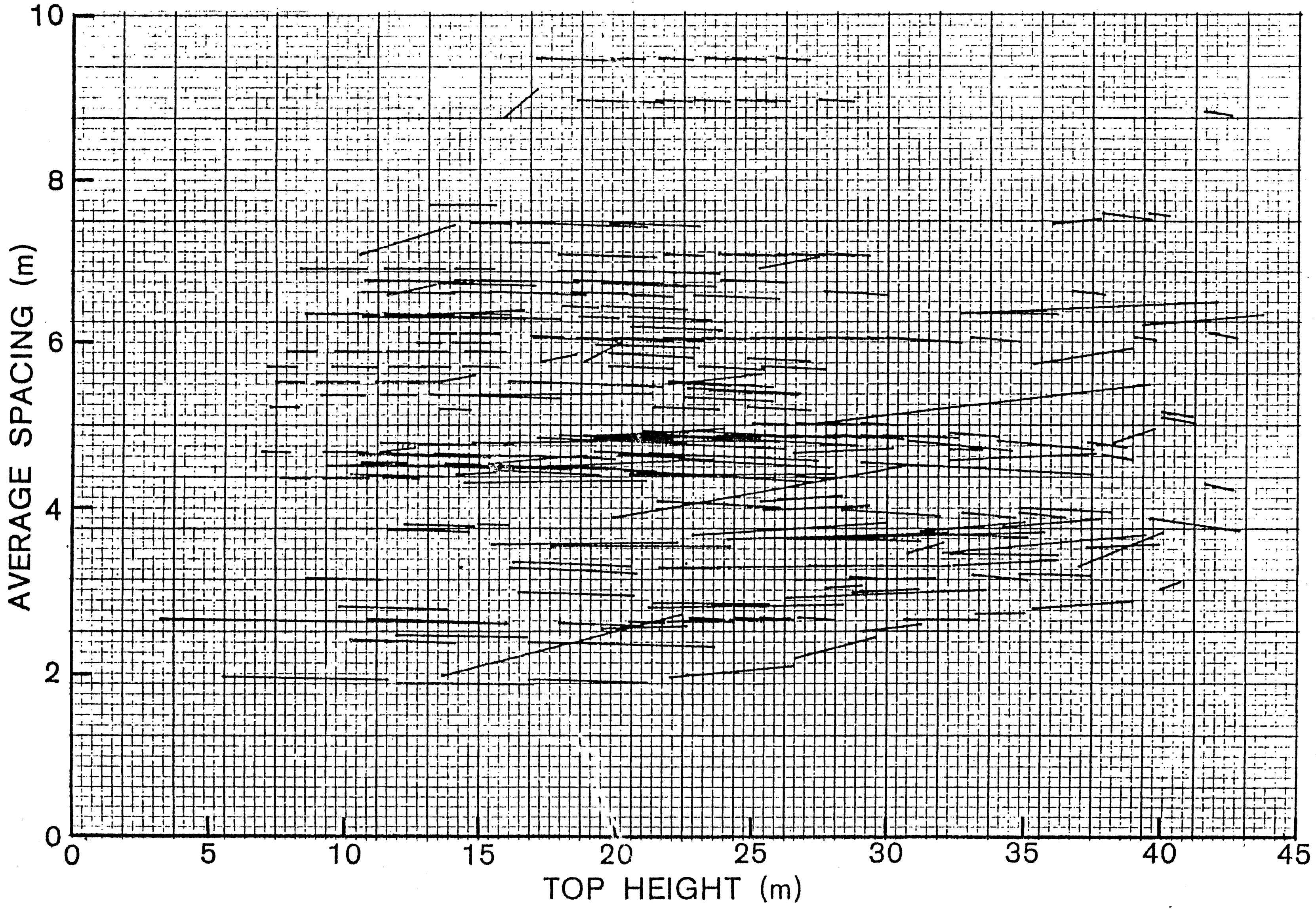

STOCKING (stems/ha)
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
45
TOP HEIGHT (m)

Figure 1



AVERAGE SPACING (m)
0
2
4
6
8
10
0
5
10
15
20
25
30
35
40
45
TOP HEIGHT (m)
PREDICTED
MEASURED

Figure 2



10
8
6
4
2
0
AVERAGE SPACING (m)
0
5
10
15
20
25
30
35
40
45
TOP HEIGHT (m)

Figure 3

1. Increment pair predictions.
Average prediction interval: 1.7 yrs. Means of 88 values.

	Measured	Predicted	Difference	t-value
Stocking	202.3	201.8	- 0.5 (- 0.2%)	1.11
Basal area	16.03	15.97	- 0.06 (- 0.4%)	0.15
Mean dbh (from mean BA and stocking)	31.8	31.7		

2. Last plot measurement, predicted from first. Average prediction interval: 3.8 yrs. Means of 37 values.

	Measured	Predicted	Difference	t-value
Stocking	210.7	209.5	- 1.2 (- 0.6%)	1.33
Basal area	20.34	20.22	- 0.12 (- 0.6%)	0.41
Mean dbh	35.1	35.1		

3. Same, prediction intervals ≥ 5 years. Average prediction interval: 6.8 yrs. Means of 12 values.

	Measured	Predicted	Difference	t-value
Stocking	193.3	192.3	- 1.0 (- 0.5%)	0.47
Basal area	25.87	25.03	- 0.84 (- 3.2%)	1.20
Mean dbh	41.3	40.7		

4. Same, prediction intervals > 6 years. Average prediction interval: 7.4 yrs. Means of 9 values.

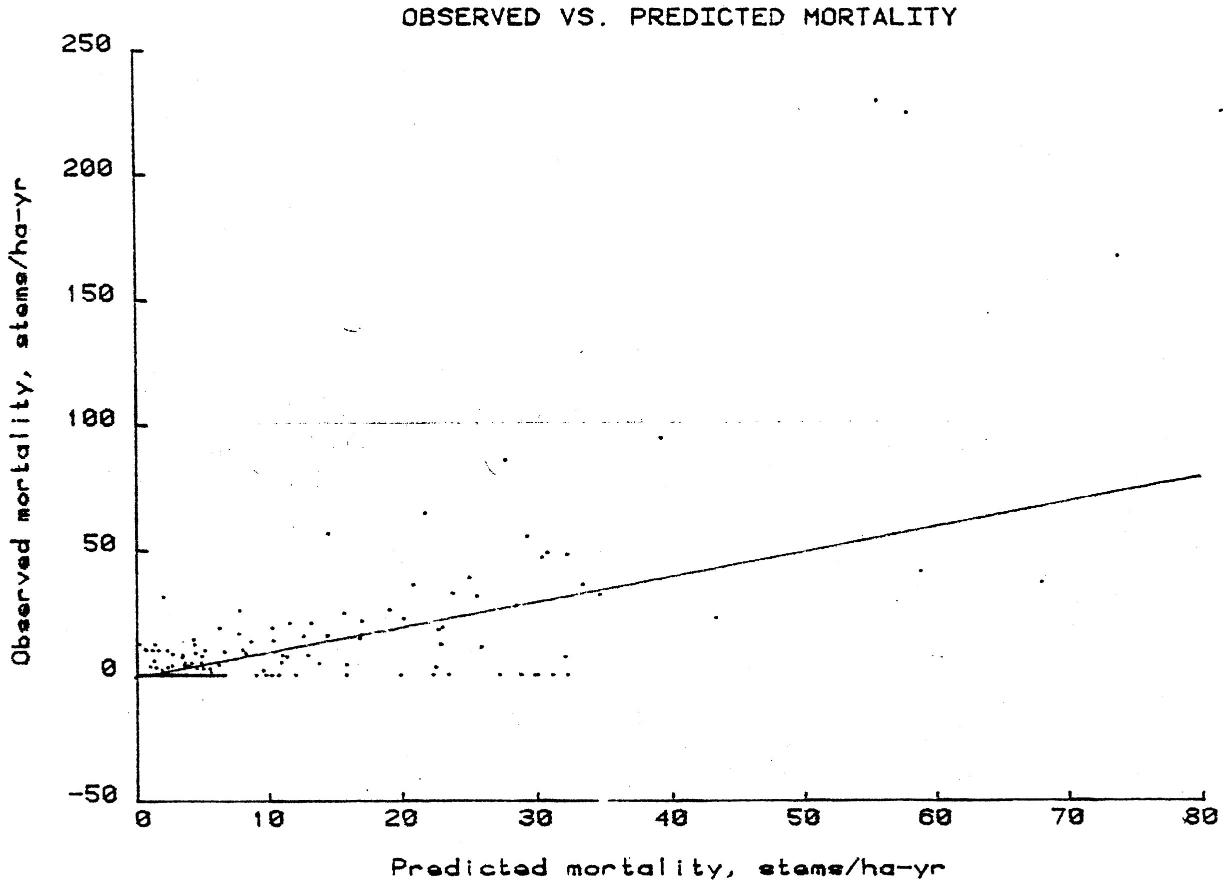
	Measured	Predicted	Difference	t-value
Stocking	188.0	187.3	- 0.7 (- 0.4%)	0.24
Basal area	27.89	26.94	- 0.95 (- 3.4%)	1.01
Mean dbh	43.5	42.8		

Figure 4

Reliability of estimates of growth from the unadjusted model for the original model derivation data.

Per. Len. (yrs)	MB	SEB	t value	Max. Resid.	SE%	Mean Value	n
Top Height							
	(m)	(m)		(m)		(m)	
1	0.16	0.035	4.455**	1.10	0.17	20.1	168
2	-0.04	0.072	-0.060	1.64	0.29	24.3	106
3	0.21	0.178	1.178	1.54	0.74	24.6	20
4	-0.09	0.221	-0.405	1.79	0.63	32.2	19
5	0.16	0.214	0.747	1.16	0.70	30.1	10
6-7	-0.50	0.612	-0.816	3.11	2.02	30.3	9
8+	-0.29	0.331	-0.864	1.51	0.97	34.1	7
Total	0.07	0.038	1.827	1.63	0.16	23.2	339
Basal Area							
	(m^2/ha)	(m^2/ha)		(m^2/ha)		(m^2/ha)	
1	0.13	0.046	2.720**	1.40	0.24	20.6	168
2	0.06	0.189	0.326	4.30	0.62	30.1	106
3	0.26	0.649	0.393	5.44	1.57	42.7	20
4	-0.72	0.835	-0.864	6.88	1.40	58.7	19
5	1.76	0.929	1.894	5.77	1.63	55.9	10
6-7	-4.06	2.183	-1.858	12.74	4.49	48.6	9
8+	-2.16	2.327	-0.927	10.70	4.26	54.6	7
Total	-0.04	0.123	-0.358	5.26	0.43	29.5	339
*** Stocking ***							
		(stms/ha)		(stms/ha)		(stms/ha)	
1	1.5	0.74	2.068*	22.2	0.18	401.4	168
2	1.2	3.83	0.326	87.4	0.82	462.7	106
3	2.3	16.30	0.138	136.1	1.69	945.0	20
4	-5.3	12.85	-0.414	104.2	1.73	729.1	19
5	1.2	6.77	0.177	35.6	0.96	715.8	10
6-7	-123.1	110.63	-1.113	579.4	16.90	654.8	9
8+	-31.7	25.84	-1.227	124.2	4.48	576.1	7
Total	-2.9	3.48	-0.833	149.5	0.70	490.6	339

Figure 5


OBSERVED VS. PREDICTED MORTALITY
Observed mortality, stems/ha-yr
Predicted mortality, stems/ha-yr
250
200
150
100
50
0
-50
0
10
20
30
40
50
60
70
80

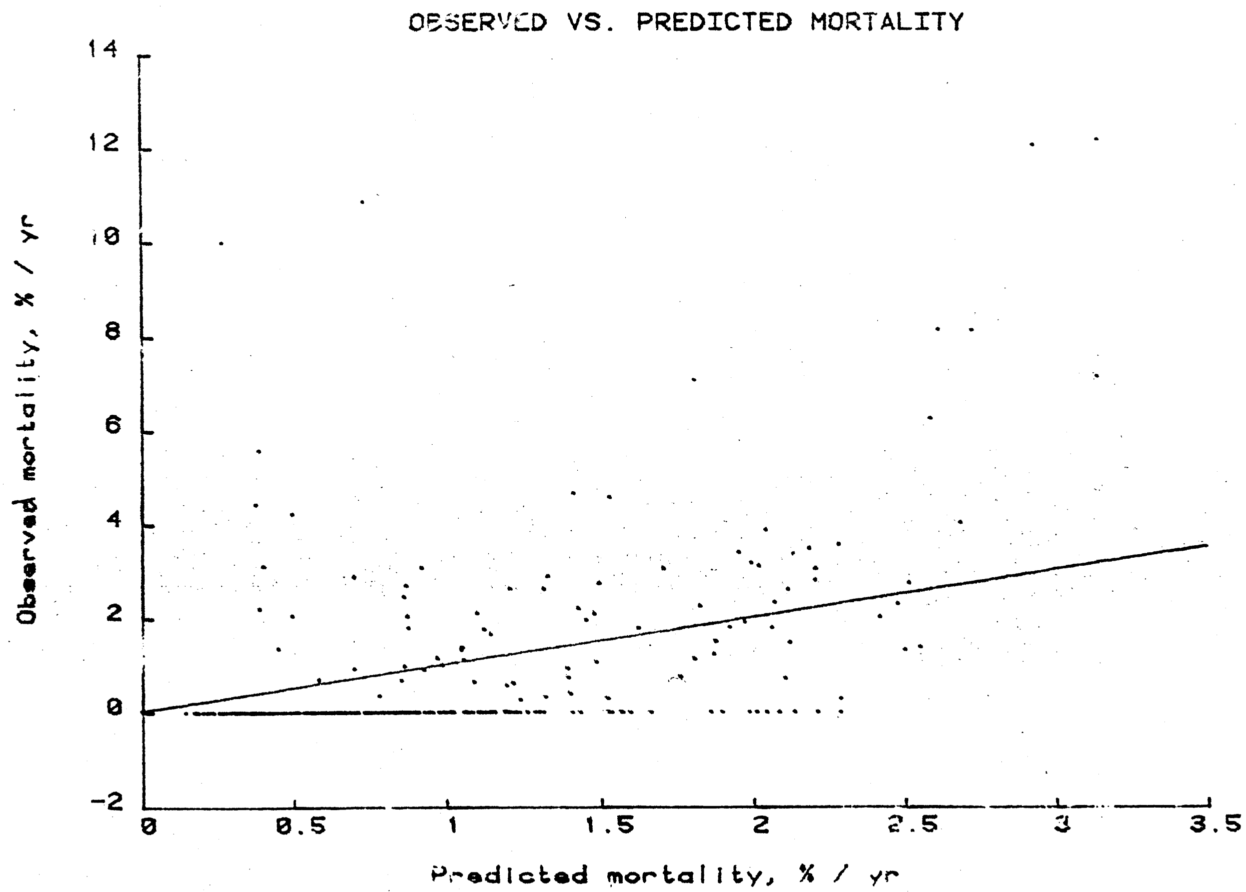
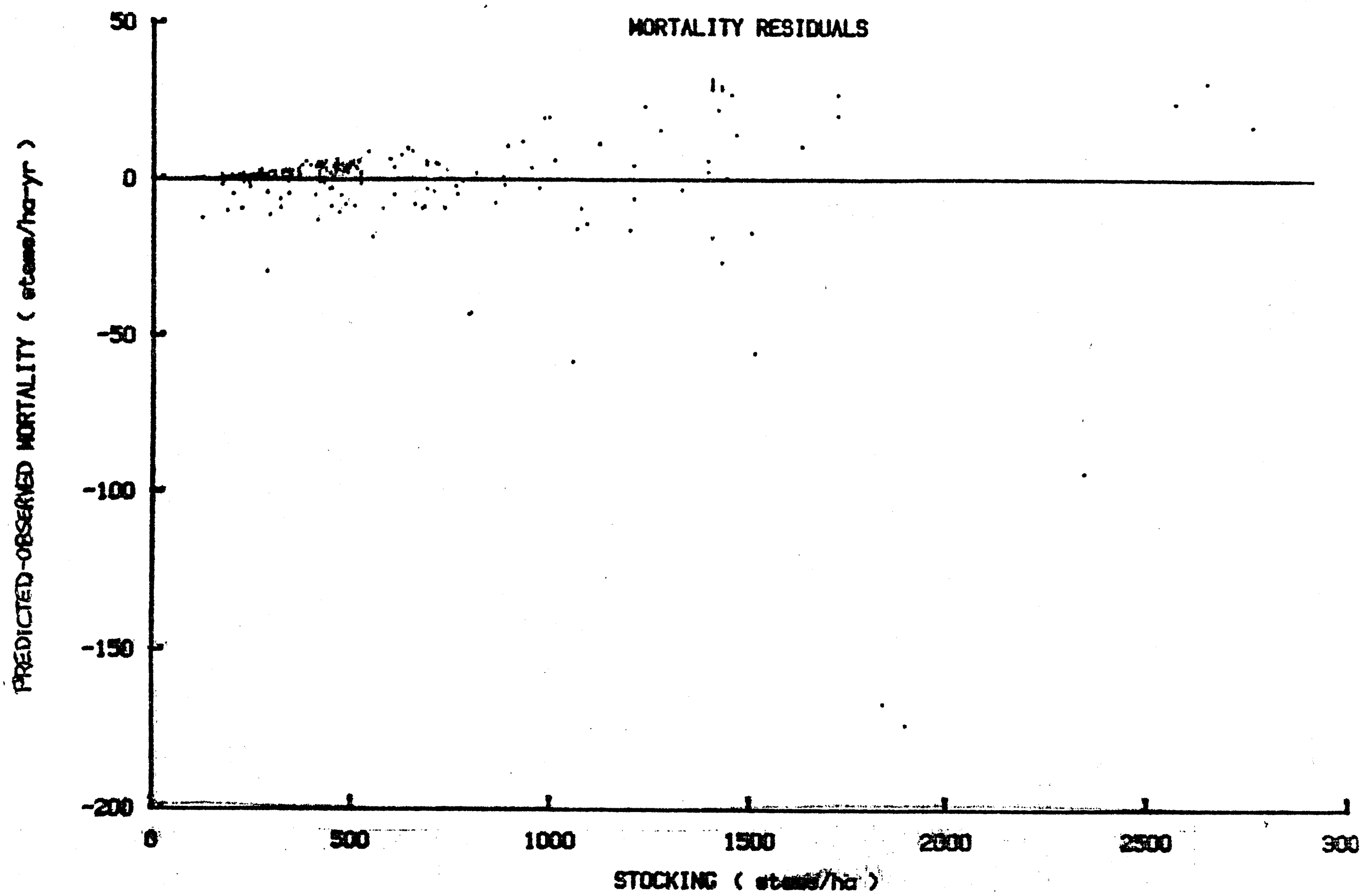

OBSERVED VS. PREDICTED MORTALITY
Observed mortality, % / yr
Predicted mortality, % / yr
14
12
10
8
6
4
2
0
-2
0
0.5
1
1.5
2
2.5
3
3.5

Figure 6


MORTALITY RESIDUALS
50
0
-50
-100
-150
-200
PREDICTED-OBSERVED MORTALITY (stems/ha-yr)
0
500
1000
1500
2000
2500
300
STOCKING (stems/ha)

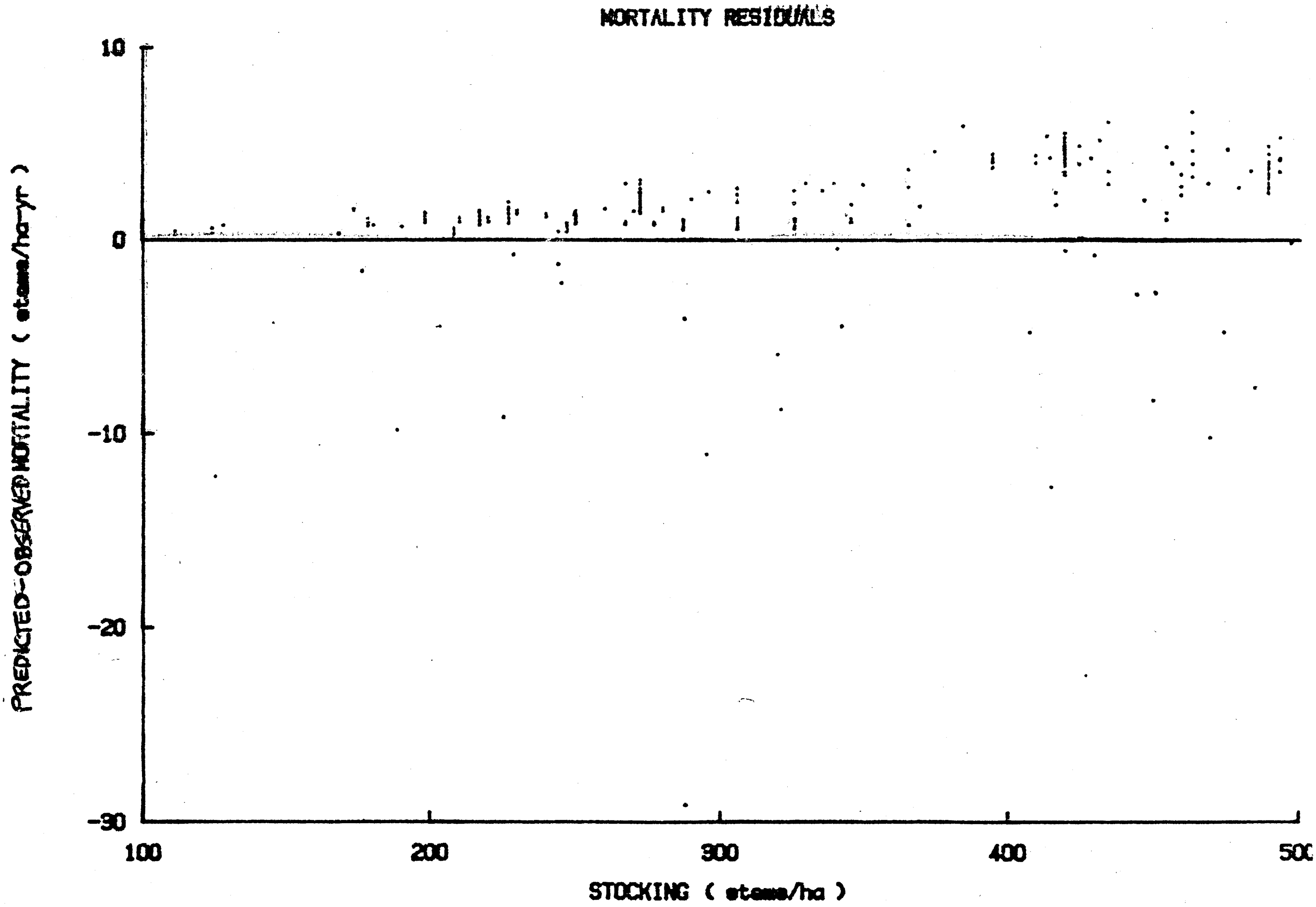
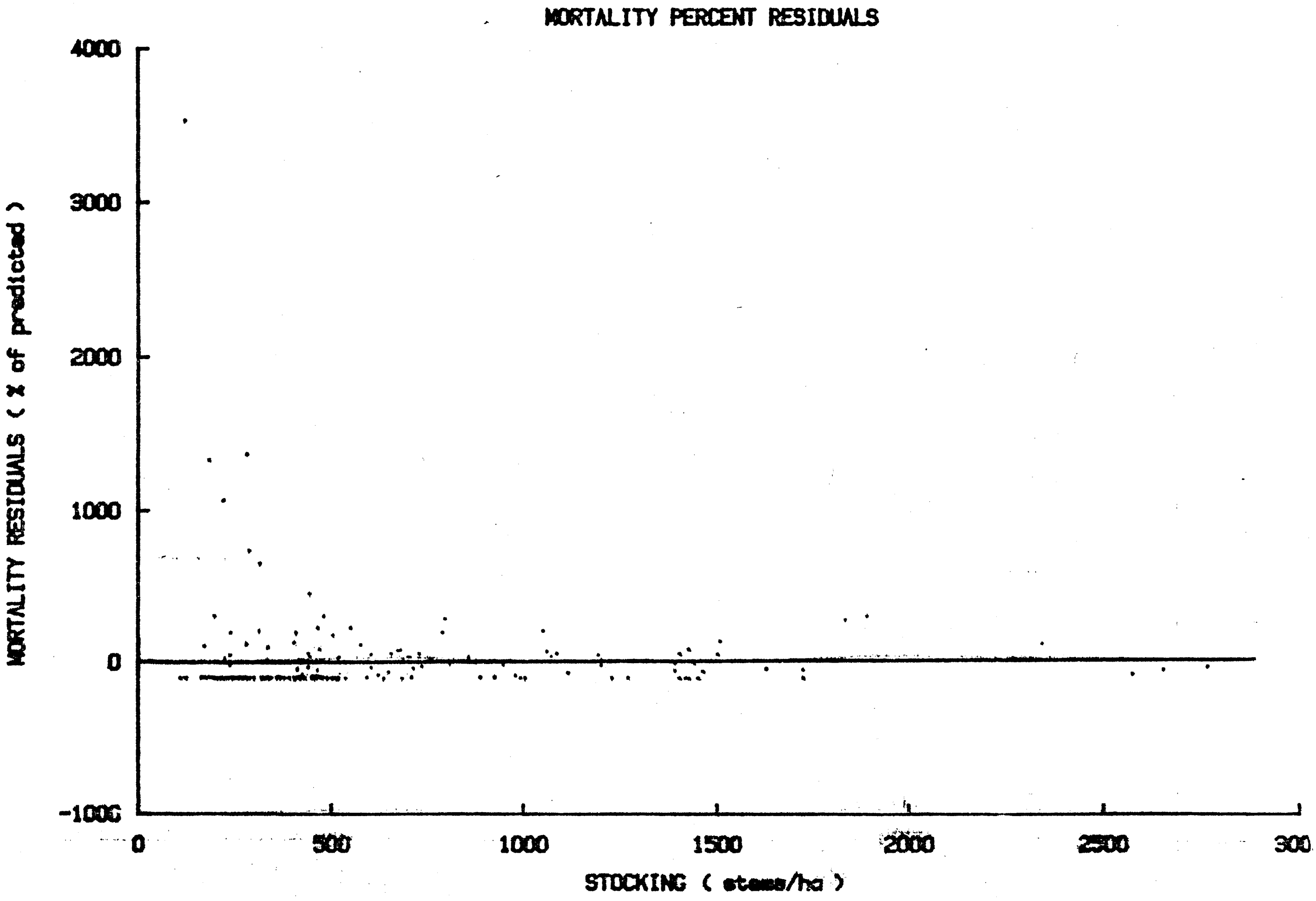

MORTALITY RESIDUALS
10
0
-10
-20
-30
PREDICTED-OBSERVED MORTALITY (stems/ha-yr)
100
200
300
400
500
STOCKING (stems/ha)

Figure 7


MORTALITY PERCENT RESIDUALS
MORTALITY RESIDUALS (% of predicted)
4000
3000
2000
1000
0
-1000
0
500
1000
1500
2000
2500
300
STOCKING (stems/ha)

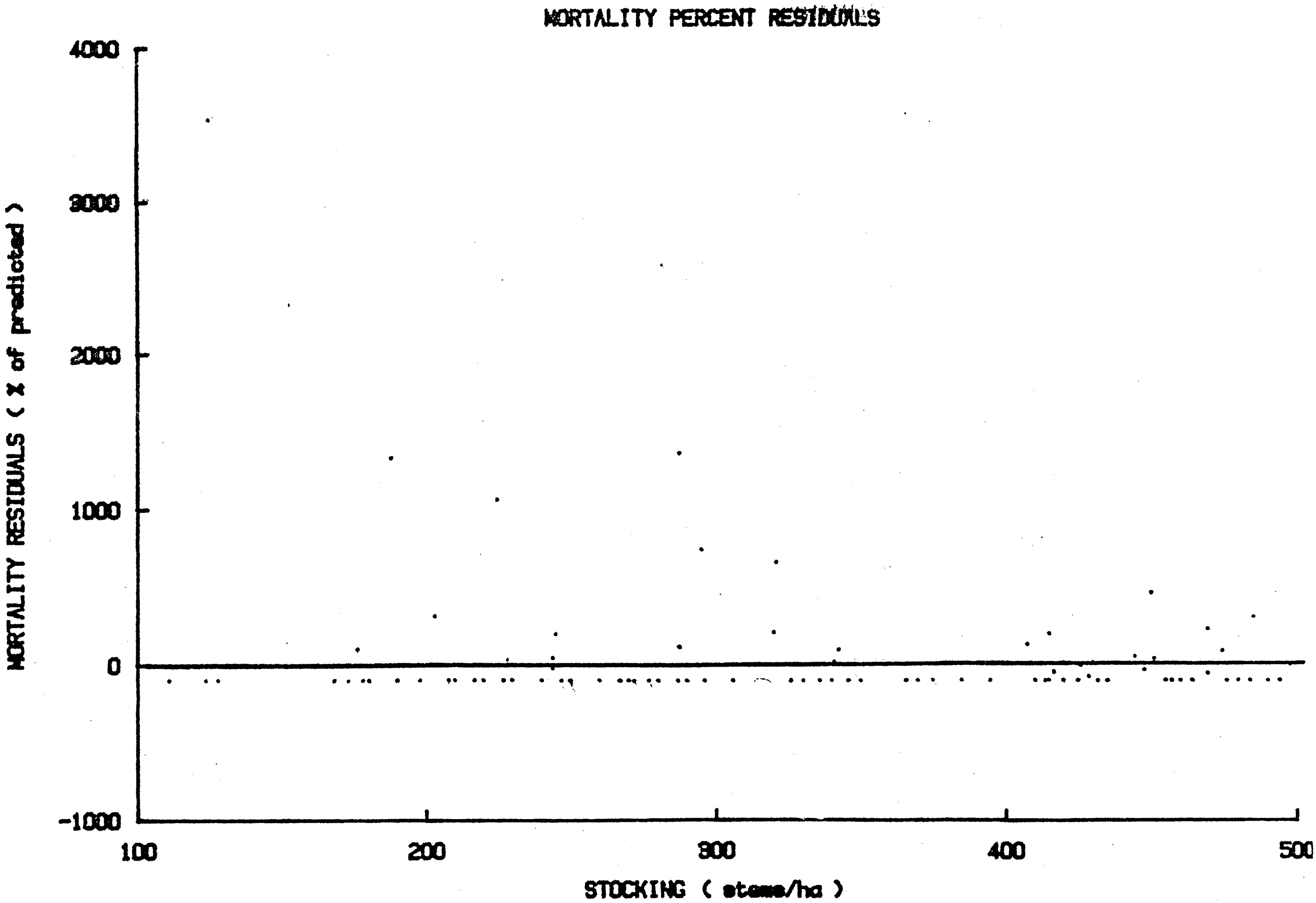
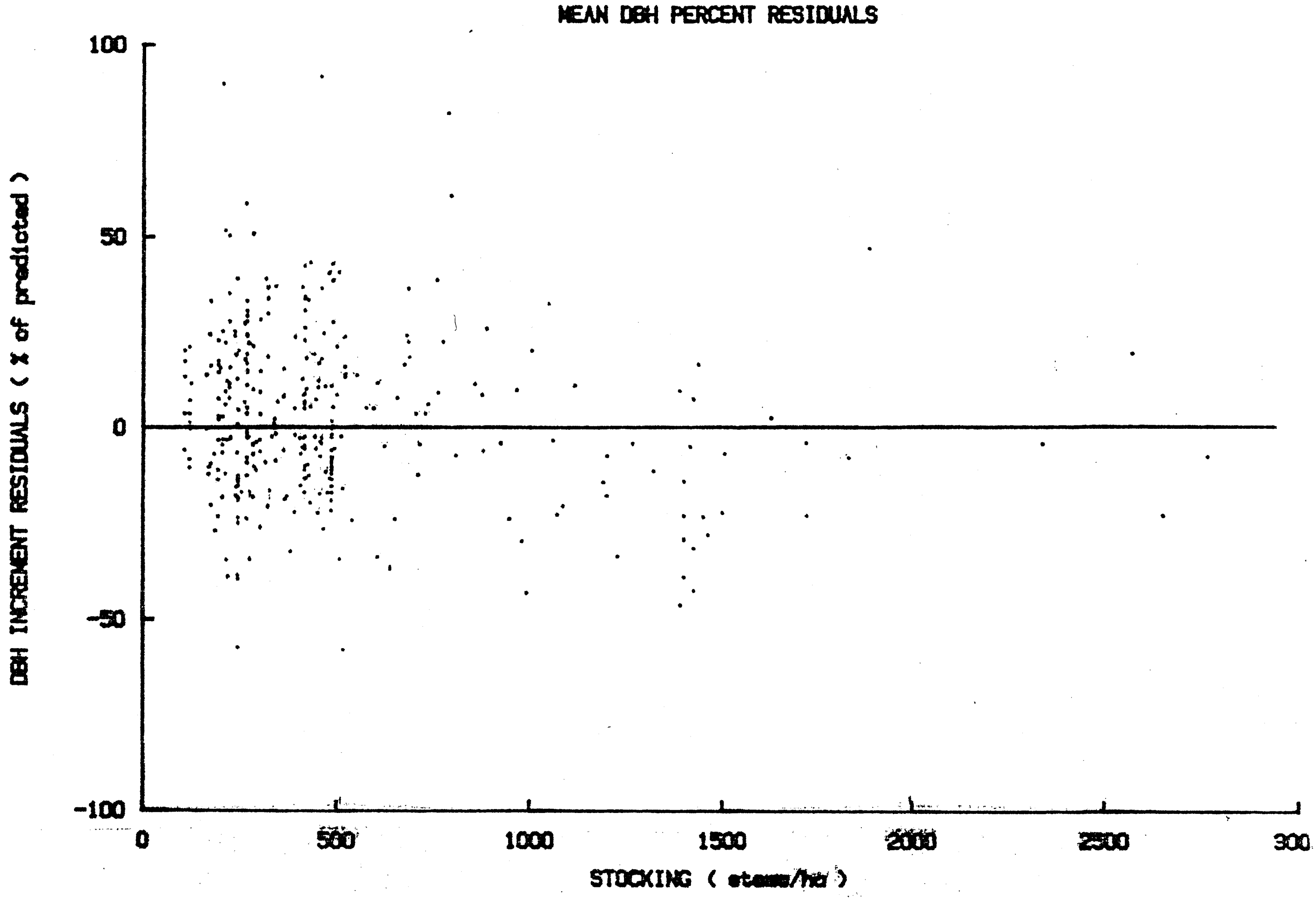

MORTALITY PERCENT RESIDUALS
MORTALITY RESIDUALS (% of predicted)
4000
3000
2000
1000
0
-1000
100
200
300
400
500
STOCKING (stems/ha)

Figure 8


MEAN DBH PERCENT RESIDUALS
DBH INCREMENT RESIDUALS (% of predicted)
100
50
0
-50
-100
0
500
1000
1500
2000
2500
300
STOCKING (stems/ha)

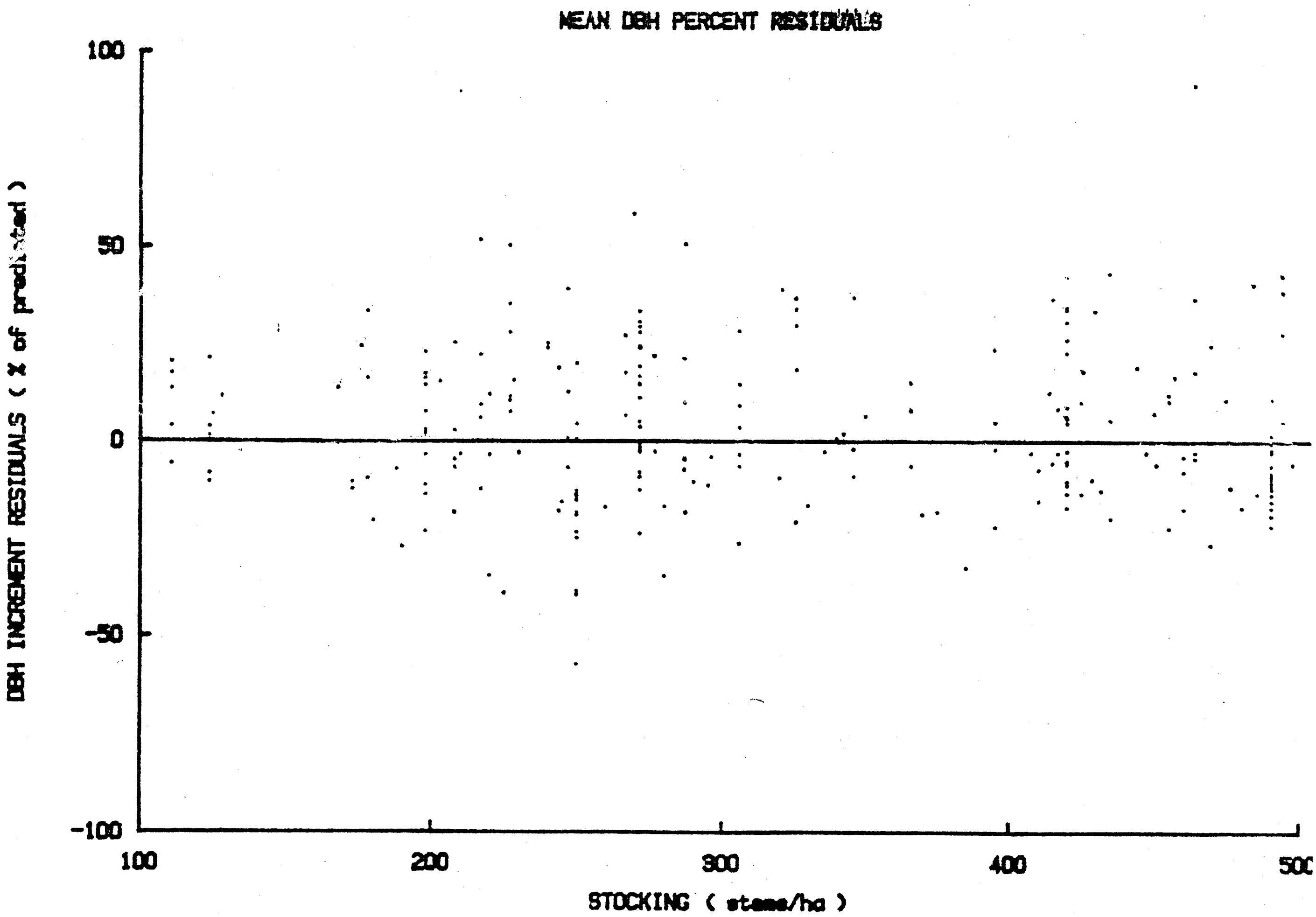
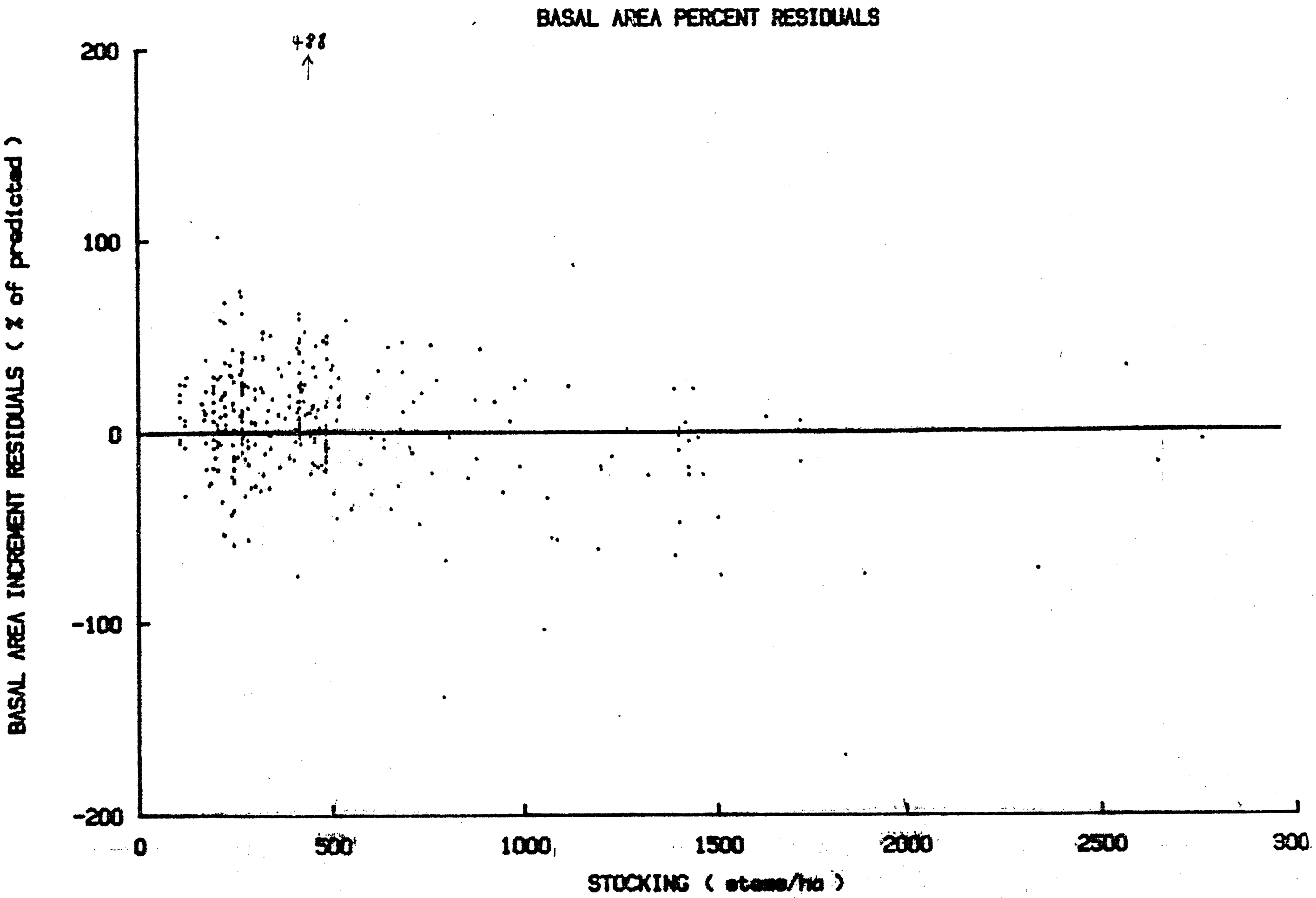

MEAN DBH PERCENT RESIDUALS
DBH INCREMENT RESIDUALS (% of predicted)
100
50
0
-50
-100
100
200
300
400
500
STOCKING (stems/ha)

Figure 9


BASAL AREA PERCENT RESIDUALS
488
200
100
0
-100
-200
BASAL AREA INCREMENT RESIDUALS (% of predicted)
0
500
1000
1500
2000
2500
300
STOCKING (stems/ha)

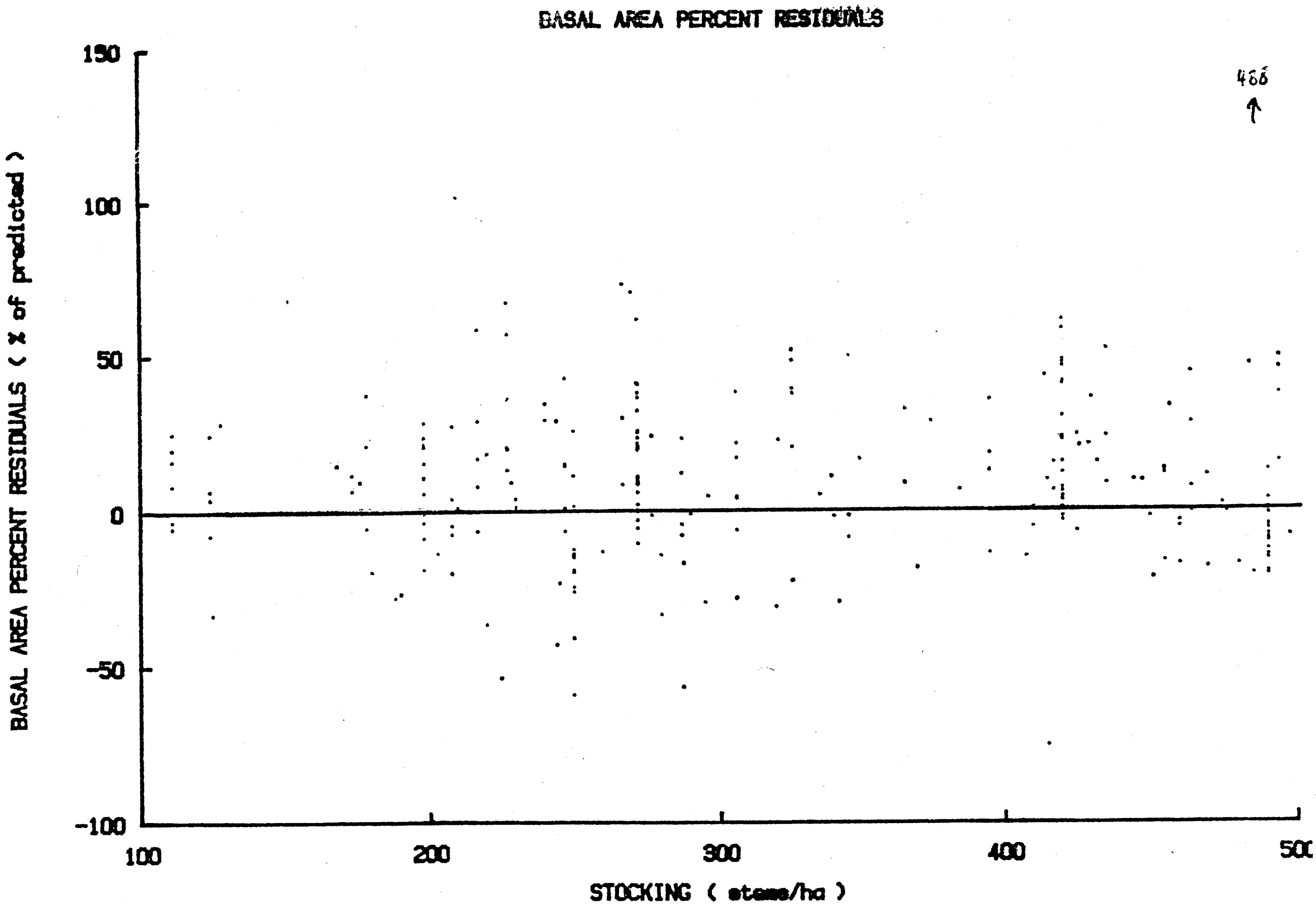
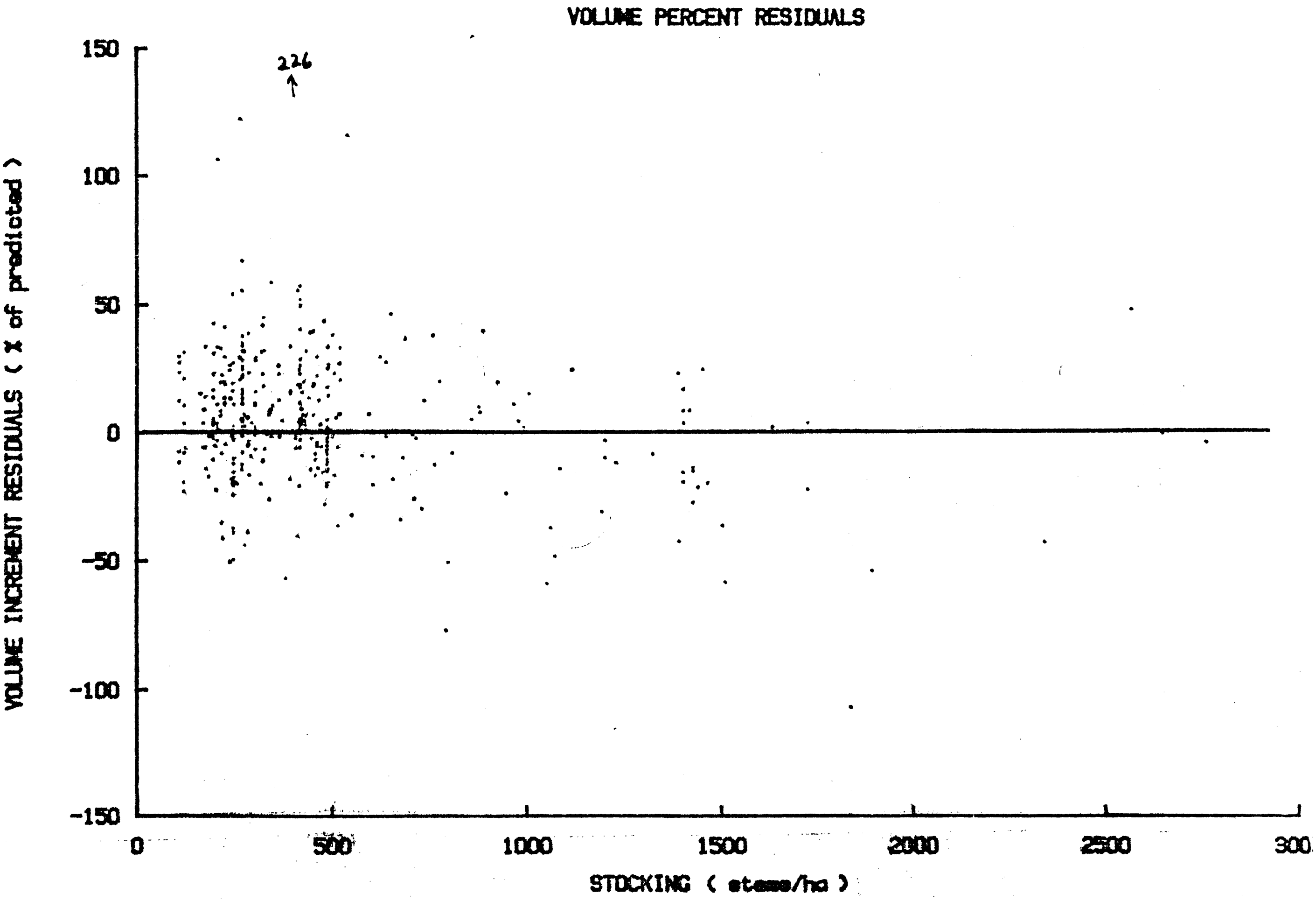

BASAL AREA PERCENT RESIDUALS
150
100
50
0
-50
-100
BASAL AREA PERCENT RESIDUALS (% of predicted)
100
200
300
400
500
STOCKING (stems/ha)

Figure 10


VOLUME PERCENT RESIDUALS
226
150
100
50
0
-50
-100
-150
VOLUME INCREMENT RESIDUALS (% of predicted)
0
500
1000
1500
2000
2500
300
STOCKING (stems/ha)

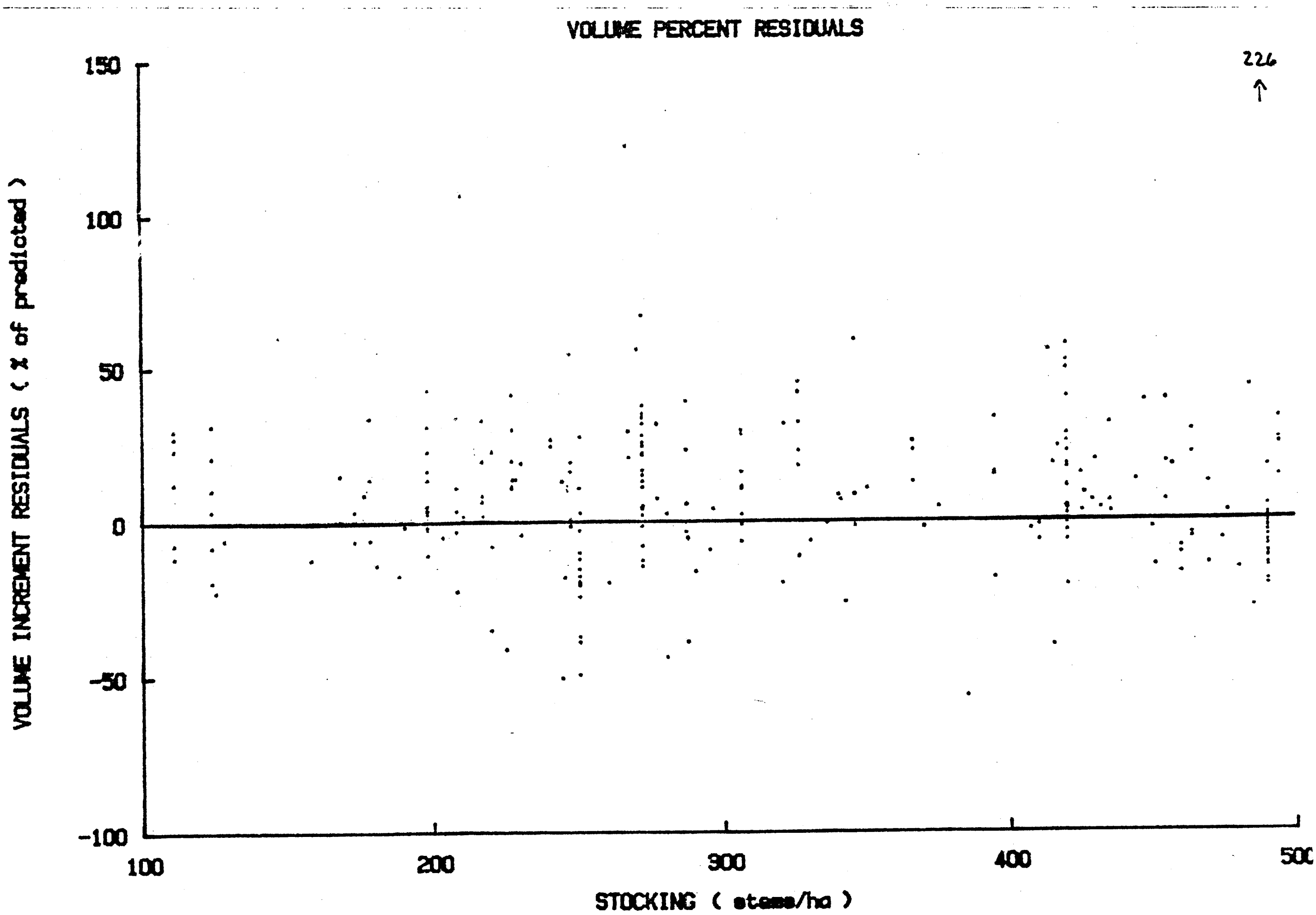

VOLUME PERCENT RESIDUALS
226
150
100
50
0
-50
-100
VOLUME INCREMENT RESIDUALS (% of predicted)
100
200
300
400
500
STOCKING (stems/ha)

Figure 11