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AN "INTERIM" STAND GROWTH MODEL FOR RADIATA PINE GROWN ON THE CENTRAL NORTH ISLAND PUMICE PLATEAU

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1.0 INTRODUCTION

The central North Island pumice plateau contains approximately half of the radiata pine (Pinus radiata D.Don) resource grown in New Zealand, and all three major New Zealand forestry companies (New Zealand Forest Service, Fletcher Challenge and N.Z. Forest Products Ltd), have substantial holdings in the area. As might be expected, considerable effort has been expended on modelling growth patterns in the region (see section 2.0), but the rapid changes in management techniques and silvicultural practices over the last decade have cast doubt on the ability of current models to accurately forecast the yield of current and future crops.

In 1984 the Forest Research Institute began work on a new growth model for the pumice plateau region, based on the methodology developed by Garcia (1979, 1983). This methodology had previously been used to produce growth models for Golden Downs Forest, the Hawkes Bay region, and for the coastal sand dune forests on the west coast of the North Island, as part of an on-going project to develop a series of regional growth models covering all New Zealand. Unfortunately, problems with the fitting procedures and a lack of resources meant the project was "put on hold" until the commencement of the Production Forestry Research Cooperative, Stand Growth Modelling Programme, in late 1986.

The timetable laid down by the Cooperative requests an "interim" growth model by the end of March 1987 and a further "complete" model by June. This report describes the "interim" model which is based on the original data, updated to include recent plot measurements. The predictors used in the model make no attempt to isolate the effects of pruning and/or thinning, although these effects are none-the-less present, through confounding, in the model. A subsequent model (in prep.) will attempt to explain these effects and refine the predictions of the model presented here.

2.0 BACKGROUND

There have been a number of attempts to model the growth of radiata pine in the central North Island, and of the early models, the 1966 Beekhuis' model was for a long time the only one widely available. The Beekhuis model was based on a series of trials in thinned and unthinned stands scattered throughout the country, although the thinnings were comparatively light by todays standards. In 1972 Bailey produced a model for N.Z.Forest Products Ltd. from data collected in the Central North Island, but limited to unthinned stands. Both these models subsequently came into disfavour as biological factors discouraged leaving stands untended and management practices altered to include heavier thinnings at younger ages.

The "second generation" of models began in 1974 when Clutter and Allison produced a model for N.Z. Forest Products Ltd. which catered for moderately thinned and unthinned stands. This model remained in use for a number of years until it was recently updated (1986). Elliot and Goulding developed a model specifically for Kaingaroa Forest, (though subsequently used elsewhere), in 1976. The "Kaingaroa Growth Model", as it became known, drew on a large data base and included the first measurements of trials designed to clarify differences between the various thinning regimes being proposed at that time.

The Kaingaroa growth model has provided the basis for regime evaluation not only in Kaingaroa, but in many other parts of the country as well. However the model is considered to over-predict increment in stands that have sustained heavy, early thinnings, even though it contains an adjustment to basal area increment for the three year period following a such an event.

The on-going problems associated with predicting the effects of thinning and pruning encouraged West, Knowles and Koehler (1982) to develop a silvicultural model specifically to cater for this situation. The model follows a stands development through the silvicultural stages from mean height 4m to 18m, at which point further progress is by the appropriate stand growth model. However, the difficulties arising from linking two entirely different models and methodologies have yet to be fully addressed.

Three individual tree growth models have also been developed from data gathered on the pumice plateau. Tennent (1981) produced a distance-dependent model to predict diameter, height and crown development in planted stands, and which allows for the effects of thinning and pruning. Although predictions of most parameters were considered adequate, the mortality and diameter increment functions did not perform as well and required a re-examination. Manley (1981) produced a distance-independent model based on data from Kaingaroa that he considered predicted stand values generally better than Tennent and at least as well as Elliot and Goulding's stand model, particularly for the heavy, early thinning regimes. Most recently, James (1983) uses a distance-dependent individual tree model to predict wood quality parameters based on the effects of silviculture, and concludes that silviculture plays a greater part than previously believed. None of the individual tree models have been used extensively.

3.0 DATA

The data were obtained from the New Zealand Forest Service Permanent Sample Plot (PSP) system (McEwen, 1979). The forests represented in the data are Kaingaroa State Forest and Tasman Forestry's Tarawera Forest.

The plots selection was restricted to stands planted since 1955 to avoid the mortality associated with the Sirex wood wasp infestation of the late 1940's and early 1950's. It has also meant that the data more accurately reflects the changes in mortality that have occurred over time (Klitscher, 1987).

The absence of data from young stands planted on frost prone sites at Kaingaroa raised doubts about height growth on those areas. With the assistance of staff from the forest, additional data was collected from these stands using stem analysis techniques. This data showed that the earlier tendency for height growth to be delayed after establishment has largely disappeared, presumably due to improved methods of establishment, and that the lack of data was unlikely to cause any severe problems.

The data was originally extracted from the PSP system in 1984. It was subsequently updated in May and November 1986 to include the latest measurements, however time constraints meant that no new plots or plots from other forests were added.

Preliminary screening of the data consists of identifying plots and measurements that fall into the categories listed below. These measurements are subsequently deleted from the database.

- measurements taken in December, January or February.
- poisoned thinned.
- regeneration in the stand.
- fertilized.
- more than 2 trees per plot windblown.
- mean DBH of windblown trees > mean DBH of remaining trees.
- basal area, stocking or height missing.
- less than 4 height trees.
- only crop trees measured.
- average height substituted for mean top height.
  (PMH is permitted as a valid estimator of MTH).
- less than two measurements per plot.
- measurement dates less than 6 months apart.

After preliminary screening, the individual measurements of basal area, height etc. for each plot are graphed and visually checked for errors or "abnormal" growth patterns. If at all possible, errors are corrected and the measurement included, otherwise the measurement is deleted from the database.

The separate pruning database was collated from plot history sheets, plot records and the New Zealand Forest Service Stand Record System. This database consisted of the pruning history (time of pruning and pruned height) for each plot in the main database and will be used in testing and modelling the effects of pruning in the later growth model.

The final database, after checking, consists of 2837 measurements from 297 plots. The data from Tarawera Forest is limited to the R0955 thinning trial of 25 plots and 433 measurements. Figures 1a, 1b and 1c illustrate the range of basic data available for use in the model.

All ages are calculated based on the month and year of measurement minus the establishment year. The corrections for month of measurement are given in Table 1 and are used to apportion growth in line with seasonal variation. (McEwen, 1979).

Table 1

Age Corrections

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
-0.3	-0.2	-0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.6

3.1 Height model data

The data used for modelling height growth is restricted to plots with three or more measurements that have a period of at least six months between each measurement. The 2551 measurements from 284 plots used to develop the model are summarised in Table 2.

Table 2

Height Model Data Statistics

Age: Initial Values			Age: Final Values		
Min	Mean	Max	Min	Mean	Max
2.8	8.0	25.1	6.0	18.5	40.0
Height: Initial Values			**Height: Final Values**		
Min	Mean	Max	Min	Mean	Max
2.6	12.4	39.6	7.5	28.5	52.0

Average measurements/plot : 9

3.2 Basal area & stocking model data

In order to determine the model coefficients for basal area and stocking, the data is formed into measurement pairs consisting of the basal area, stocking and top height at the age of each measurement and the values of the same variables at the time of the next measurement, for that plot. There is no discontinuity between measurement pairs other than for thinnings or excessive levels of windthrow.

Table 3 summarises the 2295 measurement pairs formed from 297 plots used for modelling basal area and stocking growth.

Table 3

Basal Area & Stocking Model Data Statistics

First Measurement of each Pair

Basal Area			Stocking			Height		
Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
0.5	24.4	79.3	89	541	5239	2.6	20.5	51.0

Age			Age Difference			Site		
Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
2.8	13.0	38.0	0.6	1.24	12.0	22.5	31.5	39.4

An estimate of site index is calculated for each plot from the output of the height model estimation procedure. If a plot was not used in the height model for some reason, the estimate is obtained by averaging the site indices derived from the individual measurements for that plot.

3.3 Thinning function data

The thinning information is extracted from the basic data file and consists of the measurements taken immediately before and after a thinning. Table 4 summarises the 127 thinning measurements from which the function is derived.

Table 4

Thinning Function Data Statistics

Basal Area			Stocking			Height		
Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
2.5	18.9	65.6	153	582	3300	6.0	15.4	37.2

Residual B.A.			Residual Stock			Ratio*		
Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1.4	10.0	35.0	117	263	630	0.76	0.94	1.10

* Ratio = Mean DBH thinned / Mean DBH before thinning

3.4 Initial growth function data

The initial growth function is used when starting the growth model from age zero. The function is fitted to data derived from the first measurements of plots that have had no prior thinning. This data is grown either forward or back in time and the function fitted to the basal area and stocking at a pre-determined top height. Table 5 summarises the 116 points available for use.

Table 5
Initial Growth Function Statistics

Basal Area			Stocking			Height		
Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
0.5	24.9	47.4	1170	2417	9516	2.6	10.7	17.7

3.5 Volume function data

If there is a poor height sample in the sample plot, a general volume/basal area regression is used to calculate the volume for that measurement, rather than an individual tree volume function based on DBH and height. Accordingly, the data was restricted to plots where volume was calculated from a tree volume function, the default tree volume tables being used in all cases. The 2502 measurements of volume used to develop the V/B regression are summarised in Table 6.

Table 6

Volume Function Data Statistics

Basal Area			Stocking			Height		
Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
0.5	22.7	82.4	89	434	9516	2.6	20.6	52.0

Volume			V/B		
Min	Mean	Max	Min	Mean	Max
2.0	200.6	1205.5	2.2	7.0	16.9

4.0 ANALYSIS

The growth equations used in the model are described fully in Garcia (1979, 1983), and only in a restricted format here.

4.1 Height growth

The site equation has the general form :

$$\frac{dH}{dt} = b(a^c - H^c) \qquad (1)$$

By using a, b, or a linear combination of the two as a measure of site index, it is possible to estimate the remaining parameters by using a maximum likelihood technique.

Integrating (1) with H=0 at t=t0, where t=age in years, we can obtain the general equation for top height :

$$H = a[1-e^{-b(t-t0)}]^{1/c} \qquad (2)$$

and by adopting b as the measure of site index such that:

$$b = -\ln[1-(S/a)^c]/(20-t0) \qquad (3)$$

and where S is the site index (m) and t0 is the height at age 0 years. The final parameter estimates are:

$$a = 64.601$$
$$c = 0.71395$$
$$t0 = 0$$

Top height (H) is in metres and age (t) is in years. The value of b is obtained from (3).

The height residuals from this equation are shown in Figure 2a.

Figure 2b compares the two height models currently in use, KGM1 and Burkhart and Tennent, with the new equation. For most purposes there is little difference between all three, although the new model predicts marginally greater heights between ages 0 and 15 years, and reaches a higher asymptote than the Kaingaroa model curve.

4.2 Basal area and stocking equations

Although it is usually desirable to constrain stocking to be non-increasing, it was found that the model is a much better fit overall if this constraint is removed. This does, however, cause some predictions of stocking to increase over time. Fortunately this only occurs well outside the range of data used for constructing the model, and also outside most applications. Appendix 2 contains tables which highlight the areas of concern, and the associated computer program contrains the stocking artificially and prints a warning message when it occurs.

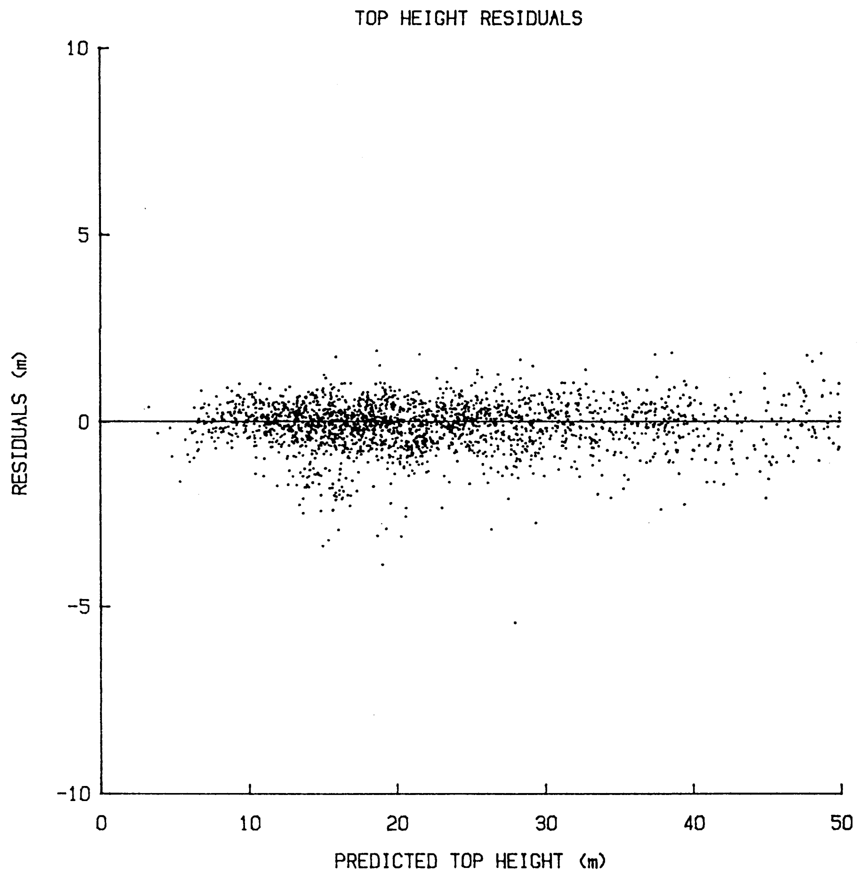

FIGURE 2a

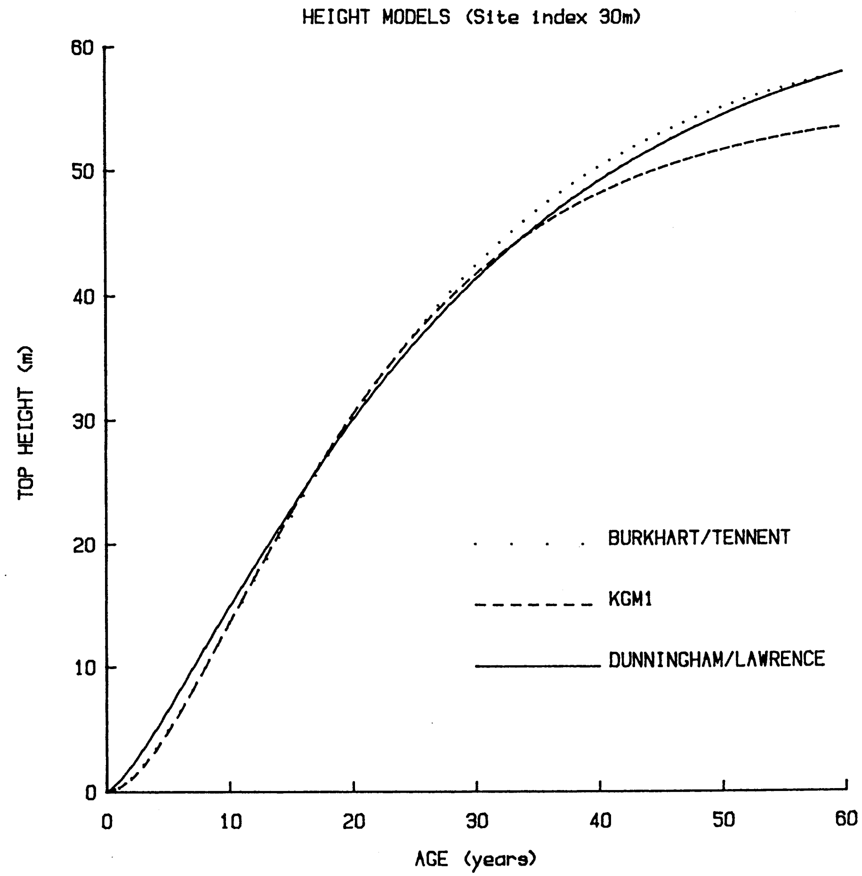

FIGURE 2b

The effect of site index is modelled through a change in the time scale and assumes site index has no effect on the relationships between the state variables. (Using (3), time 't' is scaled to become bt, and the variables change according to the scaled term). This assumption has held true in most other regions studied so far, and was found satisfactory in this case also (see Figure 4a).

The specific form of the model then becomes:

$$\frac{dB^{c11}N^{c12}H^{c13}}{dT} = a11B^{c11}N^{c12}H^{c13} + a12B^{c21}N^{c22}H^{c23} + a13H^{c33} + b1$$

$$\frac{dN^{c22}}{dT} = a21B^{c11}N^{c12}H^{c13} + a22B^{c21}N^{c22}H^{c23} + a23H^{c33} + b2$$

$$\frac{dH^{c33}}{dT} = -H^{c33} + b3$$

where T (scaled time) = bt as previously described.

The parameter estimates were obtained by maximising the log-likelihood with a general purpose optimisation algorithm. (Biggs, 1971,1973; N.O.C., 1976). A number of model variations were tried, commencing with simple formulations containing few unconstrained parameters, and more complex models which include a measure of site occupancy as a fourth state variable. Although the model selected has some problems because the stocking is not constrained, its fit is far superior to any other forms tried, and so has been adopted here. Table 7 contains the function values obtained from the optimisation algorithm for the various models studied.

Table 7

Basal area & stocking models : Function values

Model	Function	No.vars.	Description
M2	1070.7	9	a22,a23,a24,b2,c21,c23=0
AF	872.8	14	All parameters unconstrained
T44	980.8	12	a14,a22,a23,a24,b2,c21,c23,c24=0
T56	928.4	14	a22,a23,a24,b2,c21,c23=0
T57	932.6	13	a22,a23,a24,b2,c21,c23,c24=0
T58	957.7	11	a22,a23,a24,b2,c21,c23,c24=0

Note: Models M2 and AF are based on (4) as described in Garcia (1983). Models T44, T56, T57 and T58 are based on the extended version (7).

The parameter estimates for the model (AF) are:

$$C = \begin{pmatrix} 0.11914 & 0.011053 & 0.64953 \\ -0.026261 & -0.56022 & 0.076958 \\ 0.00000 & 0.00000 & 0.71395 \end{pmatrix}$$

$$A = \begin{pmatrix} -1.3163 & -48.580 & 0.40586 \\ 0.0025442 & 0.026197 & -0.0036054 \\ 0.00000 & 0.00000 & -1.0000 \end{pmatrix}$$

$$P = \begin{pmatrix} 1.00000 & 39.0813 & -1.22184 \\ 0.00204672 & 1.00000 & -0.00299394 \\ 0.000000 & 0.000000 & 1.00000 \end{pmatrix}$$

$$b = \begin{pmatrix} 29.783 \\ 0.0057582 \\ 19.609 \end{pmatrix} \quad a = \begin{pmatrix} 24.3069 \\ 0.118303 \\ 19.6092 \end{pmatrix} \quad \begin{matrix} \text{lambda1} = -1.21658 \\ \text{lambda2} = -0.0732322 \\ \text{lambda3} = -1.00000 \end{matrix}$$

where $a = -A^{-1}.b$

Note: Lambdas 1,2 and 3 are the eigenvalues of A and the rows of P are the left eigenvectors such that:

$$A = P^{-1} \Lambda P$$

and lambdas 1,2 and 3 are the elements on the diagonal of Λ. A more complete explanation is given in Garcia (1983), p.68.

Units : basal area (m2/ha) ; stocking (stems/ha) ; height (m)

The residuals for basal area and stocking from this model are shown in Figures 3a and 3b respectively, and are discussed in Section 5.0.

4.3 Thinning function

The thinning function is used to predict the basal area remaining after thinning, given the basal area and stocking before thinning and the number of stems removed. The function is:

$$B = \left(BO^{-q} - \frac{pq}{r} * H^{s} * (N^{r} - NO^{r})\right)^{(-1/q)} \qquad (4)$$

where B = basal area after thinning (m2/ha)
BO = basal area before thinning (m2/ha)
H = top height (m)
N = stocking after thinning (stems/ha)
NO = stocking before thinning (stems/ha)

Using a non-linear, least squares procedure, a number of variations were fitted by setting p, q, r, s or a combination of them equal to zero. The best estimates were:

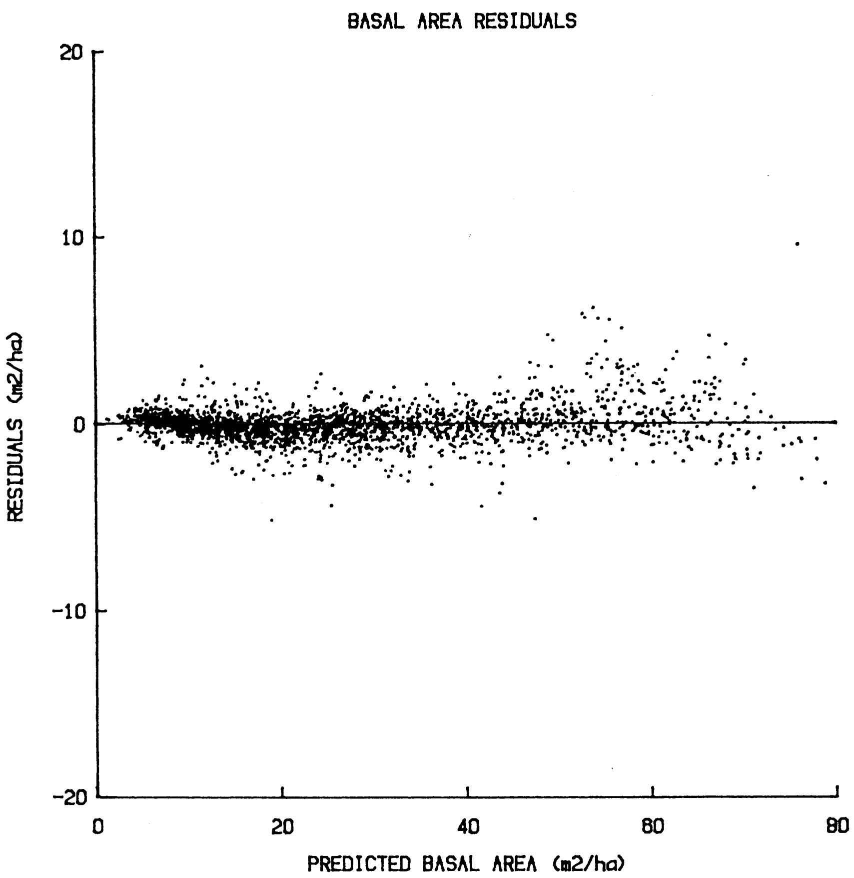

FIGURE 3a

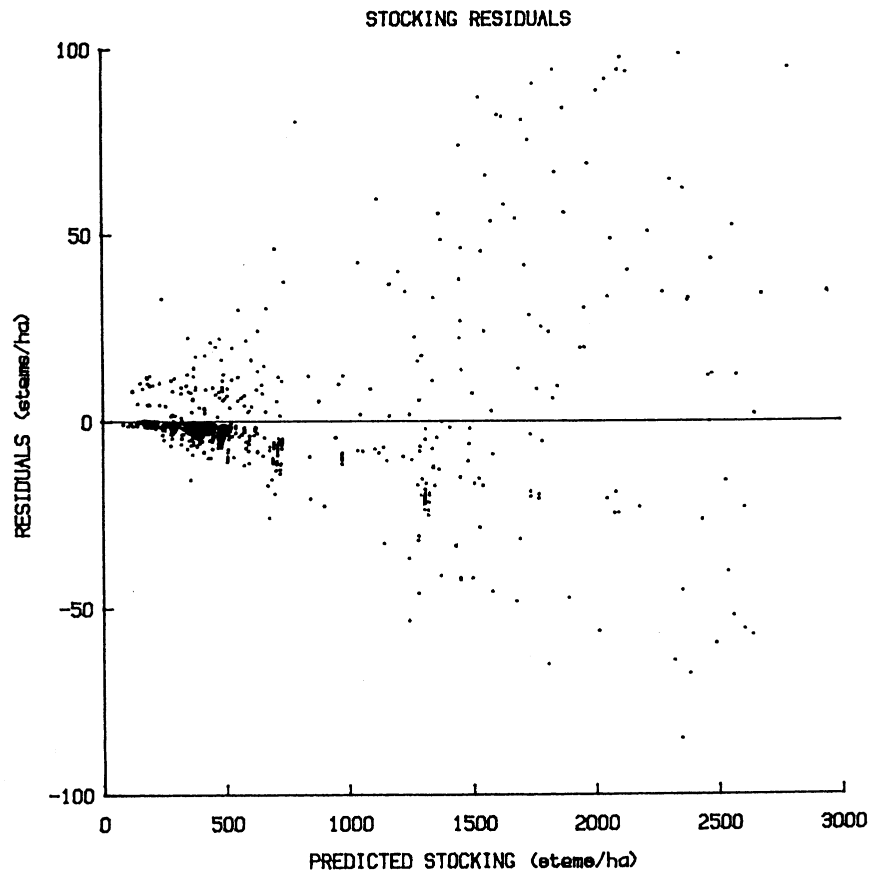

FIGURE 3b

$p = 15.7269$
$q = 0.46621$
$r = -0.31159$
$s = -0.83694$

The residuals from (4) are shown in Figure 5a.

4.4 Initial growth function

The data for the initial growth function is obtained by growing basal area and stocking estimates forward or back in time to a range of top heights; typically 4 to 8m. The starting points are taken from plots which have had their first measurement at age 10 or less, and where the first measurement has not been preceded by a thinning. A function to estimate basal area, given the stocking (and fixed top height), is then fitted to the data.

The function has the general form:

$$B = \begin{cases} (a/c - b)N & \text{for } N \le c \\ a \ln N - bN + a(1 - \ln c) & \text{for } N > c \end{cases} \qquad (5)$$

where B = basal area (m2/ha)
N = stocking (stems/ha)

Adopting the mean square of the residuals as a measure of fit, the values of a, b and c were obtained from a non-linear least squares procedure. The results for height 4m are:

$a = 8.6497$
$b = 0.00240$
$c = 1846.6$

and the function to predict basal area at top height 4m is:

$$B = 0.00228 * N \qquad \text{if } N \le 1846.6$$

or

$$B = 8.6497 * \ln(N) - 0.0024 * N - 56.408 \qquad (6)$$

$$\text{if } N > 1846.6$$

The residuals are shown in Figure 4b. Although there is no obvious bias in the results, the wide spread, possibly a result of differences in establishment or site preparation, is some cause for concern.

4.5 Stand volume function

The usual form of the stand volume function in New Zealand is:

$$V/B = a + bH \qquad (7)$$

where V = net volume (m3/ha)
B = basal area (m2/ha)
H = top height (m)

and the stand volume/basal area ratio is the dependent variable in a simple linear regression. Beekhuis (1966) claimed that (7) could not be valid immediately before and after thinning, because the thinned trees are generally shorter than the residuals so that the V/B ratio after thinning is greater than before. Taking this into account, the function was fitted using stepwise regression with independent variables H and N, and the transformations N*H/B, H/SQR(N) and H*N (where N = stems/ha).

The resulting function is:

$$V/B = (0.4998+0.3048*H+0.0004*N*H/B) \qquad (8)$$

and the residuals are shown in Figure 5b. The S.E. = 0.0065, which is 0.1% of the mean V/B ratio.

To test the validity of Beekhuis' claim, all the measurements of volume at the time of thinning were extracted and the volume estimated using both versions (7) and (8) of the function. A t-test found no significant difference between the two. The conclusion is that while all the terms in (8) are statistically significant, and it is the best function for estimating stand volume, the addition of the extra parameter cannot be justified to account for the variation in the V/B ratio before and after thinning.

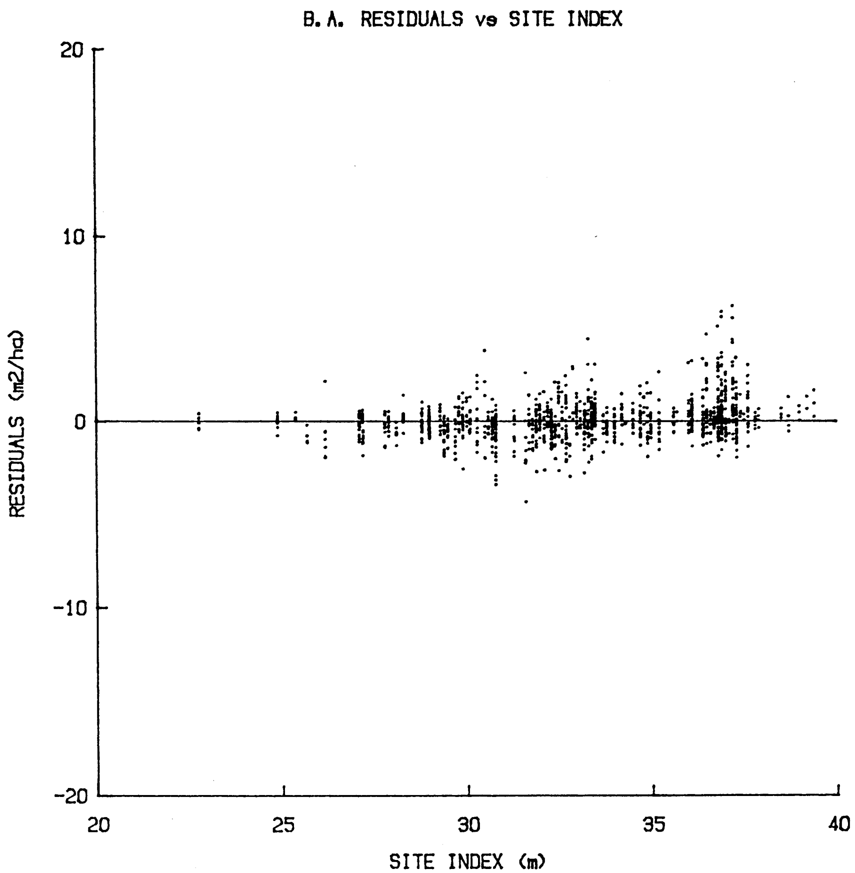

FIGURE 4a

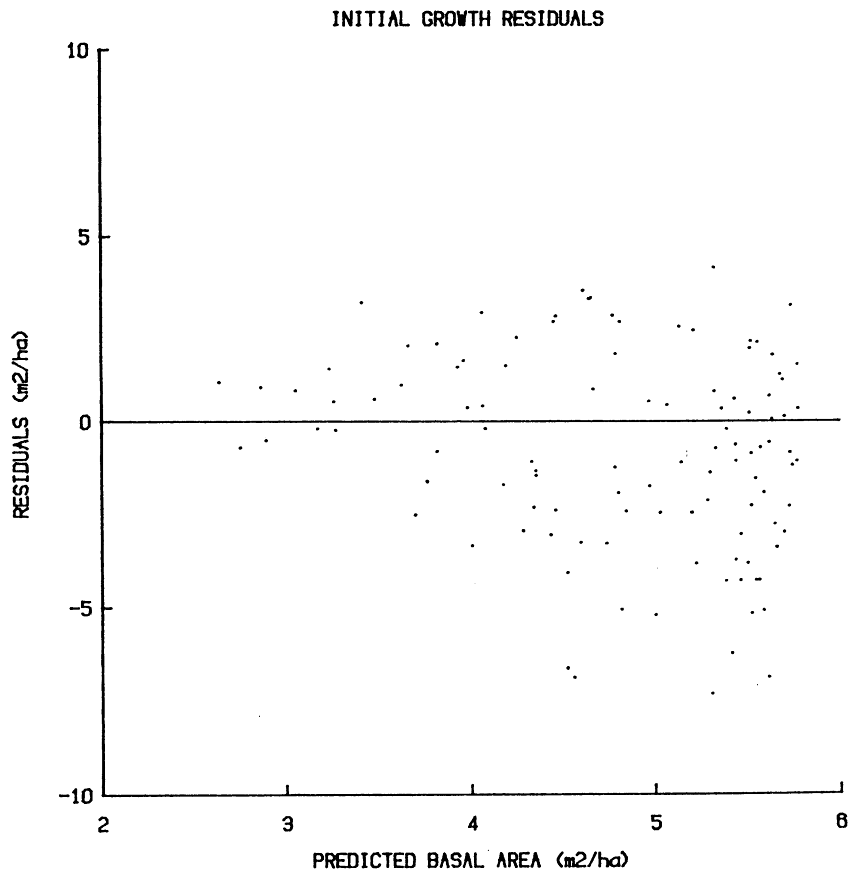

FIGURE 4b

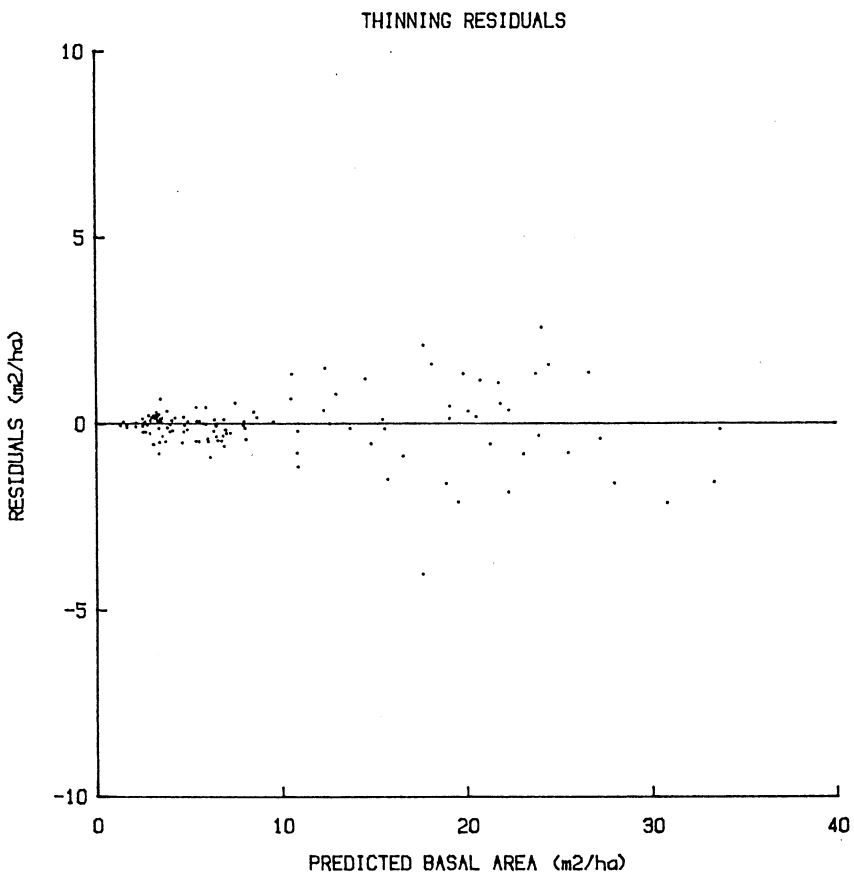

FIGURE 5a

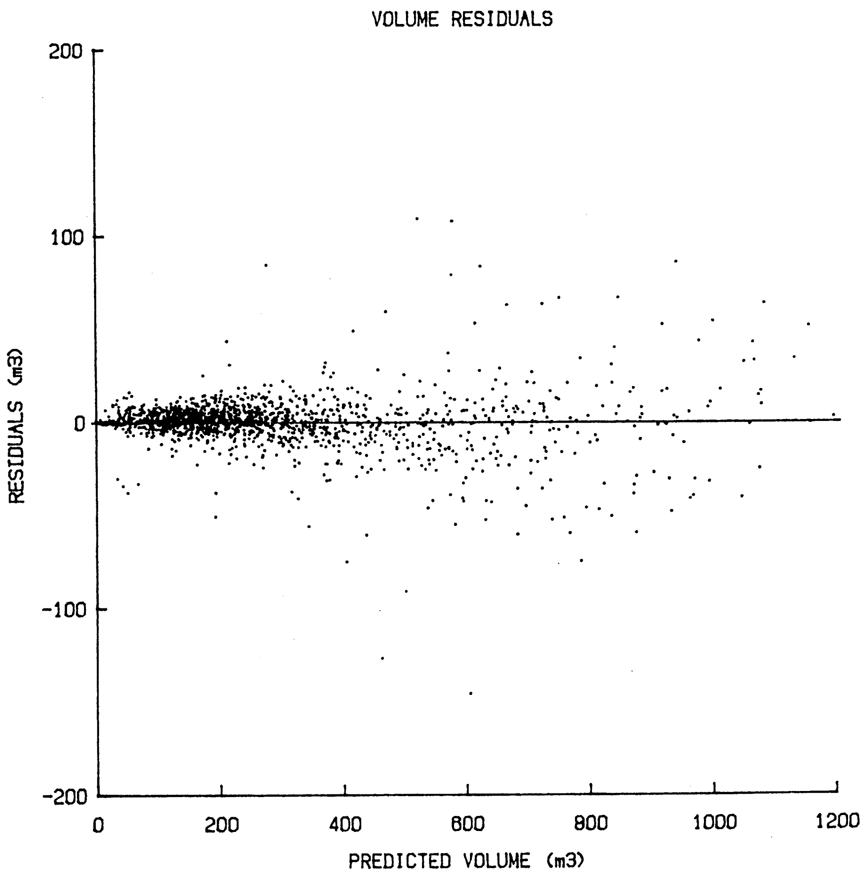

FIGURE 5b

5.0 EVALUATION and DISCUSSION

The evaluation of the basal area and stocking model is limited to a study of the residuals as illustrated in Figures 3a, 3b, and 4a. Figures 3a and 3b show no significant bias in the prediction of basal area and stocking and Figure 4a shows that the relationship between site index and basal area discovered in the Hawkes Bay growth model is absent in this model. Table 8 summarises the statistics for the model. Note: the residuals include the effects of measurement error.

Table 8

Measurement Pair Residuals

	Mean	RMS*
Basal area (m2/ha)	-.03207	.9977
Stocking (stems/ha)	2.92	36.10
Top height (m)	-0.01	.5368
Mean D.B.H (cm)	-.01436	.5508
Average spacing (m)	.00021	.0350
Basal area * height (m3/ha)	-.6486	34.59

* Residual Mean Square

There is some indication that the model under-predicts basal area following pruning in plots with high (>32m) site indices. Figure 3b would also indicate that for many plots thinned to final crop stockings below 500 stems/ha, the model predicts slightly higher mortality than in fact exists. This would appear to be balanced, however, by a significant number of plots containing higher than expected mortality. Both these questions will be addressed further during development of the full model.

The height model residuals are shown in Figure 2a and indicate no obvious trends. The height model is, for most purposes, very similar to previous developed models (Figure 2b), and is unlikely to be changed in the full model.

The residuals from the initial growth function are shown in Figure 4b. The apparent difficulty of modelling growth at very young ages, when there is an absence of data, is caused by a number of factors. These include both the range of establishment techniques practiced over a period of time, and the wide variation of basal area and stocking for a given top height. Accordingly, it is suggested that known starting points are preferable to growing from age zero if at all possible.

The residuals for the thinning and stand volume functions are shown in Figures 5a and 5b respectively. Both functions fit reasonably well and no obvious trends are apparent in the residuals, despite the fact there are a few individual estimates of volume which have fairly large errors.

Yield prediction and model comparsions

Table 9 compares the new model with KGM1 for a number of regimes. The yields are for age 30 and all regimes were run with site index equal to 30m. The five regimes are:

	Plant	Thin
Regime 1	1250	600 @ 6m 370 @ 12m
Regime 2	1250	600 @ 6m 200 @ 12m
Regime 3	1250	600 @ 6m
Regime 4	1110	600 @ 21m 350 @ 29m
Regime 5	1250	Unthinned

Table 9

Comparison between KGM1 and Interim model
(All values at age 30, for site index 30m)

	KGM1				Interim model				
	ST	BA	DBH	VOL	ST	BA	DBH	VOL	DIFF*
R1	356	64.93	48.2	879	338	60.23	47.6	793	-9.8%
R2	199	56.35	60.1	763	194	48.89	56.6	643	-15.7%
R3	511	68.60	41.4	928	504	68.02	41.4	898	-3.2%
R4	340	50.90	43.7	689	333	52.31	44.7	690	+0.1%
R5	641	65.10	36.0	881	879	75.76	33.1	1005	+14.1%

Mean top height KGM1 = 41.7m   Mean top height Interim = 41.3m

* DIFF = Volume difference: (Int-KGM1)/KGM1*100%

Figure 6 shows nett volume on age for site indices 29 - 31m. The yield curves for regimes one to three and regime six are superimposed on the data and illustrate how the long term predictions follow the general trend of the data. The volume difference between the regimes, regime one and regime two is large, but not unexpected. The over-prediction by KGM1 has been known for several years and is well documented. (Manley, 1986; Bell, 1981). The new model predicts higher volumes for framing, late production thinning, and unthinned regimes, as well as predicting lower mortality for unthinned stands.

In conclusion, the interim model fits the data reasonably well and is reliable within the bounds of the data. Although the model has been constrained artificially in some instances and predictions of initial growth are somewhat variable, neither is great cause for concern. The height model, thinning, and stand volume functions are unlikely to be changed in the full model. Study of individual plot predictions would indicate that for low final crop stockings on high sites, predictions of basal area are conservative. Initial analysis of the pruning and thinning data appears to confirm this, and basal area predictions could possibly increase by two or three percent when the effects are better understood.

6.0 ACKNOWLEDGEMENTS

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7.0 REFERENCES

Bailey, R.L. 1972: Development of unthinned stands of Pinus radiata in New Zealand. Unpublished Ph.D. Dissertation, University of Georgia, Athens, USA.

Beekhuis, J. 1966: Prediction of yield and increment in Pinus radiata stands in New Zealand. New Zealand Forest Service Technical Paper No.49.

Bell, A. C. 1981: Using the Kaingaroa growth model for heavy early thinning regimes. New Zealand Forest Service, Resource Inventory Group, Technical Note No.13. (Unpublished).

Biggs, M.C. 1971: Minimization algorithms making use of non-quadratic properties of the objective function. Journal of the Institute of Mathematics and its Applications 8: 315 - 327.

------- 1973: A note on minimization algorithms which make use of non-quadratic properties of the objective function. Journal of the Institute of Mathematics and its Applications 12: 337 - 338.

Burkhart, H.E.; Tennent, R.B. 1977: Site index equations for radiata pine in New Zealand. New Zealand Journal of Forestry Science 7(3): 408-416.

Clutter, J.L.; Allison, B.J. 1974: A growth and yield model for Pinus radiata in New Zealand. In Fries, J. (Ed.) Growth models for tree and stand simulation. Royal College of Forestry, Stockholm, Sweden.

Elliott, D.A.; Goulding, C.J. 1976: The Kaingaroa growth model for radiata pine and its implications for maximum volume production (abstract). New Zealand Journal of Forestry Science 6(2): 187.

Garcia, O. 1979: Modelling stand development with stochastic differential equations. Pp. 315-317 in Elliott, D.A. (Ed.) "Mensuration for management planning of exotic forest plantations". New Zealand Forest Service, Forest Research Institute Symposium No.20.

------- 1983: A stochastic differential equation model for the height growth of forest stands. Biometrics 39: 1059-1072.

------- 1984: New class of growth models for even-aged stands - Pinus radiata in Golden Downs Forest. New Zealand Journal of Forestry Science 14(1): 65-88.

Goulding, C.J. 1979: Validation of growth models used in forest management. New Zealand Journal of Forestry 24(1): 108-124.

James, R.N. 1983: The prediction of growth and wood quality parameters for plantation grown Pinus radiata D.Don in New Zealand. Unpublished Ph.D. Thesis, University of Oxford, Oxford, England.

Klitscher, J.A.K. 1987: Mortality trends in Pinus radiata in the Rotorua region. New Zealand Forestry 31(4): 23-25.

Lewis, E.R. 1954: Yield of unthinned Pinus radiata in New Zealand. New Zealand Forest Service, Forest Research Institute, Forest Research Notes 1(10).

Manley, B.R. 1981: A distance-independent tree growth model for radiata pine in New Zealand. Unpublished Ph.D. Thesis, University of Washington, Seattle, USA.

Manley, B.R. 1986: Performance of the Kaingaroa growth model for low-stocking regimes. New Zealand Forest Service, Forest Research Institute Bulletin No.113.

Manley, B.R.; Knowles,R.L. 1980: Growth of radiata pine under the direct sawlog regime. New Zealand Journal of Forestry Science 25(1): 15-34.

McEwen, A.D. 1979: N.Z. Forest Service computer system for permanent sample plots. Pp. 235-252 in Elliott, D.A. (Ed.) "Mensuration for management planning of exotic forest plantations". New Zealand Forest Service, Forest Research Institute Symposium No.20.

N.O.C. 1976: "OPTIMA" - Routines for Optimisation Problems". Numerical Optimisation Centre, The Hatfield Polytechnic.

Tennent, R.B. 1981: A simulation model for Pinus radiata in New Zealand. Unpublished Ph.D. Thesis, University of Georgia, Athens, USA.

West, G.G.; Knowles, R.L.; Koehler, A.R. 1982: Model to predict the effects of pruning and early thinning on the growth of radiata pine. New Zealand Forest Service, Forest Research Institute Bulletin No.5.

8.0 APPENDICES

8.1 APPENDIX 1 : LIST OF PLOTS

V = Volume function
H = Height model
I = Initial growth function
G = Basal area & stocking equations
T = Thinning function

RO(181. 0. 0. 0)	V	G	H	T	I
RO(258. 0. 0. 0)	V	G	H	T	
RO(273. 0. 0. 0)	V	G	H	T	
RO(363. 0. 1. 0)	V	G	H	T	
RO(363. 0. 2. 0)	V	G	H	T	
RO(363. 0. 3. 0)	V	G	H	T	
RO(363. 0. 4. 0)	V	G	H	T	
RO(363. 0. 5. 0)	V	G	H	T	
RO(363. 0. 6. 0)	V	G	H	T	
RO(363. 0. 7. 0)	V	G	H	T	
RO(363. 0. 8. 0)	V	G	H	T	
RO(363. 0. 9. 0)	V	G	H	T	
RO(363. 0. 10. 0)	V	G	H	T	
RO(363. 0. 11. 0)	V	G	H	T	
RO(363. 0. 12. 0)	V	G	H	T	
RO(363. 0. 13. 0)	V	G	H		
RO(363. 0. 14. 0)	V	G	H	T	
RO(418. 0. 0. 0)	V	G	H		I
RO(420. 0. 0. 0)	V	G	H		
RO(435. 0. 0. 0)	V	G	H	T	I
RO(464. 0. 0. 0)	V	G	H		
RO(472. 0. 0. 0)	V	G	H	T	
RO(477. 0. 0. 0)	V	G	H	T	
RO(484. 0. 0. 0)	V	G	H		
RO(485. 0. 0. 0)	V	G	H	T	
RO(589. 1. 1. 0)	V	G	H	T	
RO(589. 1. 2. 0)	V	G	H	T	
RO(589. 1. 3. 0)	V	G	H	T	
RO(589. 1. 4. 0)	V	G	H	T	
RO(589. 1. 5. 0)	V	G	H	T	
RO(589. 1. 6. 0)	V	G	H	T	
RO(589. 1. 7. 0)	V	G	H	T	
RO(589. 2. 8. 0)	V	G	H		
RO(589. 2. 9. 0)	V	G	H		
RO(589. 2. 10. 0)	V	G	H		
RO(589. 2. 11. 0)	V	G	H		
RO(589. 2. 12. 0)	V	G	H		
RO(589. 2. 13. 0)	V	G	H		
RO(589. 2. 14. 0)	V	G	H		
RO(589. 2. 15. 0)	V	G	H		
RO(589. 2. 16. 0)	V	G	H		
RO(589. 2. 17. 0)	V	G	H		
RO(589. 2. 18. 0)	V	G	H		
RO(589. 2. 19. 0)	V	G	H		
RO(589. 2. 20. 0)	V	G	H		
RO(589. 2. 21. 0)	V	G	H		
RO(589. 2. 23. 0)	V	G	H		
RO(589. 2. 24. 0)	V	G	H		
RO(589. 3. 25. 0)	V	G	H	T	I
RO(589. 3. 26. 0)	V	G	H	T	I
RO(589. 3. 27. 0)	V	G	H	T	I
RO(589. 3. 28. 0)	V	G	H	T	I
RO(589. 3. 29. 0)	V	G	H	T	I
RO(589. 3. 30. 0)	V	G	H	T	I

RO(589. 3. 31. 0)	V	G	H	T	I
RO(590. 0. 1. 0)	V	G	H	T	
RO(590. 0. 2. 0)	V	G	H		
RO(590. 0. 3. 0)	V	G	H		
RO(590. 0. 4. 0)	V	G	H	T	
RO(590. 0. 5. 0)	V	G	H	T	
RO(590. 0. 6. 0)	V	G	H		
RO(590. 0. 7. 0)	V	G	H	T	
RO(590. 0. 8. 0)	V	G	H	T	
RO(590. 0. 9. 0)	V	G	H	T	
RO(590. 0. 10. 0)	V	G	H		
RO(590. 0. 11. 0)	V	G	H	T	
RO(590. 0. 12. 0)	V	G	H		
RO(590. 0. 13. 0)	V	G	H	T	
RO(590. 0. 14. 0)	V	G	H	T	
RO(590. 0. 15. 0)	V	G	H	T	
RO(590. 0. 16. 0)	V	G	H	T	
RO(590. 0. 17. 0)	V	G	H	T	
RO(590. 0. 18. 0)	V	G	H	T	
RO(590. 0. 19. 0)	V	G	H	T	
RO(590. 0. 20. 0)	V	G	H		
RO(590. 0. 21. 0)	V	G	H	T	
RO(590. 0. 22. 0)	V	G	H	T	
RO(590. 0. 23. 0)	V	G	H	T	
RO(590. 0. 24. 0)	V	G	H	T	
RO(590. 0. 25. 0)	V	G	H		
RO(590. 0. 26. 0)	V	G	H	T	
RO(590. 0. 27. 0)	V	G	H	T	
RO(590. 0. 28. 0)	V	G	H	T	
RO(590. 0. 29. 0)	V	G	H	T	
RO(590. 0. 30. 0)	V	G	H	T	
RO(590. 0. 31. 0)	V	G	H	T	
RO(590. 0. 32. 0)	V	G	H	T	
RO(682. 1. 1. 0)	V	G	H		I
RO(682. 1. 2. 0)	V	G	H		I
RO(682. 1. 3. 0)	V	G	H		I
RO(682. 1. 4. 0)	V	G	H		I
RO(682. 2. 5. 0)	V	G	H		I
RO(682. 2. 6. 0)	V	G	H		I
RO(682. 2. 7. 0)	V	G	H		I
RO(682. 2. 8. 0)	V	G	H		I
RO(682. 3. 9. 0)	V	G	H		I
RO(682. 3. 10. 0)	V	G	H		I
RO(682. 3. 11. 0)	V	G	H		I
RO(682. 3. 12. 0)	V	G	H		I
RO(687. 1. 1. 0)	V	G	H		I
RO(687. 1. 2. 0)	V	G	H		I
RO(687. 1. 3. 0)	V	G	H		I
RO(687. 1. 4. 0)	V	G	H		I
RO(687. 2. 5. 0)	V	G	H		I
RO(687. 2. 6. 0)	V	G	H		I
RO(687. 2. 7. 0)	V	G	H		I
RO(687. 2. 8. 0)	V	G	H		I
RO(687. 3. 9. 0)	V	G	H		I
RO(687. 3. 10. 0)	V	G	H		I
RO(687. 3. 11. 0)	V	G	H		I
RO(687. 3. 12. 0)	V	G	H		I
RO(688. 1. 1. 0)	V	G	H		
RO(688. 1. 2. 0)	V	G	H		I
RO(688. 1. 3. 0)	V	G	H		
RO(688. 1. 4. 0)	V	G	H		I
RO(688. 2. 5. 0)	V	G	H	T	I
RO(688. 2. 6. 0)	V	G	H	T	I

RO(688. 2. 7. 0)	V	G	H	T	I
RO(688. 2. 8. 0)	V	G	H		I
RO(688. 3. 9. 0)	V	G	H	T	
RO(688. 3. 10. 0)	V	G			
RO(688. 3. 11. 0)	V	G	H	T	
RO(688. 3. 12. 0)	V	G	H	T	I
RO(690. 0. 1. 0)	V	G	H		I
RO(690. 0. 2. 0)	V	G	H		I
RO(690. 0. 3. 0)	V	G	H		
RO(690. 0. 4. 0)	V	G	H		I
RO(692. 0. 1. 0)	V	G	H		
RO(692. 0. 2. 0)	V	G	H	T	
RO(692. 0. 3. 0)	V	G	H	T	
RO(692. 0. 4. 0)	V	G	H	T	
RO(692. 0. 5. 0)	V	G	H	T	
RO(692. 0. 6. 0)	V	G	H		
RO(692. 0. 7. 0)	V	G	H	T	
RO(692. 0. 8. 0)	V	G	H	T	
RO(692. 0. 9. 0)	V	G	H	T	
RO(692. 0. 10. 0)	V	G	H		
RO(700. 0. 1. 0)	V	G	H		
RO(700. 0. 2. 0)	V	G	H		
RO(700. 0. 3. 0)	V	G	H		
RO(700. 0. 4. 0)	V	G	H		
RO(700. 0. 5. 0)	V	G	H		
RO(700. 0. 6. 0)	V	G	H		
RO(725. 0. 0. 0)	V	G	H	T	
RO(735. 0. 0. 0)	V	G	H		
RO(736. 0. 0. 0)	V	G	H		
RO(737. 0. 0. 0)	V	G	H		
RO(738. 0. 0. 0)	V	G	H		
RO(739. 0. 1. 0)				T	
RO(739. 0. 2. 0)				T	
RO(747. 0. 0. 0)	V	G	H		
RO(782. 0. 0. 0)	V	G	H	T	I
RO(790. 0. 1. 0)	V	G	H	T	
RO(790. 0. 2. 0)	V	G	H	T	
RO(790. 0. 3. 0)	V	G	H	T	
RO(793. 0. 0. 0)	V	G	H	T	I
RO(799. 0. 0. 0)	V	G	H	T	
RO(902. 0. 1. 0)	V	G	H	T	
RO(902. 0. 2. 0)	V	G	H	T	
RO(902. 0. 3. 0)	V	G	H		
RO(902. 0. 4. 0)	V	G	H		
RO(902. 0. 5. 0)	V	G	H		
RO(902. 0. 7. 0)	V	G	H		
RO(902. 0. 8. 0)	V	G	H		
RO(903. 0. 1. 1)	V	G			
RO(903. 0. 1. 2)	V	G			
RO(903. 0. 1. 3)	V	G	H		
RO(903. 0. 3. 1)	V	G	H		
RO(903. 0. 3. 2)	V	G	H		
RO(903. 0. 3. 3)	V	G	H		
RO(905. 0. 9. 0)	V	G	H		I
RO(905. 0. 10. 0)	V	G	H		I
RO(905. 0. 11. 0)	V	G	H		I
RO(905. 0. 12. 0)	V	G	H		I
RO(905. 0. 13. 0)	V	G	H		I
RO(905. 0. 14. 0)	V	G	H		I
RO(905. 0. 15. 0)	V	G	H		
RO(905. 0. 16. 0)	V	G	H		I
RO(905. 0. 17. 0)	V	G	H		I
RO(905. 0. 18. 0)	V	G	H		I

RO(905. 0. 19. 0)	V	G	H		I
RO(905. 0. 20. 0)	V	G	H		I
RO(905. 0. 21. 0)	V	G	H		
RO(905. 0. 22. 0)	V	G	H		I
RO(905. 0. 23. 0)	V	G	H		I
RO(905. 0. 24. 0)	V	G	H		I
RO(905. 0. 25. 0)	V	G	H	T	I
RO(905. 0. 26. 0)	V	G	H	T	I
RO(905. 0. 27. 0)	V	G	H	T	I
RO(905. 0. 28. 0)	V	G	H	T	I
RO(905. 0. 29. 0)	V	G	H	T	I
RO(905. 0. 30. 0)	V	G	H	T	I
RO(905. 0. 31. 0)	V	G	H	T	I
RO(905. 0. 32. 0)	V	G	H	T	I
RO(905. 0. 33. 0)	V	G	H	T	I
RO(905. 0. 34. 0)	V	G	H	T	I
RO(905. 0. 35. 0)	V	G	H	T	I
RO(905. 0. 36. 0)	V	G	H	T	I
RO(905. 0. 37. 0)	V	G	H	T	I
RO(905. 0. 38. 0)	V	G	H	T	I
RO(905. 0. 39. 0)	V	G	H	T	I
RO(911. 0. 1. 0)	V	G	H		
RO(911. 0. 2. 0)	V	G	H	T	
RO(911. 0. 3. 0)	V	G	H		
RO(911. 0. 4. 0)	V	G	H		
RO(911. 0. 7. 0)	V	G	H	T	
RO(911. 0. 8. 0)	V	G	H	T	
RO(911. 0. 9. 0)	V	G	H	T	I
RO(911. 0. 10. 0)	V	G	H	T	I
RO(955. 4. 3. 0)	V	G	H		
RO(955. 4. 4. 0)	V	G	H		
RO(955. 4. 5. 0)	V	G	H		I
RO(955. 4. 6. 0)	V	G		T	
RO(955. 4. 7. 0)	V	G	H	T	
RO(955. 4. 10. 0)	V	G			
RO(955. 4. 11. 0)	V	G	H	T	
RO(955. 4. 12. 0)	V	G	H		
RO(955. 4. 13. 0)	V	G	H		I
RO(955. 4. 14. 0)	V	G	H	T	
RO(955. 4. 15. 0)	V	G	H		I
RO(955. 4. 16. 0)	V	G	H		
RO(955. 4. 18. 0)	V	G	H	T	
RO(955. 4. 19. 0)	V	G	H	T	
RO(955. 4. 20. 0)	V	G	H		
RO(955. 6. 4. 0)	V	G		T	
RO(955. 6. 5. 0)	V	G	H		
RO(955. 6. 9. 0)	V	G	H		I
RO(955. 6. 11. 0)	V	G	H		I
RO(955. 6. 12. 0)	V	G			
RO(955. 6. 13. 0)	V	G			
RO(955. 6. 15. 0)	V	G	H		
RO(955. 6. 18. 0)	V	G	H	T	
RO(955. 6. 19. 0)	V	G	H		
RO(955. 6. 20. 0)	V	G	H		I
RO(955. 6. 21. 0)	V	G	H		
RO(955. 6. 22. 0)	V	G	H		
RO(955. 7. 1. 0)	V	G	H	T	
RO(955. 7. 4. 0)	V	G	H	T	
RO(955. 7. 6. 0)	V	G	H		I
RO(955. 7. 7. 0)	V	G	H		I
RO(955. 7. 9. 0)	V	G	H		
RO(955. 7. 10. 0)	V	G	H		
RO(955. 7. 12. 0)	V	G	H		

RO(955. 7. 13. 0)	V	G	H	T	
RO(955. 7. 15. 0)	V	G	H		
RO(955. 7. 17. 0)	V	G	H		I
RO(955. 7. 18. 0)	V	G	H		I
RO(955. 7. 19. 0)	V	G	H		
RO(955. 7. 25. 0)	V	G	H		I
RO(955. 7. 27. 0)	V	G	H		I
RO(955. 7. 28. 0)	V	G	H		I
RO(955. 7. 29. 0)	V	G	H		I
RO(955. 7. 30. 0)	V	G	H		
RO(955. 7. 31. 0)	V	G		T	
RO(955. 7. 32. 0)	V	G		T	
RO(955. 7. 33. 0)	V	G		T	
RO(955. 9. 1. 0)	V	G	H		I
RO(955. 9. 4. 0)	V	G	H		I
RO(955. 9. 5. 0)	V	G	H		I
RO(955. 9. 8. 0)	V	G	H		I
RO(955. 9. 9. 0)	V	G	H		I
RO(955. 9. 11. 0)	V	G	H		I
RO(955. 9. 13. 0)	V	G	H		I
RO(955. 9. 15. 0)	V	G	H		I
RO(955. 9. 17. 0)	V	G	H		I
RO(955. 9. 19. 0)	V	G			
RO(994. 0. 0. 0)	V	G			
RO(1008. 0. 0. 0)	V	G	H		
RO(1080. 1. 1. 2)	V	G	H	T	
RO(1080. 1. 3. 2)	V	G	H	T	
RO(1083. 1. 1. 0)	V	G	H		I
RO(1083. 1. 2. 0)	V	G	H	T	
RO(1083. 1. 5. 0)	V	G	H		I
RO(1083. 1. 10. 0)	V	G	H	T	I
RO(1083. 1. 11. 0)	V	G	H	T	
RO(1083. 1. 12. 0)	V	G	H	T	
RO(1083. 1. 15. 0)	V	G	H	T	
RO(1083. 1. 17. 0)	V	G	H	T	
RO(1083. 2. 1. 0)	V	G	H	T	I
RO(1083. 2. 2. 0)	V	G	H	T	
RO(1083. 2. 6. 0)	V	G	H		I
RO(1083. 2. 12. 0)	V	G	H		I
RO(1083. 2. 15. 0)	V	G	H	T	
RO(1083. 2. 16. 0)	V	G	H	T	
RO(1083. 2. 17. 0)	V	G	H	T	I
RO(1083. 2. 18. 0)	V	G	H	T	
RO(1891. 1. 1. 1)	V	G	H	T	
RO(1891. 1. 2. 1)	V	G	H	T	
RO(1891. 1. 3. 1)	V	G	H	T	
RO(1891. 1. 4. 1)	V	G	H	T	
RO(1891. 2. 1. 1)	V	G	H	T	
RO(1891. 2. 2. 1)	V	G	H	T	
RO(1891. 2. 3. 1)	V	G	H	T	
RO(1891. 2. 4. 1)	V	G	H	T	
RO(1891. 4. 1. 1)	V	G	H	T	
RO(1891. 4. 2. 1)	V	G	H	T	
RO(1891. 4. 3. 1)	V	G	H	T	
RO(1891. 4. 4. 1)	V	G	H	T	

8.2 APPENDIX 2 : OPERATING RANGE OF THE MODEL

The tables in this Appendix indicate those regions of the model where predictions of stocking increase over time. For a range of top heights, basal areas and stockings, a -1, 1 or blank is used to indicate the behaviour of the model as follows :

-1	predictions of stocking are increasing
1	predictions of stocking are increasing, but are less than 1 stem/year and therefore not apparent to the user.
blank	predictions of stocking behave "normally".

HEIGHT = 5m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10																	
20																	
30	1																
40	1																
50	1																
60	-1																
70	-1	1															
80	-1	1															
90	-1	1															
100	-1	1															
110	-1	-1															
120	-1	-1															
130	-1	-1															
140	-1	-1	1														
150	-1	-1	1														
160	-1	-1	1														
170	-1	-1	1														
180	-1	-1	1														
190	-1	-1	1														
200	-1	-1	1														
210	-1	-1	-1														
220	-1	-1	-1														
230	-1	-1	-1														
240	-1	-1	-1														
250	-1	-1	-1														
260	-1	-1	-1														
270	-1	-1	-1														
280	-1	-1	-1	1													
290	-1	-1	-1	1													
300	-1	-1	-1	1													
310	-1	-1	-1	1													
320	-1	-1	-1	1													
330	-1	-1	-1	1													
340	-1	-1	-1	-1													
350	-1	-1	-1	-1													
360	-1	-1	-1	-1													
370	-1	-1	-1	-1													
380	-1	-1	-1	-1													
390	-1	-1	-1	-1													
400	-1	-1	-1	-1													
410	-1	-1	-1	-1													
420	-1	-1	-1	-1													
430	-1	-1	-1	-1													
440	-1	-1	-1	-1	1												
450	-1	-1	-1	-1	1												
460	-1	-1	-1	-1	1												
470	-1	-1	-1	-1	1												
480	-1	-1	-1	-1	1												
490	-1	-1	-1	-1	1												
500	-1	-1	-1	-1	1												

HEIGHT = 6m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1																
20	1																
30	1																
40	1	1															
50	-1	1															
60	-1	1															
70	-1	1															
80	-1	1															
90	-1	-1	1														
100	-1	-1	1														
110	-1	-1	1														
120	-1	-1	1														
130	-1	-1	1														
140	-1	-1	1														
150	-1	-1	1														
160	-1	-1	-1														
170	-1	-1	-1	1													
180	-1	-1	-1	1													
190	-1	-1	-1	1													
200	-1	-1	-1	1													
210	-1	-1	-1	1													
220	-1	-1	-1	1													
230	-1	-1	-1	1													
240	-1	-1	-1	1													
250	-1	-1	-1	-1													
260	-1	-1	-1	-1													
270	-1	-1	-1	-1													
280	-1	-1	-1	-1	1												
290	-1	-1	-1	-1	1												
300	-1	-1	-1	-1	1												
310	-1	-1	-1	-1	1												
320	-1	-1	-1	-1	1												
330	-1	-1	-1	-1	1												
340	-1	-1	-1	-1	1												
350	-1	-1	-1	-1	1												
360	-1	-1	-1	-1	-1												
370	-1	-1	-1	-1	-1												
380	-1	-1	-1	-1	-1												
390	-1	-1	-1	-1	-1												
400	-1	-1	-1	-1	-1	1											
410	-1	-1	-1	-1	-1	1											
420	-1	-1	-1	-1	-1	1											
430	-1	-1	-1	-1	-1	1											
440	-1	-1	-1	-1	-1	1											
450	-1	-1	-1	-1	-1	1											
460	-1	-1	-1	-1	-1	1											
470	-1	-1	-1	-1	-1	-1											
480	-1	-1	-1	-1	-1	-1											
490	-1	-1	-1	-1	-1	-1											
500	-1	-1	-1	-1	-1	-1											

HEIGHT = 7m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1														
20	1	1															
30	1	1															
40	1	1															
50	-1	1															
60	-1	1	1														
70	-1	1	1														
80	-1	-1	1														
90	-1	-1	1														
100	-1	-1	1														
110	-1	-1	1	1													
120	-1	-1	1	1													
130	-1	-1	-1	1													
140	-1	-1	-1	1													
150	-1	-1	-1	1													
160	-1	-1	-1	1													
170	-1	-1	-1	1													
180	-1	-1	-1	1													
190	-1	-1	-1	-1	1												
200	-1	-1	-1	-1	1												
210	-1	-1	-1	-1	1												
220	-1	-1	-1	-1	1												
230	-1	-1	-1	-1	1												
240	-1	-1	-1	-1	1												
250	-1	-1	-1	-1	1												
260	-1	-1	-1	-1	1												
270	-1	-1	-1	-1	-1	1											
280	-1	-1	-1	-1	-1	1											
290	-1	-1	-1	-1	-1	1											
300	-1	-1	-1	-1	-1	1											
310	-1	-1	-1	-1	-1	1											
320	-1	-1	-1	-1	-1	1											
330	-1	-1	-1	-1	-1	1											
340	-1	-1	-1	-1	-1	1											
350	-1	-1	-1	-1	-1	1											
360	-1	-1	-1	-1	-1	-1											
370	-1	-1	-1	-1	-1	-1	1										
380	-1	-1	-1	-1	-1	-1	1										
390	-1	-1	-1	-1	-1	-1	1										
400	-1	-1	-1	-1	-1	-1	1										
410	-1	-1	-1	-1	-1	-1	1										
420	-1	-1	-1	-1	-1	-1	1										
430	-1	-1	-1	-1	-1	-1	1										
440	-1	-1	-1	-1	-1	-1	-1										
450	-1	-1	-1	-1	-1	-1	-1	1									
460	-1	-1	-1	-1	-1	-1	-1	1									
470	-1	-1	-1	-1	-1	-1	-1	1									
480	-1	-1	-1	-1	-1	-1	-1	1									
490	-1	-1	-1	-1	-1	-1	-1	1									
500	-1	-1	-1	-1	-1	-1	-1	1									

HEIGHT = 8m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1							
20	1	1	1														
30	1	1	1														
40	-1	1	1														
50	-1	1	1														
60	-1	1	1														
70	-1	-1	1	1													
80	-1	-1	1	1													
90	-1	-1	1	1													
100	-1	-1	1	1													
110	-1	-1	-1	1													
120	-1	-1	-1	1	1												
130	-1	-1	-1	1	1												
140	-1	-1	-1	1	1												
150	-1	-1	-1	1	1												
160	-1	-1	-1	-1	1												
170	-1	-1	-1	-1	1												
180	-1	-1	-1	-1	1												
190	-1	-1	-1	-1	1	1											
200	-1	-1	-1	-1	1	1											
210	-1	-1	-1	-1	1	1											
220	-1	-1	-1	-1	-1	1											
230	-1	-1	-1	-1	-1	1											
240	-1	-1	-1	-1	-1	1											
250	-1	-1	-1	-1	-1	1											
260	-1	-1	-1	-1	-1	1	1										
270	-1	-1	-1	-1	-1	1	1										
280	-1	-1	-1	-1	-1	-1	1										
290	-1	-1	-1	-1	-1	-1	1										
300	-1	-1	-1	-1	-1	-1	1										
310	-1	-1	-1	-1	-1	-1	1										
320	-1	-1	-1	-1	-1	-1	1										
330	-1	-1	-1	-1	-1	-1	1	1									
340	-1	-1	-1	-1	-1	-1	1	1									
350	-1	-1	-1	-1	-1	-1	-1	1									
360	-1	-1	-1	-1	-1	-1	-1	1									
370	-1	-1	-1	-1	-1	-1	-1	1									
380	-1	-1	-1	-1	-1	-1	-1	1									
390	-1	-1	-1	-1	-1	-1	-1	1									
400	-1	-1	-1	-1	-1	-1	-1	1	1								
410	-1	-1	-1	-1	-1	-1	-1	-1	1								
420	-1	-1	-1	-1	-1	-1	-1	-1	1								
430	-1	-1	-1	-1	-1	-1	-1	-1	1								
440	-1	-1	-1	-1	-1	-1	-1	-1	1								
450	-1	-1	-1	-1	-1	-1	-1	-1	1								
460	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
470	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
480	-1	-1	-1	-1	-1	-1	-1	-1	-1	1							
490	-1	-1	-1	-1	-1	-1	-1	-1	-1	1							
500	-1	-1	-1	-1	-1	-1	-1	-1	-1	1							

HEIGHT = 9m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1												
30	1	1	1	1													
40	-1	1	1	1													
50	-1	1	1	1													
60	-1	-1	1	1													
70	-1	-1	1	1													
80	-1	-1	1	1	1												
90	-1	-1	-1	1	1												
100	-1	-1	-1	1	1												
110	-1	-1	-1	1	1												
120	-1	-1	-1	1	1												
130	-1	-1	-1	-1	1	1											
140	-1	-1	-1	-1	1	1											
150	-1	-1	-1	-1	1	1											
160	-1	-1	-1	-1	1	1											
170	-1	-1	-1	-1	1	1											
180	-1	-1	-1	-1	-1	1	1										
190	-1	-1	-1	-1	-1	1	1										
200	-1	-1	-1	-1	-1	1	1										
210	-1	-1	-1	-1	-1	1	1										
220	-1	-1	-1	-1	-1	1	1										
230	-1	-1	-1	-1	-1	-1	1										
240	-1	-1	-1	-1	-1	-1	1	1									
250	-1	-1	-1	-1	-1	-1	1	1									
260	-1	-1	-1	-1	-1	-1	1	1									
270	-1	-1	-1	-1	-1	-1	1	1									
280	-1	-1	-1	-1	-1	-1	1	1									
290	-1	-1	-1	-1	-1	-1	-1	1									
300	-1	-1	-1	-1	-1	-1	-1	1	1								
310	-1	-1	-1	-1	-1	-1	-1	1	1								
320	-1	-1	-1	-1	-1	-1	-1	1	1								
330	-1	-1	-1	-1	-1	-1	-1	1	1								
340	-1	-1	-1	-1	-1	-1	-1	-1	1								
350	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
360	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
370	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
380	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
390	-1	-1	-1	-1	-1	-1	-1	-1	-1	1							
400	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1						
410	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1						
420	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1						
430	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1						
440	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1					
450	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1					
460	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1					
470	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1				
480	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1				
490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1				
500	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1				

HEIGHT = 10m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1										
30	1	1	1	1	1												
40	-1	1	1	1	1												
50	-1	1	1	1	1												
60	-1	-1	1	1	1												
70	-1	-1	1	1	1												
80	-1	-1	1	1	1	1											
90	-1	-1	-1	1	1	1											
100	-1	-1	-1	1	1	1											
110	-1	-1	-1	1	1	1											
120	-1	-1	-1	-1	1	1											
130	-1	-1	-1	-1	1	1	1										
140	-1	-1	-1	-1	1	1	1										
150	-1	-1	-1	-1	-1	1	1										
160	-1	-1	-1	-1	-1	1	1										
170	-1	-1	-1	-1	-1	1	1										
180	-1	-1	-1	-1	-1	1	1	1									
190	-1	-1	-1	-1	-1	1	1	1									
200	-1	-1	-1	-1	-1	-1	1	1									
210	-1	-1	-1	-1	-1	-1	1	1									
220	-1	-1	-1	-1	-1	-1	1	1	1								
230	-1	-1	-1	-1	-1	-1	1	1	1								
240	-1	-1	-1	-1	-1	-1	-1	1	1								
250	-1	-1	-1	-1	-1	-1	-1	1	1								
260	-1	-1	-1	-1	-1	-1	-1	1	1								
270	-1	-1	-1	-1	-1	-1	-1	1	1	1							
280	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
290	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
300	-1	-1	-1	-1	-1	-1	-1	-1	1	1							
310	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1						
320	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1						
330	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1						
340	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1					
350	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1					
360	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1					
370	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1					
380	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1				
390	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1				
400	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1				
410	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1			
420	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1			
430	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1		
440	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1		
450	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1		
460	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	
470	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	
480	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1
500	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1

HEIGHT = 12m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	1	1	1	1	1	1	1	1	1	1							
40	-1	1	1	1	1	1	1	1									
50	-1	-1	1	1	1	1	1	1									
60	-1	-1	1	1	1	1	1	1									
70	-1	-1	-1	1	1	1	1	1									
80	-1	-1	-1	1	1	1	1	1									
90	-1	-1	-1	-1	1	1	1	1									
100	-1	-1	-1	-1	1	1	1	1									
110	-1	-1	-1	-1	1	1	1	1	1								
120	-1	-1	-1	-1	-1	1	1	1	1								
130	-1	-1	-1	-1	-1	1	1	1	1								
140	-1	-1	-1	-1	-1	1	1	1	1	1							
150	-1	-1	-1	-1	-1	-1	1	1	1	1							
160	-1	-1	-1	-1	-1	-1	1	1	1	1							
170	-1	-1	-1	-1	-1	-1	1	1	1	1							
180	-1	-1	-1	-1	-1	-1	-1	1	1	1	1						
190	-1	-1	-1	-1	-1	-1	-1	1	1	1	1						
200	-1	-1	-1	-1	-1	-1	-1	1	1	1	1						
210	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1					
220	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1					
230	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1					
240	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1				
250	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1				
260	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1			
270	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1			
280	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1		
290	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1		
300	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	
310	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	
320	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1
330	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1
340	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1
350	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
360	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1
370	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1
380	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1
390	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1
400	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1
410	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
420	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
430	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
440	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
450	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
460	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
470	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
480	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
500	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

HEIGHT = 14m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	−1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	−1	1	1	1	1	1	1	1	1	1	1	1	1				
50	−1	−1	1	1	1	1	1	1	1	1	1	1					
60	−1	−1	−1	1	1	1	1	1	1	1	1	1					
70	−1	−1	−1	1	1	1	1	1	1	1	1						
80	−1	−1	−1	−1	1	1	1	1	1	1	1						
90	−1	−1	−1	−1	1	1	1	1	1	1	1	1					
100	−1	−1	−1	−1	−1	1	1	1	1	1	1	1					
110	−1	−1	−1	−1	−1	1	1	1	1	1	1	1					
120	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1					
130	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1				
140	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1				
150	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1			
160	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1			
170	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1			
180	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1		
190	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1	
200	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1	
210	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1	1
220	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1
230	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1	1
240	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1
250	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1	1
260	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1	1
270	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1
280	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1	1
290	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1	1
300	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1	1
310	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1
320	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	1
330	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
340	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
350	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
360	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
370	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
380	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
390	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
400	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
410	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
420	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
430	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
440	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
450	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
460	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
470	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
480	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
490	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1
500	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1

HEIGHT = 16m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
70	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	
90	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	
100	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1
110	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1
120	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1
130	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1
140	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1
150	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1
160	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
170	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
180	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1
190	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1
200	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1
210	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1
220	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1
230	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
240	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1
250	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1
260	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1
270	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
280	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
290	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
300	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
310	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
320	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
330	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
340	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
350	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
360	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
370	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
380	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
390	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
400	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
410	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
420	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
430	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
440	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
450	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
460	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
470	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
480	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
500	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

HEIGHT = 18m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
70	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1
80	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1
90	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1
100	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1
110	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1
120	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1
130	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1
140	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
150	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1
160	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1
170	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1
180	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1
190	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1
200	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1
210	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1	1
220	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	1
230	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
240	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
250	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
260	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
270	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
280	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
290	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
300	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
310	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
320	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
330	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
340	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
350	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
360	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
370	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
380	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
390	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
400	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
410	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
420	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
430	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
440	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
450	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
460	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
470	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
480	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
500	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

HEIGHT = 20m

BASAL AREA (m2/ha)

SPH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
30	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
40	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
50	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
60	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1
70	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1
80	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1
90	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1	1
100	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1	1
110	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1
120	-1	-1	-1	-1	-1	-1	-1	-1	1	1	1	1	1	1	1	1	1
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200	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
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480	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
490	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
500	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1