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MODELLING INDIVIDUAL-TREE PROBABILITY of SURVIVAL of UNTHINNED RADIATA PINE

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EXECUTIVE SUMMARY

Stand Growth Modelling Cooperative (SGMC) Report No. 54 (Lundgren and Gordon 1997) documented the initial development of individual-tree probability of survival equations for radiata pine growing in the Central North Island (CNI). The tree-level survival equations are applicable to unthinned plantations ≥ 4 years old and planted after 1960.

The objective of this Report is to document: revisions to the CNI equation; extension of the analyses to the other growth modelling regions in New Zealand; and, the investigation of weighted, non-linear regression and several new, additional explanatory variables.

The CNI probability of survival prediction equation was revised from the initial investigation (Lundgren and Gordon 1997), and nearly all regional prediction equations include new approaches/variables which index New Zealand radiata pine relative stand density and/or productivity potential. The Canterbury region dataset had too little mortality (0.4% dead trees) to justify the development of a probability of survival equation.

Across the modelling regions, adjusted R^2 values ranged from 0.09 (HBAY) to 0.25 (SOUTH). However, adjusted R^2 values are misleading due to the nature of the actual survival data (a discrete variable: 0 = dead or 1 = alive) versus the probability of survival prediction (a continuous variable: 0 to 1). Nonetheless, across regions, the relative ranking of adjusted R^2 values is informative. At the stand-level and as a proportion of stocking at the start of a time interval, error in predicting stocking at time2 ranges from about ± 2% to ± 6%.

For nearly all regions, the final number and selection of explanatory variables were the same. The final selection of explanatory variables represents 4 principal attributes useful to predict the probability of survival: stand density (either SDI or basal area), tree-size (diameter: either tree- or stand-level), potential change in tree-size (diameter), and relative tree-size (diameter).

The regional probability of survival equations, developed for unthinned stand conditions, are considered ready for beta-testing in the new generation of individual-tree growth models and any ancillary applications (e.g., GROMARVL). Nonetheless, formal validation is warranted and pending (SGMC Work Programme 1997/98: Theme 4, Project 2). Furthermore, the development of a single equation, applicable to all regions, might be worth investigation. Future work needs to investigate whether the survival prediction equations are suited to thinned stand conditions.

INTRODUCTION

Stand Growth Modelling Cooperative (SGMC) Report No. 54 (Lundgren and Gordon 1997) documented the initial development of an individual-tree probability of survival equation for radiata pine growing in the Central North Island (CNI). The tree-level survival equation is applicable to unthinned radiata plantations $\geq$ 4 years old, planted after 1960.

The objective of this Report is to document: revisions to the CNI equation; extension of the analyses to the other growth modelling regions in New Zealand; and, the investigation of weighted, non-linear regression and several new, additional explanatory variables. The current analyses used a revised and extended CNI database from that described in Lundgren and Gordon (1997).

NOTATION

dbh_i = individual-tree breast-height (1.4m) diameter (cm)
dbh_q = stand quadratic mean breast-height diameter (cm)
reldbh = relative dbh, i.e., dbh_i / dbh_q
exp(x) = e^x; e is the base, 2.71828, of the natural logarithm
G = stand basal area (m^2/hectare)
log = natural base 2.71828 logarithm
log_{10} = base 10 logarithm
MTD = stand mean top breast-height diameter (cm)
MTH = stand mean top height (m)
S = site index (m)
N = stems per hectare
alt = altitude (m)
age = plantation age (years)
bal_i = sum of basal-area of individual trees in a stand larger than tree 'i'

DATA

The current analyses used conventional growth monitoring data (i.e., not nelder experiment data) extracted from the F.R.I. Permanent Sample Plot (PSP) system according to the following acceptance criteria:

- planted after 1960,
- $\geq$4 years old,
- remeasured at least once,
- plot size $\geq$ 0.04-ha,
- windthrow $\leq$ 2 trees per plot and mean dbh of windthrow < dbh_q, and
- from an unthinned condition.

All plot and tree-level observations meeting the selection criteria were included in the regression analyses, i.e., all available data was used in the

regression analyses. **Appendix 1** provides a list of PSP's by region that were used in the analysis. The list is derived from the first measurement age of a PSP, and includes the stand-level parameters applicable at that measurement: altitude, age, mean top diameter, basal area, mean top height, tree stocking, quadratic mean breast-height diameter, and Stand Density Index (described further-on).

METHODS

Background

The initial investigation (Lundgren and Gordon 1997) established the utility of using the logistic function to predict the probability of survival between 0 and 1, concomitant with varying time intervals between measurements. The current investigation accepted this modelling approach and did not consider the issue further.

The current analyses used SAS (SAS Institute Inc. 1989) weighted, non-linear regression procedure, NLIN, (method=marquardt) to estimate parameter coefficients (α=0.05).

A generalised logistic function was fit:

$$y = \left\{ \frac{1}{\left(1 + \exp^{a_0 + a_1 x_1^{b1} + \ldots + a_n x_n^{bn}}\right)} \right\}^i \qquad [1]$$

where:

y	= probability of survival over a period of "i" years,
i	= variable time interval between measurements (years),
x_n	= tree- and stand-level explanatory variables,
a_0, a_n	= coefficients to be determined, and
b_1, b_n	= coefficients (optional) to be included/determined.

The data for the dependent variable (y) is discrete (0 or 1), however in practice, equation [1] predicts the probability of survival as a continuous variable between 0 and 1. Potential explanatory variables (x_n) included all those tried in the initial investigation, and those newly devised, and used previously in individual-tree growth analyses (Shula 1997a and b, Shula and Knowe 1998). The shape parameter (b_n) in equation [1] was generally assumed to be 1, although the parameter was explicitly determined in some instances to investigate better statistical fits.

To reduce the heterogeneity of residual variance, a variety of weighting schemes were investigated, including:

- the reciprocal of tree-size attributes (e.g., dbh), and
- iterative re-weighting using the reciprocal (or not) of the predicted.

Criteria for judging equation goodness-of-fit, homogeneity of residual variance, and acceptance included:

- adjusted R^2 (Kmenta 1986) and
- Furnival's Index (Furnival 1961).

Adjusted R^2 was used because it considers the number of explanatory variables (p) in an equation in relation to the number of observations (n) in the dataset. Thus, it provides a standardised measure of the predictive ability of equations, differing in n and p, to account for variation from the mean in respective datasets. The benefit of using weighted regression to reduce the heterogeneity of residual variance was determined by computing and comparing Furnival's Index from both unweighted and weighted regression. In a comparison of equations, the equation with the 'best' Index will exhibit residuals most normally distributed, most independent, and with most constant standard error (Furnival 1961).

Explanatory Variables

In addition to the explanatory variables tried in the initial investigation, 4 additional explanatory variables (including transformations) were tried based upon successful screening for variables from principal component analysis (Gordon and Lawrence 1994):

- SDI,
- RD,
- chg_pdbh, and
- bal_ratio.

SDI (Stand Density Index). SDI (Reineke 1933) provides a relative measure of intra-specific competition, and is a function of quadratic mean dbh (dbh_q) and tree stocking (N):

$$SDI = 1.0147*(10) \wedge [\log_{10}*N + 1 .605*\log_{10}(dbh_q) - 2.25]$$

SDI is the number of trees per hectare for a dbh_q of 25.4 cm (10 inches); and is independent of species, site quality, and age (Reineke 1933).

RD (Relative Density). RD (Curtis 1982) was developed for coastal Douglas-fir in the Pacific Northwest USA to provide a relative measure of intra-specific competition. RD is a function of dbh_q and basal area stocking (G):

$$RD = G / (dbh_q)^{0.5}$$

For coastal Douglas-fir, the power coefficient on dbh_q ranges from 0.45 to 0.50, however, among various species, the coefficient is thought to range from 0.3 to 0.5. In the present analyses, and for the simple purpose of a relative measure of intra-specific competition, the value, 0.5, was accepted.

Chg_pdbh (change in potential dbh). Diameter Potential Index, DPI, (analogous to site index, but MTD, not MTH at a base-age) was developed for each of the 6 modelling regions to index potential site productivity as a function of dominant trees' dbh and plantation age (**Appendix 2**). Regional DPI datasets were developed using MTD at the start (age) of each PSP's re-measurement period represented in the regional survival datasets. This approach, to use the most dominant trees based on height, was used to minimise the influence of stand density, and thereby, make DPI less dependent on management regime.

The DPI equation is an algebraic-difference formulation, ADF, (Clutter et al. 1983) of a exponentiated and generalised Schumacher growth equation (Schumacher 1939), and is polymorphic with respect to shape. Through algebraic manipulation, the ADF predicts a tree's potential diameter given current and future age, and DPI. Herein, DPI base-age is 20 years plantation age, although the ADF is inherently base-age invariant (i.e., in application, any base-age can be specified).

The appropriate regional DPI equation was applied to each individual-tree in the regional survival datasets to predict the 'diameter potential index of the tree' (DPIT). DPIT represents a particular tree's maximum expected diameter at age 20 years, an index of the tree's potential diameter productivity on that micro-site.

Through algebraic manipulation, the ADF predicts the potential dbh of a tree (PDT) given current and future age, and DPIT. PDT-age curves represent a tree's expected dbh maximum growth trajectory. Individual-tree 'change in potential dbh' (chg_pdbh) was calculated based upon DPIT, PDT (at time2), and initial dbh (at time1). Chg_pdbh, and transformations thereof, were screened as explanatory variables in combination with other tree- and stand-level variables as predictors of individual-tree probability of survival through variable prediction-length periods.

Bal_ratio. This variable is the ratio of bal_i to dbh_i. This transformation of bal_i provides greater specificity in implementation because trees from different plots may have an identical bal (identical 'position' in the stand's hierarchy), but have a different dbh (tree-size). Bal_ratio, then, indexes or quantifies intra-specific competition w.r.t. within-plot and between-plot relativity.

RESULTS

Database

The database is extensive (**Table 1**), as indicated by the number of regional PSPs, ranging from 56 to 180 (HBAY and SANDS, respectively). Dead trees occurred in 7% to 84% (CLAYS and SANDS, respectively) of the regional PSPs. The number of trees in the regional PSPs ranged from 4402 to 14123 (SOUTH and CNI, respectively); the range in the percentage of dead trees was 3% to 23% (SOUTH and CNI, respectively). The Canterbury region was excluded from the analyses because mortality was too low (0.4% dead trees).

Table1. Number of observations, trees, and PSPs by region in the unthinned survival analyses.

Sample	GDNS	SOUTH	CLAYS	SANDS	HBAY	CNI
No. Obs.	23982	10828	34126	73861	30011	98277
No. Trees	6407	4402	9617	11605	5917	14123
No. Dead Trees	191	157	747	1088	560	3207
% Dead Trees	3	4	8	9	10	23
No. PSP's	109	71	140	180	56	159
No. PSP's with Dead	33	23	97	151	34	126
% PSP's with Dead	30	32	7	84	59	79

Table 2 presents measures of central tendencies (sample size, mean, standard deviation, minimum, maximum for stand-level attributes for each of the regional datasets. Statistics were calculated at each age represented in a series of PSP measurements. The mean plantation age in the database is less than mid-rotation age (< age 15 years); maximum age ranges from 21 to 32 years. Mean tree stocking, representative of unthinned conditions, ranges from 941 sph to 1520 sph; maximum tree stocking ranges from 2247 to 4075 sph. The mean basal area ranges from 16 to 44 m^2/ha; maximum basal area ranges from 63 to 107 m^2/ha. The mean dbh_q ranges from 11 to 19 cm; mean Diameter Potential Index ranges from 31 to 41 cm (baseage 20 years). The mean time interval between measurements is about 1 year; maximum time interval ranges from 5 to 9 years.

Table 3 presents measures of central tendencies (sample size, mean, standard deviation, minimum, maximum) for three tree-level attributes (dbh_i, reldbh, and chg_pdbh) of 'live' and 'dead' trees from each of the regional datasets. Statistics were calculated at each age represented in a series of PSP measurements. Compared with live trees, dead trees are characterised by smaller tree size (dbh_i and reldbh) and less diameter growth (chg_pdbh). Nonetheless, large trees die, as indicated by the range in maximum diameter (34 to 60 cm) and relative diameter (1.38 to 1.99). Similarly, dead trees are not necessarily characterised by less diameter growth than live trees, as suggested by mean chg_pdbh of live and dead trees in the regions, CLAYS and SANDS. NB: Negative values for chg_pdbh are an artefact of the

prediction equation operating at the lower extreme of tree-size, and should be considered equivalent to zero.

Table 2. Measures of central tendencies (calculated at each age on a PSP) for stand-level attributes for each of the regional survival datasets.

Attribute	GDNS (n=382)	SOUTH (n=194)	CLAYS (n=526)	SANDS (n=1130)	HBAY (n=273)	CNI (n=1156)
Age (yrs)						
mean	10.2	10.0	8.4	10.8	10.9	12.9
std. dev.	4.3	2.5	4.5	4.5	5.0	6.6
minimum	4.1	5.0	4.2	4.7	4.8	4.2
maximum	26.0	21.0	31.1	26.0	24.0	32.0
N (sph)						
mean	1022	941	1368	1394	1520	1397
std. dev.	617	352	395	411	581	515
minimum	716	700	741	760	708	720
maximum	4075	2460	3526	2247	2916	2979
G (m^2/ha)						
mean	20.1	18.3	16.2	27.3	43.5	40.0
std. dev.	16.9	13.4	17.0	12.3	25.2	21.3
minimum	1.1	1.4	0.5	0.5	2.7	0.9
maximum	83.8	74.3	83.0	63.3	107.1	89.3
dbhq (cm)						
mean	15.2	15.2	11.0	15.8	19.0	19.0
std. dev.	6.7	5.3	6.0	4.2	6.6	6.7
minimum	4.0	4.0	2.0	2.0	6.0	3.0
maximum	35.0	33.0	37.0	27.0	35.0	38.0
S (m)						
mean	28.7	24.4	29.7	25.0	30.1	32.7
std. dev.	3.0	3.7	3.3	4.0	4.7	3.9
minimum	20.0	15.4	16.2	13.2	19.1	22.8
maximum	35.6	32.9	33.3	33.5	39.6	39.2
SDI (sph)						
mean	464	435	409	653	952	876
std. dev.	326	262	335	253	486	393
minimum	49	73	19	19	103	33
maximum	1535	1430	1535	1336	2044	1659
DPI (cm)						
mean	37.5	37.0	36.5	30.7	41.4	40.4
std. dev.	5.3	4.9	6.2	2.9	5.6	4.6
minimum	23.2	25.4	17.7	17.2	30.9	21.8
maximum	52.3	48.2	49.7	39.4	54.1	55.0
Interval (yrs)						
mean	1.5	1.5	1.2	1.3	1.2	1.1
std. dev.	1.0	0.9	0.7	1.0	0.7	0.6
minimum	0.5	0.4	0.1	0.1	0.1	0.2
maximum	8.7	6.3	8.0	7.2	5.1	6.0

Table 3. Measures of central tendencies for tree-level attributes of live and dead trees from each of the regional survival datasets.

Region	**dbh$_i$** (cm)		**reldbh$_i$**		**chg_pdbh$_i$** (cm)	
	live	**dead**	**live**	**dead**	**live**	**dead**
GDNS						
n	→		23701	191	←	
mean	15.7	10.0	0.97	0.58	2.6	1.8
std. dev.	8.2	6.6	0.24	0.30	2.0	1.6
minimum	0.1	1.2	0.02	0.11	-0.2	0.0
maximum	58.7	33.6	2.41	1.62	18.8	10.7
SOUTH						
n	→		10671	157	←	
mean	14.7	12.6	0.98	0.74	4.4	4.0
std. dev.	6.1	6.1	0.19	0.25	3.0	2.2
minimum	1.2	1.8	0.18	0.26	-0.1	0.4
maximum	43.8	33.8	2.37	1.38	21.5	12.8
CLAYS						
n	→		33379	747	←	
mean	11.2	11.2	0.96	0.67	2.2	2.8
std. dev.	6.8	6.1	0.32	0.29	1.5	3.4
minimum	0.1	0.1	0.01	0.03	-0.4	-0.1
maximum	59.6	44.6	3.43	1.85	19.1	18.1
SANDS						
n	→		72773	1088	←	
mean	15.2	12.0	0.98	0.68	1.4	1.4
std. dev.	5.3	4.7	0.22	0.23	0.8	0.9
minimum	0.1	0.9	0.01	0.11	-0.4	-0.3
maximum	38.8	36.3	3.00	1.51	8.6	5.0
HBAY						
	→		29451	560	←	
mean	18.2	14.4	0.98	0.67	2.0	1.5
std. dev.	7.7	5.3	0.23	0.23	1.2	1.2
minimum	0.5	2.8	0.06	0.20	-0.2	-0.1
maximum	53.3	34.0	1.85	1.62	7.8	6.9
CNI						
	→		95070	3207	←	
mean	17.8	14.0	0.98	0.65	0.6	0.2
std. dev.	8.2	5.7	0.26	0.21	0.5	0.3
minimum	0.1	0.7	0.01	0.05	-0.8	-0.8
maximum	74.7	60.0	2.70	1.99	2.8	1.8

Probability of Survival

The CNI probability of survival prediction equation was revised from the initial investigation (Lundgren and Gordon 1997), and nearly all regional prediction equations include new approaches/variables which index New Zealand radiata pine relative stand density and/or productivity potential (i.e., SDI and chg_pdbh, respectively).

Across the modelling regions, adjusted R^2 values ranged from 0.09 (HBAY) to 0.25 (SOUTH) (**Table 4**). However, adjusted R^2 values are misleading due to the nature of the actual survival data (a discrete variable: 0 = dead or 1 = alive) versus the probability of survival (ps) prediction (a continuous variable: $0 < ps < 1$). Nonetheless, across regions, the relative ranking of adjusted R^2 values is informative. Furthermore, it is not possible to objectively determine percent-error of prediction because this requires subjective selection of a probability of survival (continuous between 0 and 1) to define either a 'dead' (0) or 'live' (1) condition.

For all regions, weighted regression provided a better Furnival Index than unweighted regression (Table 4), indicating more homogeneous standard error of prediction, and for the construction of confidence intervals, more asymptotically efficient parameter estimators. For all regions, the weight, (predicted probability of survival)$^{-1}$ was the best weighting scheme (provided the best Furnival's Index).

For nearly all regions, the final number and selection of explanatory variables were the same (**Table 5**). Improvement in adjusted R^2 was not evident with the inclusion of additional explanatory variables, e.g., RD and bal_ratio. The final selection of explanatory variables represents 4 principal attributes useful to predict the probability of survival:

- stand density (either SDI or basal area),
- tree-size (diameter: either tree- or stand-level),
- potential change in tree-size (diameter), and
- relative tree-size (diameter).

Fit Statistics and Parameter Coefficients

Table 4. Region, mean residual, adjusted R^2, and Furnival's Index from the regression analyses.

Region	**Mean Residual** (std. dev.)	**Adjusted R^2**	**Furnival Index**	
			Weighted	Not Weighted
GDNS	0.003 (0.085)	0.10	0.081	0.083
SOUTH	-0.006 (0.104)	0.25	0.099	0.104
CLAYS	-0.004 (0.131)	0.19	0.123	0.132
SANDS	0.011 (0.114)	0.10	0.108	0.112
HBAY	0.000 (0.129)	0.09	0.123	0.129
CNI	0.005 (0.164)	0.15	0.154	0.164

Table 5. Region, parameters, and coefficients from the regression analyses using equation [1]:

Region	Parameter	Coefficient (α=0.05)	Standard Error
GDNS	intercept	-1.8287	0.1217
	$SDI^{0.5}$	0.0419	0.0036
	chg_pdbh	-1.3190	0.0573
	reldbh	-2.9365	0.1834
	exponent of reldbh	2.0553	0.2180
SOUTH	intercept	-12.0293	0.7162
	log(G)	4.1115	0.2853
	$log(dbh_q)$	-0.8409	0.2504
	reldbh	-6.8109	0.2836
CLAYS	intercept	-15.8653	0.4366
	log(SDI)	2.1126	0.0653
	chg_pdbh	0.1693	0.0071
	reldbh	-4.2596	0.1135
	exponent of reldbh	2.2831	0.1190
SANDS	intercept	-6.1293	0.2051
	log(SDI)	0.7547	0.0302
	chg_pdbh	0.1645	0.0127
	reldbh	-3.7207	0.0678
	exponent of reldbh	1.6174	0.0553
HBAY	intercept	-11.2897	0.7011
	log(SDI)	1.3632	0.0942
	chg_pdbh	0.1141	0.0238
	reldbh	-4.0960	0.1315
	exponent of reldbh	2.2499	0.1687
CNI	intercept	-7.7498	0.2694
	log(SDI)	1.2584	0.0411
	$dbh_i^{0.5}$	-0.1499	0.0221
	reldbh	-4 .7389	0.1303
	exponent of reldbh	1.3056	0.0675

Residuals

Appendix 3, Figures 1-3 present prediction residuals vs stand dbh_i for the 6 growth modelling regions. The residuals were calculated as the actual (0 or 1) minus the predicted probability of survival (0.0 to 1.0). Trend-lines observable in the figures (e.g., SOUTH region) represent single PSPs, but different trees (i.e., trend-lines do not represent one tree's consecutive prediction residual). The following descriptions are provided to interpret further the pattern of residuals in Figures 1-3.

All positive residuals represent trees that were actually alive at the end of the prediction period; the respective predicted probability of survival (equation 1) is equivalent to (1 minus the value of the residual). For example, a residual of

1 equates to a predicted probability of survival of 0, while a residual of 0.2 equates to a predicted probability of survival of 0.8. Therefore, positive residuals close to 0 represent predicted probabilities of survival close to 1 (i.e., more likely to be live) for trees that were actually live at time of prediction. Similarly, positive residuals close to 1 represent predicted probabilities of survival close to 0 (i.e., more likely to be dead) for trees that were actually live at time of prediction.

Conversely, all negative residuals represent trees that were actually dead at the end of the prediction period; the respective predicted probability of survival (from equation 1) is equivalent to (0 minus the value of the residual). For example, a residual of -1 equates to a predicted probability of survival of 1, while a residual of -0.2 equates to a predicted probability of survival of 0.2. Therefore, negative residuals close to 0 represent predicted probabilities of survival close to 0 (i.e., more likely to be dead) for trees that were actually dead at time of prediction. Alternatively, negative residuals close to -1 represent predicted probabilities of survival close to 1 (i.e., more likely to be live) for trees that were actually dead at time of prediction.

Figures 1-3 enable the reader to identify various sets of predictions with respect to various degrees of probability of survival for trees that were actually dead or live at time of prediction. In this respect, the reader is able to stratify predicted probabilities of survival from equation [1] and to subjectively classify predictions as representative of 'dead' or 'live' tree conditions. For example, the bulk of residuals with $0 \leq$ residual value ≤ 0.2 (live trees across regions), suggests that predicted probabilities of survival ≥ 0.8 might best represent 'live' trees. However, the bulk of residuals with $-1.0 \leq$ residual value ≤ -0.4 (dead trees across regions), suggests that predicted probabilities ≥ 0.8 might just as well represent 'dead' trees. Therefore, ambiguity exists in the assignment of a 'dead' or 'live' condition based on a tree's predicted probability of survival.

Appendix 3, Figures 4-5 present mean prediction residuals by actual mean relative diameter (reldbh) for the 6 modelling regions. Residuals were calculated as previously described. Mean prediction residuals were calculated on the basis of reldbh groups with near equal sample size. The minimum and maximum group sample size by region ranged from 200 - 340 (SOUTH) to 2200 - 2700 (CNI). In Figures 4-5, the dot and star symbols represent 'paired items' which identify 'mean residual' (the left vertical axis) and the accompanying standard error of the mean residual (the right vertical axis), respectively.

Figures 4-5 indicate that, on average, prediction residuals are more centralised around zero (predictions approach the 'actual') as relative diameter increases, or as individual tree-size approaches and exceeds stand quadratic mean breast-height diameter. Across all regions, the bulk of mean prediction residuals are $\pm$ 0.02 (i.e., within $\pm$ 0.02 of either 0 or 1). The regions, HBAY and CLAYS, have the most centralised mean prediction residuals, while mean prediction residuals from GDNS and SANDS exhibit a strong bias of under-prediction (i.e., predict lower probabilities of survival for

trees actually 'live') when relative diameter is < 1 (small diameter trees); note however, this bias is reversed in the SOUTH region (i.e., predict higher probabilities of survival for trees actually 'dead'). Inspection of the standard errors of the mean residuals reveals that the variation about the mean is highest for small trees (low reldbh), and steadily decreases to a lower asymptote when reldbh is approximately 1 (i.e., dbh_q).

Appendix 3, Figures 6-7, for the six modelling regions, present PSP stocking (N) residuals by stocking at the start of a plot re-measurement interval (i.e., 'initial' stocking, sph1). PSP stocking residual was calculated as:

sph_residual = actual sph2 - (PSP mean predicted prob. of surv. x sph1).

Figures 6-7 have extreme residuals (< -300 sph) removed, so that the y-axis is not unduly extended by the presence of 'outlier' predictions. These extreme residuals occurred in < 10 instances across all regions (5 in CNI), and represent the inability to predict catastrophic mortality (e.g., HBAY PSP plot WN 226 0 15 0: 2125 sph1 to 758 sph2 from age 9 to 10). Plot records were checked to confirm 'unthinned' conditions prevailed. No explanation for this catastrophic mortality is at-hand, other than a wave of competition-induced mortality due to age and a high stocking level.

Figures 6-7 illustrate that stocking residuals are biased towards under-prediction of stocking at time2 (i.e., over-prediction of mortality) across the range of initial stockings. The residuals are not normally distributed and the tendency to over-predict mortality could be a response to balance against large under-estimates of mortality in a few plots. Across all regions, the bulk of stocking residuals are about ± 50 sph. Minimum and maximum initial stocking ranges from about 800 to 2500 sph, respectively; therefore, as a proportion of initial stocking, maximum and minimum error in predicting stocking at time2 ranges from about ± 6% to ± 2%, respectively.

DISCUSSION

Explanatory variables. For the most part, prediction variables relate to tree-level attributes (diameter, relative diameter, and chg_pdbh), however stand-level attributes common to all trees on a PSP (basal area and SDI) were also useful aides to predict the probability of survival at the tree-level. In combination, then, tree- and stand-level attributes collectively describe the probability of survival for individual-trees.

In all cases but one, chg_pdbh, the sign of the coefficients for the explanatory variables in equation [1] conform with anticipated effects on the predicted probability of survival. For example, reduction in the predicted probability of survival attributable to increased competition (ln_sdi and ln_ba), and the positive effects attributable to increased tree-size (reldbh, sqrt_dbh, and ln_dbhq). An anomaly, however, is the positive sign (except for GDNS region) of the coefficient (significantly different from zero at ≥ 95%) for the explanatory variable, chg_pdbh. Intuitively, increased diameter growth corresponds with a greater probability of survival, however, the positive

coefficient imparts a reduction in the predicted probability of survival, as potential growth increases. Explanations at-hand, include:

- an artefact of the multiple least squares statistical fitting procedure,
- a correspondence of greater diameter growth with younger, smaller diameter trees in more highly stocked plots (young trees grow faster than old trees), which are more predisposed to mortality than older, larger diameter trees.

Implementation. In an individual-tree growth simulator, equation [1] will predict the probability of survival of each tree in a tree-list. The predicted probability of survival will then be multiplied by the tree's expansion factor. With this approach, a tree's expansion factor will be progressively reduced with each time-step through the simulator. This implementation approach removes the dilemma in the assignment of a 'dead' or 'live' condition to 'a tree'. Rather, the probability of survival is assigned proportionally to a tree's expansion factor, such that, a proportion of trees represented by the expansion factor will be considered 'dead' or 'live'. This implementation approach suits the nature of the logistic equation to predict a probability of survival, whereby, e.g., a low probability of survival still imparts the potential to survive.

Future work. The similar number and commonality of explanatory variables in equation [1] across regions suggests that the development of a single equation, applicable to all regions, might be worth investigation. Nonetheless, the prediction of survival is difficult (note, the residual analyses and low adjusted R^2s), due largely to natural variation (both within region and between regions), as evidenced by the disparity in sample size for 'live' and 'dead' trees. Therefore, it is likely that maintaining specific regional equations is required. At this stage, whether or not this specificity can be accommodated in a generalised, single equation is uncertain.

Future work also needs to extend this investigation of probability of survival in unthinned stand conditions to thinned stand conditions. The appropriateness of the existing explanatory variables for prediction in the thinned stand condition needs to be tested. Perhaps moreover, though, the level of mortality in thinned stands needs to be examined to justify the development of probability of survival equations. It may be that these survival equations will adequately predict the anticipated lower mortality in thinned stands.

CONCLUSION

The regional probability of survival equations, developed for unthinned stand conditions, are considered ready for beta-testing in the new generation of individual-tree growth models and any ancillary applications (e.g., GROMARVL). Nonetheless, formal validation is warranted and pending (SGMC Work Programme 1997/98: Theme 4, Project 2). Furthermore, the development of a single equation, applicable to all regions, might be worth investigation. Future work needs to investigate whether the survival prediction equations are suited to thinned stand conditions.

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APPENDIX 1: PSPs BY REGION INCLUDED IN THE ANALYSES

- GDNS
- SOUTH
- CLAYS
- SANDS
- HBAY
- CNI

GDNS Survival Dataset:

OBS	PLOT	ALT	AGE1	MTD1	BA1	MTH1	SPH1	DBHQ	SDI
1	NN 151 2 1 0	442	6.2	9.0	2.49	.	1086	5	82
2	NN 151 2 2 0	442	6.2	9.3	2.65	.	1086	6	110
3	NN 151 2 3 0	442	6.2	8.2	2.84	.	1086	6	110
4	NN 151 2 4 0	442	6.2	9.4	3.77	.	1086	7	141
5	NN 193 0 1 0	85	7.1	10.4	3.88	7.6	741	8	119
6	NN 193 0 10 0	85	7.1	7.5	1.33	5.0	741	5	56
7	NN 193 0 11 0	85	7.1	9.2	2.39	7.0	716	7	93
8	NN 193 0 12 0	85	7.1	13.9	7.90	9.6	741	12	228
9	NN 193 0 13 0	85	7.1	15.6	8.41	10.5	741	12	228
10	NN 193 0 14 0	85	7.1	15.3	9.56	10.7	741	13	259
11	NN 193 0 15 0	85	7.1	8.8	2.64	6.7	716	7	93
12	NN 193 0 2 0	85	7.1	9.2	2.59	6.5	741	7	96
13	NN 193 0 3 0	85	7.1	13.6	7.78	8.7	741	12	228
14	NN 193 0 4 0	85	7.1	8.9	2.60	6.4	741	7	96
15	NN 193 0 5 0	85	7.1	8.4	2.25	7.4	741	6	75
16	NN 193 0 6 0	85	7.1	13.8	7.94	10.2	741	12	228
17	NN 193 0 7 0	85	7.1	8.6	1.82	6.7	716	6	72
18	NN 193 0 8 0	85	7.1	14.7	8.01	9.0	741	12	228
19	NN 193 0 9 0	85	7.1	11.0	3.97	7.8	741	8	119
20	NN 195 0 1 0	90	7.1	15.7	9.47	9.6	716	13	251
21	NN 195 0 10 0	90	7.1	9.6	2.92	7.7	716	7	93
22	NN 195 0 11 0	90	7.1	10.7	3.98	6.8	741	8	119
23	NN 195 0 12 0	90	7.1	13.0	5.86	8.2	741	10	170
24	NN 195 0 13 0	90	7.1	13.8	6.50	9.1	741	11	198
25	NN 195 0 14 0	90	7.1	13.4	6.03	8.9	741	10	170
26	NN 195 0 15 0	90	7.1	9.6	3.18	7.2	741	7	96
27	NN 195 0 16 0	90	7.1	14.8	8.18	10.1	716	12	220
28	NN 195 0 17 0	90	7.1	12.3	4.90	9.5	716	9	139
29	NN 195 0 18 0	90	7.1	15.2	8.81	10.3	716	13	251
30	NN 195 0 19 0	90	7.1	10.4	2.96	7.7	741	7	96
31	NN 195 0 2 0	90	7.1	13.8	7.52	8.9	741	11	198
32	NN 195 0 20 0	90	7.1	12.8	5.56	9.2	716	10	165
33	NN 195 0 21 0	90	7.1	10.4	2.79	7.5	716	7	93
34	NN 195 0 22 0	90	7.1	10.9	4.17	7.2	741	8	119
35	NN 195 0 23 0	90	7.1	9.0	3.27	6.3	741	7	96
36	NN 195 0 24 0	90	7.1	13.6	6.87	9.3	741	11	198
37	NN 195 0 3 0	90	7.1	10.4	3.09	7.2	716	7	93
38	NN 195 0 4 0	90	7.1	13.6	7.35	9.3	716	11	192
39	NN 195 0 5 0	90	7.1	11.2	5.25	8.2	741	9	144
40	NN 195 0 6 0	90	7.1	14.2	8.01	9.8	741	12	228
41	NN 195 0 7 0	90	7.1	10.6	4.56	8.0	716	9	139
42	NN 195 0 8 0	90	7.1	15.2	9.33	10.4	741	13	259
43	NN 195 0 9 0	90	7.1	10.2	3.05	7.4	741	7	96
44	NN 262 1 1 0	500	5.0	14.2	12.71	9.1	1481	10	340
45	NN 262 1 2 0	500	5.0	12.4	8.66	8.1	1481	9	287
46	NN 262 1 3 0	500	5.0	11.8	7.29	7.8	1481	8	238
47	NN 262 1 4 0	500	5.0	11.2	6.18	6.7	1481	7	192
48	NN 262 1 5 0	500	5.0	12.5	8.72	7.3	1481	9	287

49	NN	262	1	6	0	500	5.0	13.2	10.35	7.6	1481	9	287
50	NN	267	2	1	0	488	5.2	7.4	2.14	3.9	1111	5	84
51	NN	267	2	2	0	488	5.2	10.3	5.93	6.5	1111	8	178
52	NN	267	2	3	0	488	5.2	10.5	5.78	6.0	1111	8	178
53	NN	267	2	4	0	488	5.2	10.2	6.11	5.8	1111	8	178
54	NN	267	2	5	0	488	5.2	7.8	2.93	4.3	1111	6	112
55	NN	267	2	6	0	488	5.2	9.7	5.33	5.3	1111	8	178
56	NN	267	2	7	0	488	5.2	9.2	4.19	5.2	1111	7	144
57	NN	267	2	8	0	488	5.2	8.7	3.95	5.1	1111	7	144
58	NN	267	2	9	0	488	5.2	6.4	1.90	4.0	1111	5	84
59	NN	311	2	5	0	320	7.1	18.5	18.99	13.4	1117	15	492
60	NN	324	2	1	0	457	6.5	6.3	1.56	4.7	950	5	72
61	NN	324	2	11	0	457	6.5	11.1	12.44	7.5	3875	6	392
62	NN	324	2	2	0	457	6.5	9.9	3.54	5.8	725	8	116
63	NN	324	2	4	0	457	6.5	9.8	9.37	6.3	4075	5	308
64	NN	324	2	6	0	457	6.5	10.5	10.36	6.9	3375	6	342
65	NN	324	2	8	0	457	6.5	12.1	5.06	6.7	775	9	150
66	NN	324	2	9	0	457	6.5	12.1	6.23	7.2	900	9	175
67	NN	421	0	11	0	259	13.2	32.4	36.70	21.1	817	24	765
68	NN	421	0	12	0	274	15.2	27.4	21.12	15.0	1100	16	537
69	NN	421	0	13	0	160	13.3	21.5	14.45	18.1	783	15	345
70	NN	421	0	15	0	137	14.7	29.9	32.35	21.4	800	23	700
71	NN	421	0	16	0	146	15.3	29.7	35.76	22.4	933	22	760
72	NN	421	0	19	0	152	12.7	31.8	39.82	18.2	900	24	843
73	NN	421	0	22	0	24	11.6	27.6	23.17	17.8	867	18	512
74	NN	421	0	23	0	116	12.6	24.9	27.24	20.3	983	19	633
75	NN	421	0	24	0	229	12.6	26.0	27.72	18.1	867	20	606
76	NN	421	0	25	0	250	11.3	25.8	29.74	14.3	1017	19	655
77	NN	421	0	26	0	207	11.6	26.9	25.09	19.7	1017	18	600
78	NN	421	0	27	0	198	11.6	23.6	38.66	18.9	1567	18	925
79	NN	421	0	3	0	183	13.0	24.3	38.76	18.8	1400	19	901
80	NN	421	0	4	0	84	12.0	24.1	16.98	18.1	825	16	403
81	NN	421	0	6	0	381	8.7	18.4	13.70	12.4	825	15	363
82	NN	421	0	9	0	268	14.2	23.1	14.97	17.1	767	16	375
83	NN	452	2	999	1	355	4.1	6.0	1.13	3.9	920	4	49
84	NN	452	3	999	2	55	4.1	6.6	1.89	3.9	1160	5	88
85	NN	452	4	999	3	250	4.1	8.1	2.94	4.9	1040	6	105
86	NN	461	0	72	5	7	5.6	8.8	3.30	6.8	1210	6	122
87	NN	461	0	80	1	7	9.2	21.6	18.11	16.2	750	18	443
88	NN	469	0	77	16	270	6.2	11.1	5.25	6.8	1030	8	165
89	NN	469	0	77	18	430	6.2	13.9	9.49	7.7	1150	10	264
90	NN	469	0	77	20	250	5.2	9.5	3.50	4.6	950	7	123
91	NN	469	0	77	21	260	5.2	9.1	3.09	4.9	1140	6	115
92	NN	472	0	77	5	130	14.0	28.8	43.30	22.1	1440	20	1007
93	NN	473	0	77	2	90	15.2	35.5	68.82	24.2	1300	26	1385
94	NN	474	0	77	5	150	13.0	21.0	35.92	14.3	2540	13	889
95	NN	514	3	2	0	225	16.1	40.9	59.44	24.3	875	29	1110
96	NN	514	3	3	0	125	6.1	11.4	8.56	8.5	1739	8	279
97	NN	546	1	11	0	500	7.0	14.8	9.39	9.3	740	13	259
98	NN	546	1	18	0	500	7.0	15.7	9.41	9.3	750	13	263
99	NN	546	1	19	0	500	7.0	14.7	9.51	8.7	750	13	263
100	NN	546	1	22	0	500	7.0	14.2	8.40	8.9	740	12	228

101	NN	546	1	23	0	500	7.0	14.3	7.65	10.1	740	11	198
102	NN	546	1	4	0	500	7.0	15.1	8.91	8.8	750	12	231
103	NN	79	1	56	0	503	9.3	20.4	13.81	13.1	760	15	335
104	NN	79	1	58	0	550	14.5	24.5	21.30	18.8	778	19	501
105	NN	79	1	59	0	533	7.3	13.6	7.02	7.9	1038	9	201
106	NN	79	1	63	0	518	6.5	11.4	4.53	6.1	1038	7	135
107	NN	79	2	62	0	503	5.5	10.9	3.49	6.7	852	7	110
108	NN	87	0	4	0	124	6.0	9.4	2.84	7.1	741	7	96
109	NN	87	0	8	0	124	6.0	12.2	5.43	7.9	741	10	170

SOUTH Survival Dataset:

OBS	PLOT	ALT	AGE1	MTD1	BA1	MTH1	SPH1	DBHQ	SDI
1	FR 102 5 3 1	250	7.1	16.5	16.69	8.7	1209	13	423
2	FR 102 5 3 3	250	7.1	14.6	13.21	8.5	1209	12	372
3	FR 102 5 3 6	250	7.1	13.9	12.61	8.2	1209	12	372
4	FR 102 6 1 1	0	9.1	27.7	38.61	14.7	944	23	826
5	SD 130 0 26 0	220	8.5	18.7	12.05	8.9	741	14	292
6	SD 170 0 24 0	214	5.0	10.5	3.57	5.1	978	7	127
7	SD 170 0 26 0	214	5.0	8.4	2.38	4.4	1018	5	77
8	SD 170 0 31 0	330	8.0	14.0	6.41	5.2	761	10	175
9	SD 170 0 32 0	330	7.0	13.8	6.85	5.6	800	10	184
10	SD 170 0 34 0	203	8.5	13.4	7.73	7.8	781	11	209
11	SD 170 0 35 0	200	8.5	13.3	11.35	9.0	1294	11	347
12	SD 170 0 36 0	360	8.5	10.9	4.46	5.4	741	9	144
13	SD 170 0 37 0	360	8.5	10.8	3.83	5.6	721	8	116
14	SD 170 0 38 0	360	8.5	13.7	6.87	7.4	741	11	198
15	SD 170 0 42 0	225	6.6	14.1	7.85	7.6	791	11	212
16	SD 170 0 43 0	231	6.6	11.8	4.15	5.8	860	8	138
17	SD 180 0 22 0	270	9.7	20.2	41.35	11.6	2370	15	1044
18	SD 180 0 23 0	230	11.7	24.4	45.68	13.4	1679	19	1081
19	SD 180 0 27 0	280	8.7	18.2	15.35	8.4	889	15	392
20	SD 180 0 28 0	457	8.6	14.4	7.70	7.9	721	12	222
21	SD 180 0 29 0	230	7.6	15.8	10.14	8.6	800	13	280
22	SD 180 0 41 0	548	9.0	13.4	6.67	6.3	788	10	181
23	SD 188 0 1 0	50	8.8	16.0	22.36	9.0	1926	12	593
24	SD 188 0 2 0	103	10.8	17.2	14.47	9.1	840	15	370
25	SD 190 0 39 0	220	6.1	13.1	17.52	6.7	2460	10	565
26	SD 419 0 1 0	365	8.1	14.1	6.82	.	775	11	208
27	SD 419 0 11 0	365	8.1	15.8	9.36	.	800	12	246
28	SD 419 0 12 0	365	8.1	13.8	5.69	.	700	10	161
29	SD 419 0 13 0	365	8.1	13.7	7.20	.	900	10	207
30	SD 419 0 14 0	365	8.1	13.0	5.91	.	800	10	184
31	SD 419 0 15 0	365	8.1	13.5	6.58	.	775	10	178
32	SD 419 0 16 0	365	8.1	13.2	5.58	.	725	10	167
33	SD 419 0 2 0	365	8.1	15.4	7.82	.	725	12	223
34	SD 419 0 3 0	365	8.1	13.5	7.22	.	875	10	201
35	SD 419 0 4 0	365	8.1	13.6	7.41	.	800	11	214
36	SD 419 0 5 0	365	8.1	14.9	9.91	.	1000	11	268
37	SD 419 0 6 0	365	8.1	14.8	6.99	.	750	11	201
38	SD 419 0 7 0	365	8.1	12.9	5.24	.	725	10	167
39	SD 419 0 8 0	365	8.1	12.2	3.81	.	725	8	116
40	SD 419 0 9 0	365	8.1	13.3	6.08	.	775	10	178
41	SD 448 2 1 0	200	8.2	15.2	16.31	7.5	2218	10	510
42	SD 448 2 2 0	200	8.2	13.3	6.34	7.5	772	10	177
43	SD 454 4 5 0	427	9.2	19.0	16.07	9.1	833	16	407
44	SD 454 4 6 0	427	9.2	16.3	12.55	8.4	917	13	321
45	SD 457 2 1 0	336	6.0	11.1	4.73	4.5	738	9	143
46	SD 457 2 4 0	336	6.0	11.0	4.11	5.5	725	8	116
47	SD 474 0 2 0	266	6.5	12.2	5.37	5.5	725	10	167
48	SD 474 0 6 0	266	6.5	12.1	5.92	5.5	800	10	184

49	SD	488	0	9	0	130	9.0	21.8	18.31	.	700	18	413
50	SD	532	0	12	0	300	9.3	10.8	5.36	.	950	8	153
51	SD	532	0	14	0	300	10.0	13.6	7.08	.	725	11	194
52	SD	532	0	15	0	300	9.3	10.9	4.73	.	875	8	141
53	SD	532	0	16	0	300	10.0	14.9	9.34	.	850	12	262
54	SD	532	0	17	0	300	10.0	14.7	8.66	.	875	11	234
55	SD	532	0	18	0	300	10.0	15.7	9.82	.	750	13	263
56	SD	532	0	19	0	300	10.0	15.4	9.26	.	750	13	263
57	SD	532	0	6	0	300	9.3	10.2	4.11	.	850	8	137
58	SD	532	0	8	0	300	10.0	13.8	6.92	.	775	11	208
59	SD	532	0	9	0	300	10.0	11.8	6.09	.	850	10	195
60	SD	564	2	3	51	200	13.6	34.0	44.37	.	721	28	865
61	SD	568	6	1	1	570	8.5	10.4	6.74	5.2	1475	8	237
62	SD	568	6	1	2	570	8.5	9.7	5.34	4.2	1325	7	172
63	SD	568	6	2	1	570	8.5	15.5	16.95	6.1	1725	11	462
64	SD	568	6	2	2	570	8.5	17.0	22.41	7.1	1700	13	595
65	SD	624	2	7	0	0	7.0	18.4	11.59	8.2	740	14	292
66	SD	624	2	8	0	0	7.0	16.3	10.45	7.8	860	12	265
67	SD	651	0	2	0	460	6.0	13.1	6.43	7.0	700	11	187
68	SD	651	0	4	0	460	6.0	14.0	7.61	7.8	700	12	216
69	SD	651	0	5	0	460	6.0	11.8	5.07	6.4	700	10	161
70	SD	651	0	6	0	460	6.0	11.2	4.57	5.8	710	9	138
71	SD	681	0	1	0	240	5.5	6.8	1.36	.	1375	4	73

CLAYS Survival Dataset:

OBS	PLOT	ALT	AGE1	MTD1	BA1	MTH1	SPH1	DBHQ	SDI
1	AK 286 1 1 0	91	6.1	13.4	9.40	7.9	1852	8	297
2	AK 286 1 2 0	91	6.1	12.8	8.57	8.1	2148	7	278
3	AK 286 1 3 0	91	6.1	11.9	7.18	6.9	1654	7	214
4	AK 286 1 4 0	91	6.1	14.8	8.59	7.8	2074	7	269
5	AK 286 1 5 0	91	6.1	12.6	6.29	7.5	1704	7	221
6	AK 286 1 6 0	91	6.1	11.8	7.10	7.5	2074	7	269
7	AK 286 2 1 0	91	6.1	15.8	17.72	10.2	1753	11	469
8	AK 286 2 2 0	91	6.1	18.9	18.32	10.7	1383	13	484
9	AK 286 2 3 0	91	6.1	18.4	20.90	11.3	1728	12	532
10	AK 286 2 4 0	91	6.1	16.2	17.75	9.7	1753	11	469
11	AK 286 2 5 0	91	6.1	16.8	15.94	10.3	1654	11	443
12	AK 286 2 6 0	91	6.1	17.1	18.71	10.6	1605	12	494
13	AK 286 2 7 0	91	6.1	17.0	14.63	10.6	1531	11	410
14	AK 286 3 1 0	76	7.0	16.8	20.28	.	1679	12	517
15	AK 286 3 2 0	76	7.0	17.5	22.25	.	1901	12	585
16	AK 286 3 3 0	76	7.0	15.1	15.85	.	1802	11	483
17	AK 286 3 4 0	76	7.0	15.4	16.57	.	1654	11	443
18	AK 286 3 5 0	76	7.0	15.4	15.74	.	1679	11	450
19	AK 286 3 6 0	76	7.0	17.7	23.35	.	1704	13	597
20	AK 286 3 7 0	76	7.0	15.9	13.93	.	1778	10	409
21	AK 286 4 1 0	122	5.2	14.4	12.08	7.4	1679	10	386
22	AK 286 4 2 0	122	5.2	14.6	12.70	7.1	1605	10	369
23	AK 286 4 3 0	122	5.2	13.7	11.62	7.1	1753	9	340
24	AK 286 4 4 0	122	5.2	14.6	11.40	8.8	1383	10	318
25	AK 286 4 5 0	122	5.2	13.4	12.44	7.2	1877	9	364
26	AK 286 4 6 0	122	5.2	13.6	13.68	8.4	2099	9	407
27	AK 286 4 7 0	122	5.2	15.2	17.03	7.7	2000	10	460
28	AK 286 4 8 0	122	5.2	14.6	15.46	9.2	2099	10	482
29	AK 286 6 1 0	91	6.5	7.1	1.67	4.4	1012	5	76
30	AK 286 6 10 0	91	6.5	7.7	1.46	4.5	1037	4	55
31	AK 286 6 11 0	91	6.5	6.3	0.99	4.1	938	4	50
32	AK 286 6 12 0	91	6.5	5.4	0.92	3.8	963	3	32
33	AK 286 6 13 0	91	6.5	7.1	1.75	4.5	1037	5	78
34	AK 286 6 14 0	91	6.5	6.9	1.34	4.3	1086	4	57
35	AK 286 6 15 0	91	6.5	4.1	0.49	2.9	1086	2	19
36	AK 286 6 16 0	91	6.5	4.7	0.92	3.5	1086	3	36
37	AK 286 6 17 0	91	6.5	6.4	1.40	4.4	1086	4	57
38	AK 286 6 18 0	91	6.5	6.6	1.34	4.4	1012	4	53
39	AK 286 6 19 0	91	6.5	4.8	0.58	3.3	889	3	30
40	AK 286 6 2 0	91	6.5	7.8	1.54	4.6	988	4	52
41	AK 286 6 20 0	91	6.5	5.6	0.84	4.0	988	3	33
42	AK 286 6 21 0	91	6.5	8.4	1.41	4.8	988	4	52
43	AK 286 6 22 0	91	6.5	5.7	0.85	3.8	914	3	30
44	AK 286 6 3 0	91	6.5	8.9	2.48	5.4	988	6	100
45	AK 286 6 4 0	91	6.5	7.5	1.60	4.8	1012	4	53
46	AK 286 6 5 0	91	6.5	5.2	0.95	3.6	1037	3	35
47	AK 286 6 6 0	91	6.5	7.1	0.76	4.6	864	3	29
48	AK 286 6 7 0	91	6.5	7.2	1.47	4.4	914	5	69

49	AK	286	6	8	0	91	6.5	7.5	1.20	4.5	1062	4	56
50	AK	286	6	9	0	91	6.5	8.1	1.90	4.9	1037	5	78
51	AK	401	0	10	0	30	8.7	20.9	28.64	14.9	1647	15	726
52	AK	401	0	11	0	30	8.7	17.7	26.48	15.0	2043	13	715
53	AK	401	0	6	0	30	8.7	18.8	24.80	16.3	1730	14	682
54	AK	734	1	1	1	122	8.0	11.6	7.28	8.3	1550	8	249
55	AK	734	1	1	2	122	8.0	12.6	10.67	8.6	2050	8	329
56	AK	734	1	1	3	122	8.0	12.9	11.78	8.9	2000	9	388
57	AK	734	1	1	4	122	8.0	11.6	8.24	6.6	2025	7	263
58	AK	734	1	1	5	122	8.0	11.2	7.26	6.5	1925	7	250
59	AK	734	1	1	6	122	8.0	11.2	7.55	7.6	2000	7	259
60	AK	734	1	1	7	122	8.0	12.5	6.17	7.2	1675	7	217
61	AK	734	1	2	1	122	8.0	12.4	6.87	8.1	1750	7	227
62	AK	734	1	2	2	122	8.0	10.2	4.14	6.7	1450	6	147
63	AK	734	1	2	3	122	8.0	11.0	9.79	7.3	2050	8	329
64	AK	734	1	2	4	122	8.0	10.7	7.26	6.6	1900	7	246
65	AK	734	1	2	5	122	8.0	11.9	6.31	8.1	1525	7	198
66	AK	734	1	2	6	122	8.0	12.6	6.01	9.5	1550	7	201
67	AK	734	1	2	7	122	8.0	10.8	6.32	7.3	1875	7	243
68	AK	734	1	3	1	122	8.0	12.6	3.88	8.4	1175	6	119
69	AK	734	1	3	2	122	8.0	8.5	3.70	6.5	1575	5	119
70	AK	734	1	3	3	122	8.0	9.9	6.00	7.4	2175	6	220
71	AK	734	1	3	4	122	8.0	10.1	5.28	8.0	1700	6	172
72	AK	734	1	3	5	122	8.0	11.9	8.09	9.6	1775	8	285
73	AK	734	1	3	6	122	8.0	10.7	6.34	8.1	1825	7	237
74	AK	734	1	3	7	122	8.0	8.9	2.85	6.2	1500	5	113
75	AK	734	2	1	0	91	4.5	6.2	1.05	.	1125	3	37
76	AK	734	2	1	1	91	4.5	9.1	2.44	.	1025	6	104
77	AK	734	2	1	2	91	4.5	6.7	1.66	.	1275	4	67
78	AK	734	2	1	3	91	4.5	5.0	0.91	.	1000	3	33
79	AK	734	2	1	4	91	4.5	5.7	1.15	.	1125	4	59
80	AK	734	2	1	5	91	4.5	7.5	1.82	.	1250	4	66
81	AK	734	2	1	6	91	4.5	8.1	1.86	.	1225	4	65
82	AK	734	2	1	7	91	4.5	9.6	2.53	.	1125	5	85
83	AK	734	2	1	8	91	4.5	7.7	1.99	.	1375	4	73
84	AK	734	2	1	9	91	4.5	8.0	2.26	.	1200	5	91
85	AK	734	2	10	0	91	4.5	5.4	0.91	.	1175	3	39
86	AK	734	2	2	1	91	4.5	7.2	1.35	.	975	4	51
87	AK	734	2	2	2	91	4.5	7.6	2.14	.	1075	5	81
88	AK	734	2	2	3	91	4.5	6.8	1.48	.	1100	4	58
89	AK	734	2	2	4	91	4.5	7.0	1.15	.	1025	4	54
90	AK	734	2	2	5	91	4.5	6.0	1.13	.	1000	4	53
91	AK	734	2	2	6	91	4.5	5.0	0.94	.	1150	3	38
92	AK	734	2	2	7	91	4.5	7.5	1.72	.	1050	5	79
93	AK	734	2	2	8	91	4.5	6.1	1.37	.	1300	4	69
94	AK	734	2	2	9	91	4.5	7.9	1.83	.	1025	5	77
95	AK	734	2	3	1	91	4.5	5.3	1.15	.	1300	3	43
96	AK	734	2	3	2	91	4.5	7.2	1.41	.	1025	4	54
97	AK	734	2	3	3	91	4.5	8.4	1.73	.	1200	4	63
98	AK	734	2	3	4	91	4.5	6.1	0.71	.	950	3	32
99	AK	734	2	3	5	91	4.5	8.1	1.75	.	975	5	74
100	AK	734	2	3	6	91	4.5	7.2	1.28	.	1000	4	53

101	AK	734	2	3	7	91	4.5	6.9	1.72	.	975	5	74
102	AK	734	2	3	8	91	4.5	7.4	1.63	.	1100	4	58
103	AK	734	2	3	9	91	4.5	4.6	0.83	.	1300	3	43
104	AK	734	3	2	1	152	4.6	12.0	6.13	.	1200	8	193
105	AK	734	3	2	8	152	4.6	10.6	4.75	.	1150	7	149
106	AK	734	3	2	9	152	4.6	10.3	4.36	.	1300	7	169
107	AK	734	3	3	1	152	4.6	8.1	3.43	.	1300	6	132
108	AK	734	3	3	2	152	4.6	8.6	2.43	.	875	6	89
109	AK	734	3	3	4	152	4.6	8.2	2.45	.	1425	5	108
110	AK	734	3	3	6	152	4.6	9.1	3.74	.	1325	6	134
111	CA	399	0	4	0	90	5.8	12.7	15.24	8.1	2257	9	438
112	CA	399	0	5	0	90	5.8	13.7	15.53	7.6	2405	9	467
113	CA	399	0	6	0	96	5.8	11.9	13.57	7.2	2471	8	397
114	CA	399	0	7	0	80	5.1	9.8	12.52	5.8	3526	7	457
115	CA	444	0	12	0	119	14.8	27.0	43.81	.	2050	16	1002
116	CA	444	0	17	0	52	12.8	28.1	35.30	19.0	1880	15	828
117	CA	934	0	2	0	133	6.0	11.7	9.02	8.8	1500	9	291
118	CA	934	0	4	0	133	6.0	15.7	11.89	9.0	1280	11	343
119	CA	934	0	9	0	133	6.0	11.3	7.25	8.0	1450	8	233
120	CA	992	0	1	2	133	8.9	18.9	17.20	11.9	1710	11	458
121	CA	992	0	1	4	133	9.1	18.3	17.08	12.2	1880	11	503
122	CA	992	0	2	2	133	10.0	21.0	16.10	15.6	1250	13	438
123	CA	992	0	2	4	133	9.0	19.0	21.72	14.7	1660	13	581
124	CA	992	0	3	2	133	9.0	14.3	11.22	10.0	1730	9	336
125	CA	992	0	3	4	133	9.1	16.6	18.11	12.4	2310	10	531
126	FR	105	0	2	0	200	5.5	14.4	11.44	7.6	1325	10	304
127	FR	105	0	5	0	200	5.5	14.2	14.67	8.3	1825	10	419
128	FR	105	0	9	0	200	5.5	13.7	7.44	8.7	1100	9	213
129	FR	68	2	1	0	250	4.2	10.1	6.01	4.8	1425	7	185
130	FR	68	2	10	0	250	4.2	7.4	2.25	3.9	1075	5	81
131	FR	68	2	11	0	250	4.2	7.8	2.43	4.3	975	6	99
132	FR	68	2	12	0	250	4.2	8.5	3.78	4.3	1450	6	147
133	FR	68	2	2	0	250	4.2	8.6	4.08	4.5	1450	6	147
134	FR	68	2	3	0	250	4.2	9.2	4.39	4.9	1275	7	165
135	FR	68	2	4	0	250	4.2	9.0	3.70	4.6	1450	6	147
136	FR	68	2	5	0	250	4.2	9.0	3.46	4.3	1250	6	127
137	FR	68	2	6	0	250	4.2	10.4	4.55	4.7	1475	6	149
138	FR	68	2	7	0	250	4.2	8.4	2.23	4.5	875	6	89
139	FR	68	2	8	0	250	4.2	9.0	2.95	4.6	825	7	107
140	FR	68	2	9	0	250	4.2	8.8	2.45	4.9	925	6	94

SANDS Survival Dataset:

OBS	PLOT	ALT	AGE1	MTD1	BA1	MTH1	SPH1	DBHQ	SDI
1	AK 1021 0 1 11	30	5.9	15.9	11.57	9.0	850	13	298
2	AK 1021 0 1 16	30	5.9	16.8	12.33	9.2	820	14	323
3	AK 1021 0 1 2	30	5.9	15.5	10.64	9.1	840	13	294
4	AK 1021 0 1 5	30	5.9	16.4	12.06	9.0	830	14	327
5	AK 1021 0 2 1	30	5.9	15.7	10.74	9.0	840	13	294
6	AK 1021 0 2 15	30	5.9	16.0	12.31	8.8	880	13	308
7	AK 1021 0 2 6	30	5.9	16.5	12.22	9.0	830	14	327
8	AK 1021 0 2 9	30	5.9	16.1	11.13	9.1	830	13	291
9	AK 1021 0 3 10	30	5.9	17.4	13.40	8.3	850	14	335
10	AK 1021 0 3 13	30	5.9	18.4	14.40	9.0	830	15	366
11	AK 1021 0 3 3	30	5.9	17.9	13.55	8.9	830	14	327
12	AK 1021 0 3 7	30	5.9	16.5	12.62	8.6	810	14	319
13	AK 1021 0 4 12	30	5.9	16.2	12.43	8.6	840	14	331
14	AK 1021 0 4 14	30	5.9	18.1	13.83	8.8	840	14	331
15	AK 1021 0 4 4	30	5.9	17.1	12.07	9.2	830	14	327
16	AK 1021 0 4 8	30	5.9	17.1	12.86	9.1	850	14	335
17	AK 1029 0 111 0	50	7.1	14.8	13.47	12.2	1300	11	348
18	AK 1029 0 112 0	50	7.1	17.1	19.05	11.1	1300	14	513
19	AK 1029 0 121 0	50	7.1	15.3	16.50	12.1	1375	12	423
20	AK 1029 0 122 0	50	7.1	19.5	24.69	11.5	1450	15	639
21	AK 1029 0 131 0	50	7.1	14.9	12.90	11.2	1250	11	335
22	AK 1029 0 132 0	50	7.1	18.1	19.26	11.2	1325	14	523
23	AK 1029 0 141 0	50	7.1	15.5	14.63	11.8	1350	12	416
24	AK 1029 0 142 0	50	7.1	19.4	20.44	11.8	1375	14	542
25	AK 1029 0 211 0	50	7.1	14.4	11.06	11.2	1250	11	335
26	AK 1029 0 212 0	50	7.1	17.2	19.27	11.8	1325	14	523
27	AK 1029 0 221 0	50	7.1	15.2	13.45	11.4	1250	12	385
28	AK 1029 0 222 0	50	7.1	18.3	17.33	12.8	1250	13	438
29	AK 1029 0 231 0	50	7.1	15.1	14.17	10.8	1250	12	385
30	AK 1029 0 232 0	50	7.1	18.1	19.89	11.5	1300	14	513
31	AK 1029 0 241 0	50	7.1	15.7	15.06	11.3	1275	12	393
32	AK 1029 0 242 0	50	7.1	19.9	23.66	11.3	1350	15	595
33	AK 1029 0 311 0	50	7.1	14.6	11.88	12.6	1250	11	335
34	AK 1029 0 312 0	50	7.1	18.2	19.97	11.9	1275	14	503
35	AK 1029 0 321 0	50	7.1	14.8	13.85	10.8	1275	12	393
36	AK 1029 0 322 0	50	7.1	19.6	19.53	12.6	1275	14	503
37	AK 1029 0 331 0	50	7.1	15.7	15.18	11.0	1325	12	408
38	AK 1029 0 332 0	50	7.1	18.5	20.42	11.6	1300	14	513
39	AK 1029 0 341 0	50	7.1	17.1	16.18	12.0	1275	13	446
40	AK 1029 0 342 0	50	7.1	19.4	19.48	10.7	1250	14	493
41	AK 1029 0 41 0	50	7.1	15.6	14.38	9.5	1250	12	385
42	AK 1029 0 42 0	50	7.1	16.5	14.01	10.2	1300	12	400
43	AK 1029 0 43 0	50	7.1	16.0	14.99	10.4	1250	12	385
44	AK 1029 0 51 0	50	7.1	17.0	15.60	10.1	1275	12	393
45	AK 1029 0 52 0	50	7.1	15.2	13.93	10.5	1250	12	385
46	AK 1029 0 53 0	50	7.1	17.3	16.17	11.2	1300	13	455
47	AK 287 0 1 3	60	5.0	11.3	8.56	6.3	1432	9	278
48	AK 287 0 1 4	60	5.0	11.3	10.93	6.2	2173	8	349

49	AK	287	0	2	1	60	5.0	11.4	9.04	5.7	2222	7	288
50	AK	287	0	2	4	60	5.0	11.7	6.60	5.6	1309	8	210
51	AK	287	0	3	2	60	5.0	10.7	7.35	5.7	1481	8	238
52	AK	287	0	3	4	60	5.0	12.5	11.42	6.0	2198	8	353
53	AK	287	0	4	2	60	5.0	9.5	4.71	4.8	1481	6	150
54	AK	287	0	4	3	60	5.0	10.2	7.35	5.7	2173	7	282
55	AK	287	0	5	2	60	5.0	11.0	10.14	6.5	2247	8	361
56	AK	287	0	5	4	60	5.0	10.8	8.83	6.3	1481	9	287
57	AK	287	0	6	1	60	5.0	11.9	6.50	6.1	1333	8	214
58	AK	287	0	6	3	60	5.0	12.0	9.87	6.2	1877	8	301
59	AK	287	0	7	1	60	5.0	12.1	6.56	5.9	1383	8	222
60	AK	287	0	7	4	60	5.0	11.3	7.72	6.2	2000	7	259
61	AK	287	0	8	2	60	5.0	12.7	8.19	6.0	1457	8	234
62	AK	287	0	8	4	60	5.0	11.5	8.41	6.2	2198	7	285
63	AK	287	0	9	2	60	5.0	10.9	7.61	.	1457	8	234
64	AK	287	0	9	4	0	5.0	11.2	8.79	.	2222	7	288
65	AK	520	1	1	0	18	6.8	13.4	10.05	7.1	1580	9	307
66	AK	520	1	2	0	18	6.8	13.8	12.09	6.4	1556	10	358
67	AK	520	1	3	0	18	8.8	12.6	11.95	5.9	1802	9	350
68	AK	520	1	4	0	18	8.8	13.9	17.51	6.9	2025	10	465
69	AK	520	5	3	0	18	7.8	15.5	9.10	6.9	1133	10	260
70	AK	520	5	9	0	18	8.8	20.6	30.34	10.0	1683	15	741
71	AK	520	6	1	0	45	4.8	7.6	2.09	4.4	1425	4	75
72	AK	520	6	3	0	10	4.7	4.8	0.51	2.6	1075	2	19
73	AK	520	6	4	0	25	7.7	17.2	23.23	8.6	1800	13	630
74	AK	520	6	6	0	15	7.7	14.5	14.72	7.2	1900	10	437
75	AK	520	6	7	0	15	7.5	16.8	17.14	9.8	1625	12	500
76	AK	830	1	1	0	46	5.6	11.4	5.67	7.3	822	9	160
77	AK	830	1	10	0	46	5.6	12.9	7.76	8.8	878	11	235
78	AK	830	1	11	0	46	5.6	13.1	7.79	8.2	889	11	238
79	AK	830	1	12	0	46	5.6	13.2	8.67	8.4	911	11	244
80	AK	830	1	2	0	46	5.6	12.9	6.79	8.2	867	10	199
81	AK	830	1	4	0	46	5.6	12.5	6.34	8.6	778	10	179
82	AK	830	1	9	0	46	5.6	12.7	6.96	8.6	844	10	194
83	AK	864	1	1	0	150	9.1	23.0	29.53	.	1075	19	692
84	AK	864	1	10	0	150	9.1	20.1	36.03	.	1975	15	870
85	AK	864	1	11	0	150	9.1	22.6	25.50	.	925	19	595
86	AK	864	1	12	0	150	9.1	23.2	32.64	.	1175	19	756
87	AK	864	1	13	0	150	9.1	20.3	24.84	16.5	1200	16	586
88	AK	864	1	14	0	150	9.1	21.4	25.85	.	1100	17	592
89	AK	864	1	15	0	150	9.1	22.5	28.17	.	1150	18	679
90	AK	864	1	16	0	150	9.1	19.1	29.01	16.3	1750	15	771
91	AK	864	1	17	0	150	9.1	21.5	33.45	.	1425	17	767
92	AK	864	1	18	0	150	9.1	21.0	37.60	.	2000	15	881
93	AK	864	1	2	0	150	9.1	20.6	32.66	.	1525	17	821
94	AK	864	1	3	0	150	9.1	19.9	27.96	.	1650	15	727
95	AK	864	1	4	0	150	9.1	22.0	32.61	.	1425	17	767
96	AK	864	1	5	0	150	9.1	19.6	31.93	.	1875	15	826
97	AK	864	1	6	0	150	9.1	22.3	31.28	.	1200	18	708
98	AK	864	1	7	0	150	9.1	19.6	28.85	.	1550	15	683
99	AK	864	1	8	0	150	9.1	20.5	28.79	.	1325	17	714
100	AK	864	1	9	0	150	9.1	20.3	28.55	.	1525	15	672

101	AK	864	2	1	0	150	9.1	18.4	29.57	16.9	1700	15	749
102	AK	864	2	10	0	150	9.1	21.0	23.61	.	950	18	561
103	AK	864	2	11	0	150	9.1	19.4	30.24	.	1625	15	716
104	AK	864	2	12	0	150	9.1	21.8	28.53	.	1400	16	684
105	AK	864	2	13	0	150	9.1	20.2	20.57	.	950	17	512
106	AK	864	2	14	0	150	9.1	21.0	26.98	.	1525	15	672
107	AK	864	2	15	0	150	9.1	22.0	23.38	.	975	17	525
108	AK	864	2	16	0	150	9.1	22.7	24.71	.	1075	17	579
109	AK	864	2	17	0	150	9.1	20.6	29.34	.	1625	15	716
110	AK	864	2	18	0	150	9.1	20.6	27.61	.	1375	16	672
111	AK	864	2	2	0	150	9.1	20.5	19.95	.	900	17	485
112	AK	864	2	3	0	150	9.1	21.3	28.92	16.4	1325	17	714
113	AK	864	2	4	0	150	9.1	19.9	21.87	.	1325	14	523
114	AK	864	2	5	0	150	9.1	22.0	25.41	.	1050	18	620
115	AK	864	2	6	0	150	9.1	22.8	27.12	.	1225	17	660
116	AK	864	2	7	0	150	9.1	22.0	26.93	.	1200	17	646
117	AK	864	2	8	0	150	9.1	23.0	26.75	.	1125	17	606
118	AK	864	2	9	0	150	9.1	21.9	29.85	.	1300	17	700
119	AK	898	1	1	0	55	4.7	11.5	10.82	7.6	1750	9	340
120	AK	898	1	16	0	55	4.7	10.7	6.10	5.5	1475	7	191
121	AK	898	2	11	0	60	4.7	11.7	10.67	6.5	1850	9	359
122	AK	898	2	5	0	60	4.7	8.5	3.70	4.6	1575	5	119
123	AK	898	2	7	0	60	4.7	9.2	6.35	5.0	1975	6	200
124	AK	898	3	1	0	60	4.8	9.5	7.65	6.7	2100	7	272
125	AK	898	3	11	0	60	4.8	9.2	6.21	5.3	2225	6	225
126	AK	898	3	12	0	60	4.8	9.2	5.44	5.4	2150	6	218
127	AK	898	3	16	0	60	4.8	9.2	5.31	5.7	1825	6	185
128	AK	898	3	5	0	60	4.8	9.3	7.31	6.1	1950	7	253
129	AK	911	0	1	2	50	5.0	12.9	11.80	6.5	1600	10	368
130	AK	911	0	1	5	50	5.0	11.9	10.94	6.3	1725	9	335
131	AK	911	0	1	6	50	5.0	11.8	10.95	6.4	1500	10	345
132	AK	911	0	1	8	50	5.0	12.8	9.67	7.0	1350	10	310
133	AK	911	0	2	11	50	5.0	12.2	10.09	5.9	1450	9	281
134	AK	911	0	2	12	50	5.0	13.0	10.51	5.9	1425	10	327
135	AK	911	0	2	15	50	5.0	11.9	10.22	5.9	1625	9	315
136	AK	911	0	3	19	50	5.0	12.3	10.42	5.8	1450	10	333
137	AK	911	0	3	21	50	5.0	12.9	9.98	6.0	1550	9	301
138	AK	911	0	3	23	50	5.0	14.6	16.37	6.4	1850	11	495
139	AK	911	0	3	24	50	5.0	13.4	13.15	6.4	1575	10	362
140	AK	977	0	10	1	30	5.0	8.6	2.56	4.9	1100	5	83
141	AK	977	0	11	1	30	5.0	7.5	2.22	.	1075	5	81
142	AK	977	0	12	1	30	5.0	10.8	5.39	6.7	1575	7	204
143	AK	977	0	13	1	30	5.0	7.2	1.53	3.9	1100	4	58
144	AK	977	0	14	1	30	5.0	9.1	2.79	5.8	1250	5	94
145	AK	977	0	15	1	30	5.0	8.1	2.26	6.1	1125	5	85
146	AK	977	0	16	1	30	5.0	6.7	1.76	4.0	1000	5	76
147	AK	977	0	33	1	30	5.0	11.8	8.40	7.5	1925	7	250
148	AK	977	0	34	1	30	5.0	11.6	6.45	7.6	1450	8	233
149	AK	977	0	35	1	30	5.0	11.7	10.01	7.1	1900	8	305
150	AK	977	0	36	1	30	5.0	11.1	10.27	7.0	2075	8	333
151	AK	977	0	9	1	30	5.0	10.0	5.48	6.0	1475	7	191
152	CA	383	0	10	0	15	5.5	12.8	13.39	6.6	2123	9	412

153	CA	383	0	6	0	15	5.5	14.3	16.15	7.4	1975	10	454
154	CA	383	0	7	0	15	5.5	13.9	13.81	7.5	1802	10	414
155	CA	383	0	8	0	15	5.5	14.0	15.45	8.0	1926	10	443
156	CA	383	0	9	0	15	5.5	14.1	13.96	7.4	1827	10	420
157	CA	428	0	10	0	40	8.6	19.8	27.80	13.9	1580	15	696
158	CA	428	0	18	0	40	8.6	20.6	21.78	14.1	1350	14	532
159	CA	724	0	1	3	100	5.5	14.7	14.91	8.0	1375	12	423
160	CA	724	0	2	3	100	9.0	20.4	28.92	13.3	1300	17	700
161	CA	724	0	3	3	100	5.5	13.7	11.78	7.7	1400	10	322
162	CA	724	0	4	3	100	5.5	13.1	10.97	8.4	1550	9	301
163	CA	724	0	5	3	100	5.5	14.6	13.90	8.7	1350	11	361
164	WN	1300	1	103	2	15	8.5	15.4	15.84	8.4	1802	11	483
165	WN	1300	1	113	3	15	7.5	12.2	7.48	7.1	1432	8	230
166	WN	276	0	1	1	15	19.2	31.9	39.43	25.4	850	24	796
167	WN	276	0	1	2	15	19.2	30.9	36.88	24.1	900	23	787
168	WN	276	0	1	3	15	19.2	31.7	39.62	25.6	1050	22	855
169	WN	276	0	1	4	17	19.2	30.1	46.63	24.0	1325	21	1002
170	WN	276	0	2	5	15	19.2	29.2	39.95	25.2	975	23	853
171	WN	276	0	2	6	15	19.2	30.3	50.09	25.2	1550	20	1083
172	WN	276	0	2	7	20	19.2	28.7	39.28	25.1	1175	21	888
173	WN	276	0	2	8	22	19.2	28.6	33.22	20.2	900	22	733
174	WN	276	0	3	10	15	19.2	28.7	47.01	24.1	1300	21	983
175	WN	276	0	3	11	18	19.2	29.0	47.36	23.5	1300	22	1059
176	WN	276	0	3	12	20	19.2	28.2	38.36	23.8	975	22	794
177	WN	276	0	3	9	15	19.2	31.5	45.90	24.7	1150	23	1006
178	WN	301	0	2	0	122	5.0	15.0	18.23	7.5	1767	11	473
179	WN	301	0	6	0	122	5.0	16.3	17.78	7.6	1467	12	452
180	WN	301	0	9	0	122	5.0	16.3	20.78	7.7	1967	12	606

HBAY Survival Dataset:

OBS	PLOT	ALT	AGE1	MTD1	BA1	MTH1	SPH1	DBHQ	SDI
1	FR 10 0 52 18	500	4.8	18.5	16.13	.	847	16	414
2	FR 10 0 53 18	500	4.8	16.8	14.30	.	903	14	356
3	FR 10 0 54 28	500	4.8	18.4	17.82	.	944	16	461
4	FR 121 3 18 16	410	5.6	15.7	10.38	7.8	860	12	265
5	FR 121 3 19 16	410	5.6	16.9	12.98	8.1	940	13	329
6	FR 121 3 20 16	410	5.6	16.6	11.24	7.9	740	14	292
7	FR 166 6 6 1	305	5.0	16.8	16.33	7.9	1070	14	422
8	FR 166 6 6 12	305	5.0	17.9	15.47	8.1	900	15	396
9	FR 166 6 6 14	305	5.0	17.9	16.51	8.6	910	15	401
10	RO 1125 0 0 0	299	10.0	29.3	35.14	17.2	790	24	740
11	RO 1132 2 2 0	165	5.0	13.5	8.59	8.5	957	11	256
12	RO 1141 4 10 0	436	5.3	15.0	11.66	7.9	988	12	304
13	RO 1141 4 9 0	427	5.3	14.8	11.46	7.5	988	12	304
14	RO 1141 5 11 0	454	5.3	16.2	27.53	7.9	2342	12	721
15	RO 1141 5 12 0	457	5.3	15.5	21.91	7.5	2125	11	569
16	RO 1187 3 3 0	410	16.0	35.7	77.12	24.5	1621	25	1621
17	WN 1100 1 200 1	488	7.7	19.1	27.99	8.9	2198	13	770
18	WN 1100 1 210 1	503	13.5	28.0	33.86	16.5	860	22	701
19	WN 1100 1 216 1	518	6.8	15.0	9.29	8.3	820	12	252
20	WN 1150 1 53 1	280	5.9	12.4	5.77	6.0	751	10	173
21	WN 1150 1 57 1	207	4.9	10.3	4.19	5.5	899	8	144
22	WN 216 0 1 1	488	11.1	24.1	56.44	16.0	2916	16	1425
23	WN 216 0 1 2	488	11.1	26.1	66.29	16.8	2537	18	1498
24	WN 225 0 4 0	335	6.0	12.8	11.03	7.2	1746	9	339
25	WN 225 0 5 0	335	6.0	12.1	13.29	7.2	2059	9	400
26	WN 225 0 6 0	335	6.0	10.7	7.91	7.6	2273	7	295
27	WN 226 0 11 0	518	5.3	11.0	9.33	5.6	1862	8	299
28	WN 226 0 12 0	518	5.3	10.4	9.15	5.2	2224	7	288
29	WN 226 0 13 0	518	5.3	9.2	8.11	5.3	2339	7	303
30	WN 226 0 15 0	518	5.3	8.6	7.09	5.0	2488	6	252
31	WN 226 0 16 0	518	5.3	8.4	2.76	5.1	791	7	103
32	WN 226 0 2 0	518	5.3	9.6	8.60	5.5	2125	7	275
33	WN 226 0 3 0	518	5.3	8.7	7.59	4.9	2438	6	247
34	WN 226 0 5 0	518	5.3	9.0	6.92	4.8	2175	6	220
35	WN 226 0 6 0	518	5.3	10.5	9.97	5.8	2339	7	303
36	WN 226 0 7 0	518	5.3	10.9	11.46	5.3	2372	8	381
37	WN 312 1 14 2	335	14.0	28.8	58.33	21.9	1700	21	1285
38	WN 312 1 22 1	341	8.0	21.9	47.29	10.5	2569	15	1132
39	WN 312 1 55 1	305	5.3	14.1	17.64	8.0	2292	10	527
40	WN 313 1 201 4	503	10.0	27.1	43.19	14.9	1443	20	1009
41	WN 313 1 27 4	506	10.0	25.1	51.88	13.5	2243	17	1208
42	WN 314 1 25 4	390	10.8	26.2	50.99	15.6	2026	18	1196
43	WN 314 1 57 1	390	8.0	23.0	42.72	13.6	1877	17	1011
44	WN 354 0 15 0	860	5.1	8.3	3.45	4.2	1247	6	126
45	WN 354 0 18 0	780	5.1	9.8	7.36	5.4	1696	7	220
46	WN 354 0 9 0	845	5.1	8.3	3.94	4.2	1550	6	157
47	WN 364 1 1 0	850	7.0	13.2	12.84	5.7	1521	10	350
48	WN 364 2 7 0	800	7.0	12.3	11.35	6.0	1571	10	361

49	WN	364	3	9	0	760	5.0	12.4	9.09	5.8	1397	9	271
50	WN	364	4	7	0	240	5.0	18.6	14.63	8.5	898	14	354
51	WN	364	5	2	0	213	5.0	16.5	23.16	8.8	1596	14	629
52	WN	369	0	17	0	220	5.0	8.0	2.74	3.2	1025	6	104
53	WN	369	0	19	0	230	7.0	18.3	14.03	9.7	786	15	346
54	WN	379	0	14	0	400	12.0	32.3	47.55	20.1	912	26	971
55	WN	379	0	24	0	400	12.0	33.1	44.04	19.8	864	25	864
56	WN	379	0	6	0	400	12.0	33.0	50.70	19.8	912	27	1032

CNI Survival Dataset:

OBS	PLOT	ALT	AGE1	MTD1	BA1	MTH1	SPH1	DBHQ	SDI
1	AK 953 0 6 0	40	9.1	22.7	28.27	12.1	1380	16	674
2	FR 121 2 25 17	295	4.8	14.5	10.21	7.7	1000	11	268
3	FR 121 2 26 17	295	4.8	13.7	8.73	7.8	940	11	252
4	FR 121 2 27 17	295	4.8	15.3	11.41	8.2	960	12	296
5	FR 121 2 28 17	295	4.8	17.0	12.60	9.2	980	13	343
6	FR 121 2 29 17	295	4.8	15.4	11.90	8.2	980	12	302
7	FR 121 6 20 17	60	4.9	13.7	9.05	7.7	940	11	252
8	FR 121 6 21 17	60	4.9	13.7	8.18	7.7	940	11	252
9	FR 121 6 23 17	60	4.9	13.3	8.85	8.0	980	11	262
10	FR 121 6 24 17	60	4.9	13.3	8.41	7.9	920	11	246
11	FR 121 6 25 17	60	4.9	13.0	8.31	7.3	960	10	221
12	FR 40 0 4 0	320	4.7	11.5	5.00	7.0	1025	8	165
13	FR 40 0 6 0	320	4.7	10.3	4.09	6.9	825	8	133
14	FR 40 0 7 0	320	4.7	10.1	4.88	6.8	1175	7	152
15	FR 40 0 8 0	320	4.7	10.7	4.36	6.2	1125	7	146
16	FR 40 0 9 0	320	4.7	11.1	4.48	6.4	825	8	133
17	FR 85 0 13 12	553	4.7	13.6	7.28	7.7	822	11	220
18	FR 85 0 14 12	553	4.7	11.2	4.26	6.5	789	8	127
19	FR 85 0 15 12	553	4.7	11.0	4.17	6.6	779	8	125
20	FR 85 0 16 12	553	4.7	14.2	8.15	8.4	789	11	211
21	FR 85 0 17 22	553	4.7	14.1	8.04	8.6	811	11	217
22	FR 85 0 22 22	553	4.7	14.4	8.58	9.2	822	12	253
23	FR 85 0 23 22	553	4.7	14.6	8.28	8.5	811	11	217
24	FR 85 0 25 22	553	4.7	13.6	7.15	8.4	877	10	202
25	FR 85 0 27 22	553	4.7	14.1	7.82	8.2	822	11	220
26	FR 85 0 31 22	553	4.7	13.4	7.53	7.9	844	11	226
27	FR 85 0 5 12	553	4.7	12.8	5.42	7.1	833	9	162
28	FR 85 0 6 12	553	4.7	13.5	6.93	7.8	844	10	194
29	RO 1 0 12 0	282	10.3	29.2	24.93	19.7	838	19	539
30	RO 1 0 14 0	162	13.1	28.6	33.06	23.8	888	22	723
31	RO 1 0 15 0	195	10.1	27.1	30.40	19.1	1050	19	676
32	RO 1 0 217 0	500	8.1	23.6	24.18	12.3	930	18	549
33	RO 1 0 218 0	400	8.1	21.5	32.65	12.7	2180	14	860
34	RO 1 0 25 0	195	8.0	23.0	21.93	14.6	950	17	512
35	RO 1 0 26 0	396	6.0	19.0	13.86	9.6	850	14	335
36	RO 1 0 27 0	408	6.0	15.8	10.31	8.1	800	13	280
37	RO 1 0 9 0	111	10.2	23.2	31.21	18.5	1338	17	721
38	RO 1029 2 90 0	590	5.0	15.9	20.04	7.3	2010	11	538
39	RO 1029 2 91 0	590	5.0	16.0	20.49	7.5	1850	12	570
40	RO 1070 1 6 0	210	5.0	10.7	5.27	5.5	1104	8	177
41	RO 1070 1 7 0	210	5.0	11.6	6.02	6.0	1269	8	204
42	RO 1070 1 8 0	210	5.0	12.2	7.61	6.3	1219	9	237
43	RO 1083 1 5 0	610	11.0	23.2	48.56	18.4	2925	15	1289
44	RO 1083 1 6 0	610	9.0	20.0	39.44	14.1	2975	13	1042
45	RO 1083 1 7 0	610	5.3	11.9	12.72	6.4	2775	8	446
46	RO 1083 2 11 0	671	6.3	11.5	10.71	6.4	2500	7	324
47	RO 1083 2 12 0	671	6.3	11.4	12.40	6.3	2725	8	438

48	RO	1083	2	19	0	671	6.3	11.4	10.80	6.5	2275	8	365
49	RO	1083	2	6	0	671	6.3	12.0	14.31	6.8	2900	8	466
50	RO	1085	2	1	0	0	12.0	23.9	46.71	.	2850	14	1124
51	RO	1825	1	1	1	457	5.0	10.6	5.06	6.0	939	8	151
52	RO	1825	1	1	3	457	5.0	10.4	4.32	5.9	939	8	151
53	RO	1825	1	10	1	457	7.0	19.5	27.10	11.0	1746	14	689
54	RO	1825	1	10	2	457	7.0	18.0	24.04	10.6	1829	13	640
55	RO	1825	1	10	3	457	7.0	17.9	23.13	10.0	1779	13	623
56	RO	1825	1	2	2	457	5.0	10.3	4.52	6.0	840	8	135
57	RO	1825	1	2	3	457	5.0	10.2	4.37	6.0	840	8	135
58	RO	1825	1	2	4	457	5.0	9.7	4.11	5.6	840	8	135
59	RO	1867	3	10	0	190	5.8	16.5	11.46	8.9	940	12	289
60	RO	1867	3	4	0	190	7.1	25.0	31.87	14.2	1120	19	721
61	RO	1867	3	6	0	190	5.8	17.2	21.44	9.6	1480	14	584
62	RO	1867	3	9	0	170	5.8	18.4	18.62	10.6	1240	14	489
63	RO	2082	0	18	4	500	4.8	11.3	5.90	6.8	1033	9	200
64	RO	2082	0	19	4	500	4.8	12.4	7.08	7.6	1017	9	197
65	RO	2082	0	20	1	500	4.8	11.8	6.69	7.1	1183	8	190
66	RO	2082	0	21	1	500	4.8	10.7	5.01	6.1	1050	8	169
67	RO	2082	0	24	3	500	4.8	9.0	3.73	5.4	1067	7	138
68	RO	2082	0	27	4	500	4.8	11.9	5.76	6.7	917	9	178
69	RO	231	2	17	0	396	5.0	6.7	3.19	3.4	1481	5	112
70	RO	231	2	2	0	396	5.0	9.8	8.15	4.9	2321	7	301
71	RO	231	3	1	0	558	5.0	5.8	1.91	3.3	1496	4	79
72	RO	231	3	11	0	558	5.0	7.0	3.74	3.2	2979	4	157
73	RO	231	3	14	0	558	7.0	13.7	12.71	8.3	1582	10	364
74	RO	231	3	2	0	558	5.0	5.8	2.16	3.1	2274	3	76
75	RO	231	3	3	0	558	9.7	19.5	18.43	11.9	1298	13	454
76	RO	395	1	1	0	120	5.1	16.3	14.22	9.9	1120	13	392
77	RO	395	1	10	0	120	5.1	16.1	18.98	9.3	2043	11	547
78	RO	395	1	11	0	120	5.1	15.1	17.59	9.9	1960	11	525
79	RO	395	1	2	0	120	5.1	16.9	14.67	10.0	1104	13	387
80	RO	395	1	3	0	120	5.1	17.0	15.55	10.7	1120	13	392
81	RO	487	0	0	0	494	4.9	11.4	9.80	6.9	2630	7	341
82	RO	680	0	10	0	542	8.0	20.9	19.53	11.1	1481	13	519
83	RO	680	0	11	0	542	8.0	16.8	19.31	10.5	1556	13	545
84	RO	680	0	12	0	542	8.0	17.8	17.16	11.4	1481	12	456
85	RO	680	0	17	0	542	8.0	15.0	15.35	10.6	1679	11	450
86	RO	680	0	18	0	542	7.0	14.7	9.88	8.4	1481	9	287
87	RO	680	0	19	0	542	7.0	17.6	13.54	9.6	1481	11	397
88	RO	680	0	20	0	542	8.0	20.8	18.03	11.2	1506	12	464
89	RO	680	0	29	0	542	8.3	16.7	15.91	10.4	1481	12	456
90	RO	680	0	30	0	542	7.3	14.5	11.49	9.4	1333	10	306
91	RO	680	0	31	0	542	7.0	14.7	9.06	9.2	1037	11	278
92	RO	680	0	32	0	542	8.0	17.8	14.83	10.6	1432	11	383
93	RO	680	0	5	0	542	9.0	21.7	22.54	13.1	1481	14	584
94	RO	680	0	6	0	542	9.0	19.1	18.56	13.2	1481	13	519
95	RO	680	0	7	0	542	9.0	20.6	19.37	13.0	1556	13	545
96	RO	680	0	8	0	542	9.0	18.2	20.02	12.8	1457	13	510
97	RO	680	0	9	0	542	8.0	15.5	16.23	10.0	1481	12	456
98	RO	681	0	13	0	421	6.1	14.0	11.81	8.6	1481	10	340
99	RO	681	0	14	0	421	6.1	12.8	11.56	8.6	1481	10	340

100	RO	681	0	15	0	421	6.3	13.6	12.48	8.6	1481	10	340
101	RO	681	0	16	0	421	6.2	15.5	13.36	7.9	1481	11	397
102	RO	681	0	5	0	436	6.1	13.8	11.54	8.0	1481	10	340
103	RO	681	0	6	0	436	6.1	14.0	10.34	7.4	1481	9	287
104	RO	681	0	7	0	436	6.2	15.4	14.47	8.1	1481	11	397
105	RO	681	0	8	0	436	6.2	14.5	11.38	8.3	1481	10	340
106	RO	695	7	25	0	433	8.1	15.7	13.01	9.3	1374	11	368
107	RO	695	7	26	0	433	8.1	15.8	11.56	9.6	1107	12	341
108	RO	695	7	27	0	433	8.1	16.8	14.61	10.3	1433	11	384
109	RO	695	7	28	0	433	8.1	17.6	13.16	10.1	1235	12	380
110	RO	699	5	1	0	454	4.2	6.0	0.91	3.5	998	3	33
111	RO	699	5	11	0	454	4.3	6.7	1.18	4.0	988	4	52
112	RO	699	5	17	0	454	4.3	7.5	1.79	4.2	988	5	75
113	RO	704	0	0	0	445	6.5	16.1	14.31	9.9	1557	11	417
114	RO	705	0	0	0	457	6.3	14.2	12.38	8.4	1520	10	349
115	RO	706	0	0	0	536	6.0	13.5	9.94	9.4	1780	8	286
116	RO	707	0	0	0	570	6.5	11.0	10.01	8.9	2472	7	320
117	RO	710	0	0	0	500	6.6	12.7	12.45	9.8	2151	9	417
118	RO	723	0	0	0	488	7.0	15.2	9.18	7.4	1028	11	275
119	RO	730	0	0	0	725	8.6	15.4	17.01	8.0	1611	12	496
120	RO	731	0	0	0	704	8.6	16.0	17.43	8.2	1512	12	466
121	RO	787	0	2	0	417	15.6	30.6	36.03	25.6	1180	20	825
122	RO	787	0	3	0	417	15.7	25.7	43.56	23.8	1740	18	1027
123	RO	790	0	1	0	433	7.7	16.0	22.54	13.0	2260	11	605
124	RO	790	0	2	0	445	7.7	19.2	34.66	15.0	2767	13	969
125	RO	790	0	3	0	439	7.7	19.0	33.21	14.2	2550	13	893
126	RO	896	0	0	2	250	5.3	13.8	8.58	7.9	1320	9	256
127	RO	911	1	10	0	366	7.1	20.2	33.01	10.9	1939	15	854
128	RO	911	1	9	0	366	6.3	16.3	24.33	9.5	1828	13	640
129	RO	912	0	1	0	366	21.0	43.3	59.70	31.9	900	29	1142
130	RO	912	0	1	1	366	4.3	7.1	2.43	4.3	1597	4	84
131	RO	955	4	10	0	183	6.3	15.6	16.07	.	1334	12	411
132	RO	955	4	11	0	183	6.3	16.3	16.99	.	1334	13	467
133	RO	955	4	13	0	183	12.0	24.7	47.59	23.8	2570	15	1132
134	RO	955	4	14	0	183	6.3	15.9	17.57	.	1334	13	467
135	RO	955	4	15	0	183	14.0	26.5	58.20	27.0	2916	16	1425
136	RO	955	4	16	0	183	6.3	15.6	17.05	.	1334	13	467
137	RO	955	4	18	0	183	6.3	16.1	17.58	.	1334	13	467
138	RO	955	4	19	0	183	6.3	16.1	17.95	.	1334	13	467
139	RO	955	4	20	0	183	6.3	15.2	16.88	.	1334	13	467
140	RO	955	4	5	0	183	12.0	24.3	46.69	23.7	2751	15	1212
141	RO	955	4	6	0	183	6.3	16.0	18.09	.	1351	13	473
142	RO	955	4	7	0	183	6.3	17.3	18.43	.	1351	13	473
143	RO	955	6	11	0	183	6.3	17.6	37.79	12.2	2702	13	946
144	RO	955	6	18	0	183	6.3	17.3	21.08	.	1334	14	526
145	RO	955	6	2	0	183	6.3	18.8	23.09	.	1334	15	588
146	RO	955	6	20	0	183	6.3	20.0	35.67	12.1	2669	13	934
147	RO	955	6	4	0	183	6.3	19.9	24.22	.	1334	15	588
148	RO	955	6	9	0	183	6.3	17.4	36.43	12.0	2471	14	974
149	RO	955	7	1	0	183	6.5	19.3	22.15	12.9	1334	15	588
150	RO	955	7	13	0	183	6.5	19.8	22.32	11.7	1334	15	588
151	RO	955	7	17	0	183	7.0	20.7	20.86	13.2	988	16	483

152	RO	955	7	18	0	183	6.3	19.8	31.03	12.2	2125	14	838
153	RO	955	7	19	0	183	7.0	22.5	21.16	12.6	988	17	532
154	RO	955	7	25	0	183	6.3	17.5	34.23	11.9	2619	13	917
155	RO	955	7	9	0	183	6.3	20.4	30.96	11.3	1845	15	813
156	RO	955	9	13	0	183	6.3	20.7	23.73	11.6	1384	15	610
157	RO	955	9	15	0	183	6.3	20.1	28.53	11.7	1565	15	689
158	RO	955	9	17	0	183	6.3	18.7	24.68	11.7	1697	14	669
159	WN	363	0	28	0	770	6.0	14.7	10.46	7.1	823	13	288

APPENDIX 2: CHANGE IN POTENTIAL DIAMETER (chg_pdbh)

Basic Function: $MTD = \exp(a_0 + a_1 \times age^{a2})$

where:

- MTD = stand mean top diameter (cm),
- exp(x) = e^x, e is the base of the natural logarithm
- age = plantation age (years).

Algebraic Difference Formulation - Polymorphic

- Isolate a_2: let shape parameter be site-specific
- Equate MTD and age at time1 and time2
- Solve for MTD @ time2: f(age @ time2, MTD and age @ time1)

$$MTD_2 = \exp\{ a_0 + a_1 \times \exp\{ \ln [\frac{[\ln(MTD_1) - a_0]}{a_1}] \times [\frac{\ln(age_2)}{\ln(age_1)}] \} \}$$

where:

- MTD_1, MTD_2 = stand mean top diameter at time1 and time2
- age_1, age_2 = plantation age at time1 and time2
- exp(x) = e^x, e is the base of the natural logarithm
- ln = natural logarithm, and
- a_0, a_1 = coefficients to be determined.

- The estimate of diameter potential index (DPI) is given by MTD_2, when age2 is 20 years.
- The estimate of diameter potential index of a tree (DPIT) is given by MTD_2, when dbh_{i1} is used instead of MTD_1, and age2 is 20 years.
- The estimate of potential diameter at time2 (PD_{i2}) is given by MTD_2, when DPI is used instead of MTD_1, age1 is 20 years, and age2 is age at time2.
- **To estimate change in potential diameter (chg_pdbh)**: Calculate DPIT, calculate PD_{i2}, and then, subtract dbh_{i1} from PD_{i2}.

Fit Statistics and Parameter Coefficients (using regional survival datasets)

Region (no. obs.)	a0	a1	Adjusted r^2
SOUTH (194)	4.2310	-12.7456	0.96
HBAY (273)	4.3270	-6.7906	0.99
CNI (1156)	4.5930	-5.8909	0.99
SANDS (1130)	3.9172	-5.4356	0.98
GDNS (382)	4.4231	-8.3460	0.99
CLAYS (526)	4.0905	-10.4621	0.99

APPENDIX 3:

- Figures 1 - 3: By region, probability of survival residuals by dbh_i
- Figures 4 - 5: By region, mean predicted residuals by actual mean relative diameter (reldbh)
- Figures 6 - 7: By region, PSP stocking (N) residuals by stocking at the start of time intervals

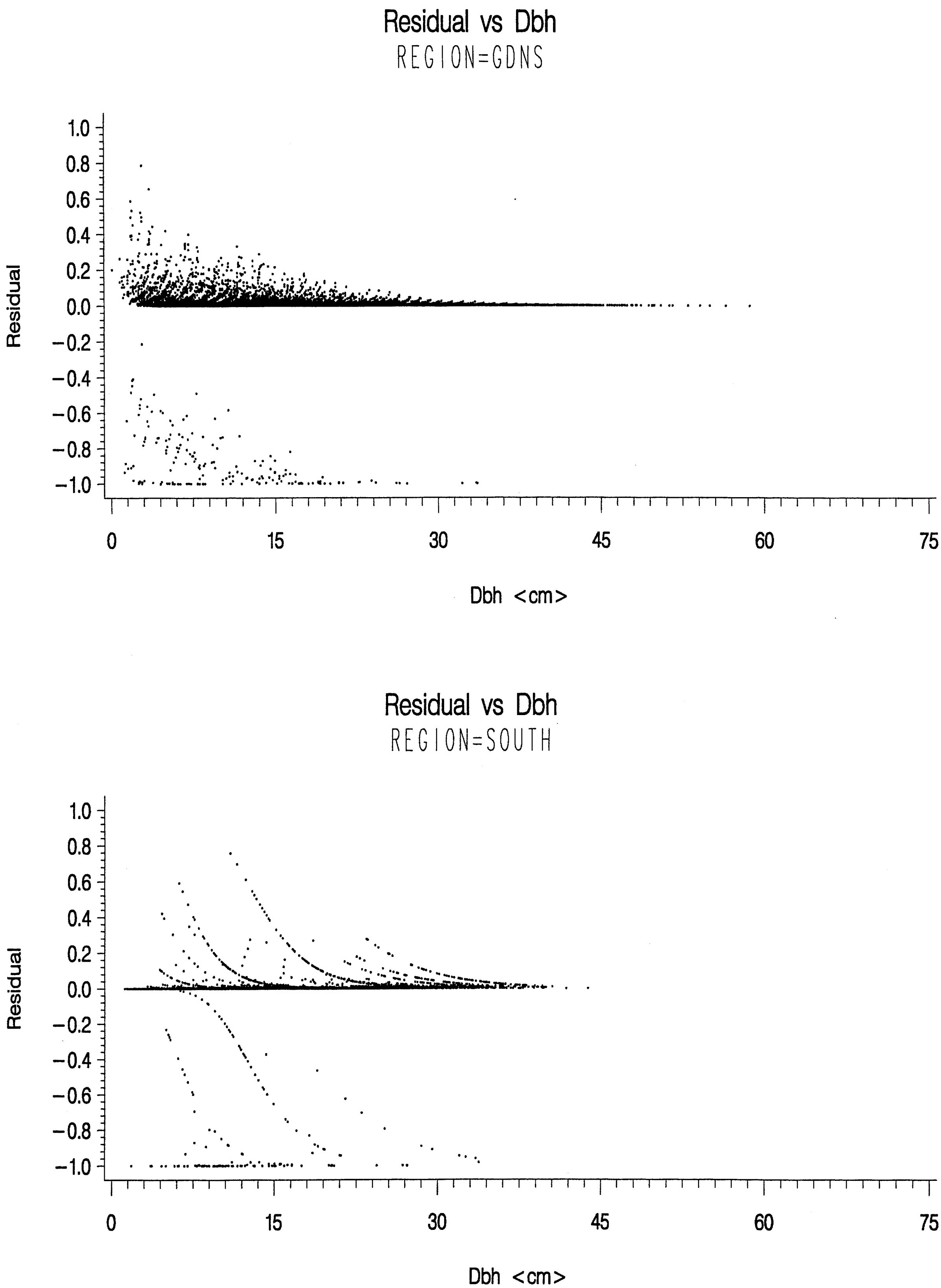
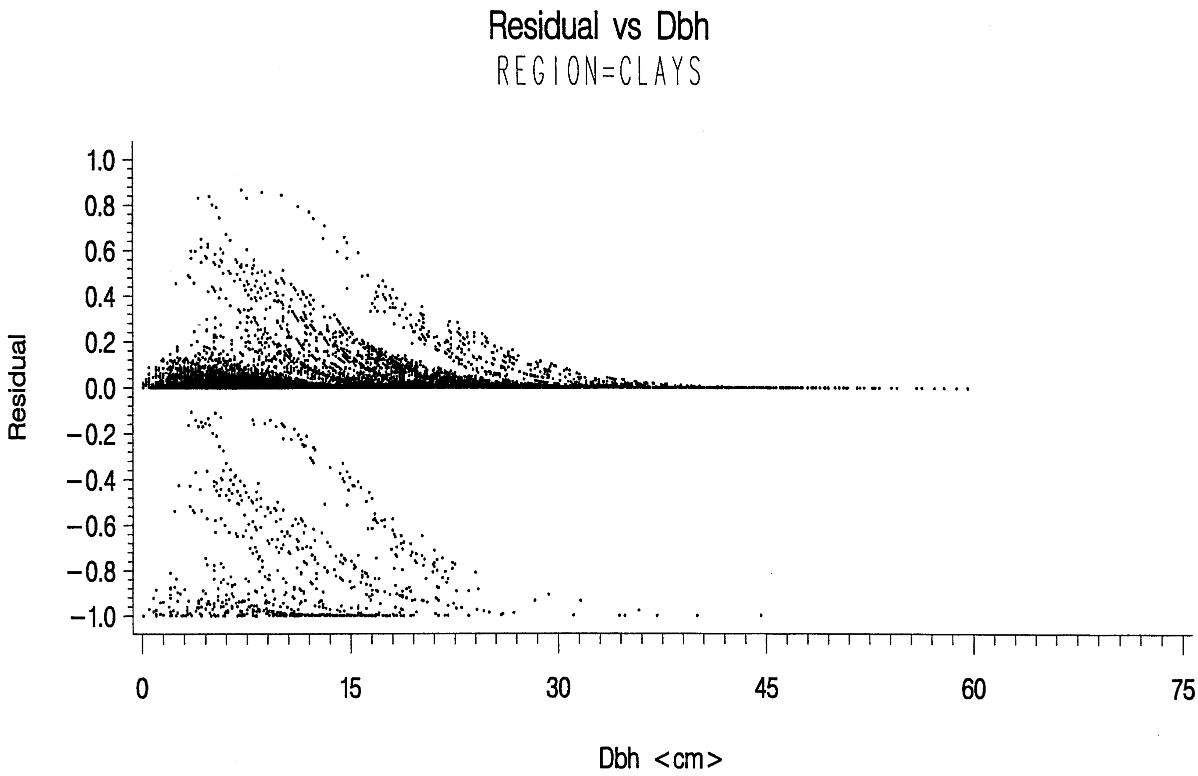
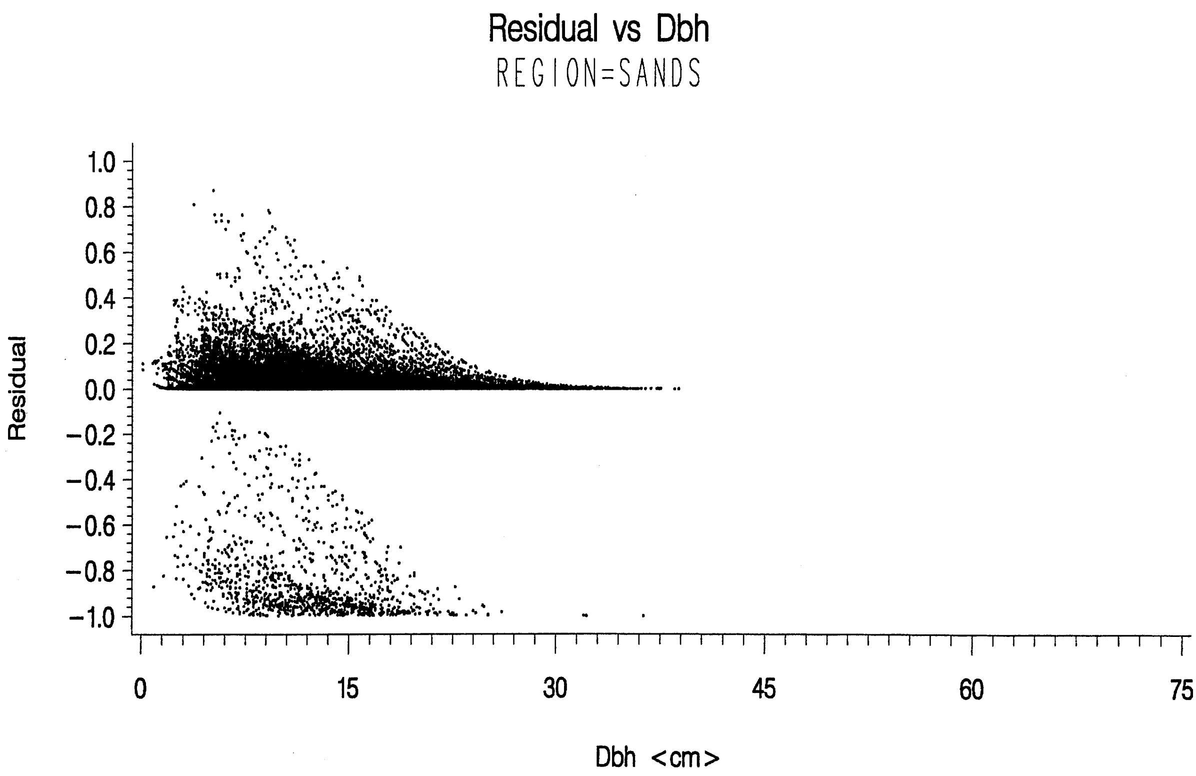

Residual vs Dbh
REGION=GDNS
Residual
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0
15
30
45
60
75
Dbh <cm>
Residual vs Dbh
REGION=SOUTH
Residual
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0
15
30
45
60
75
Dbh <cm>

Figure 1.

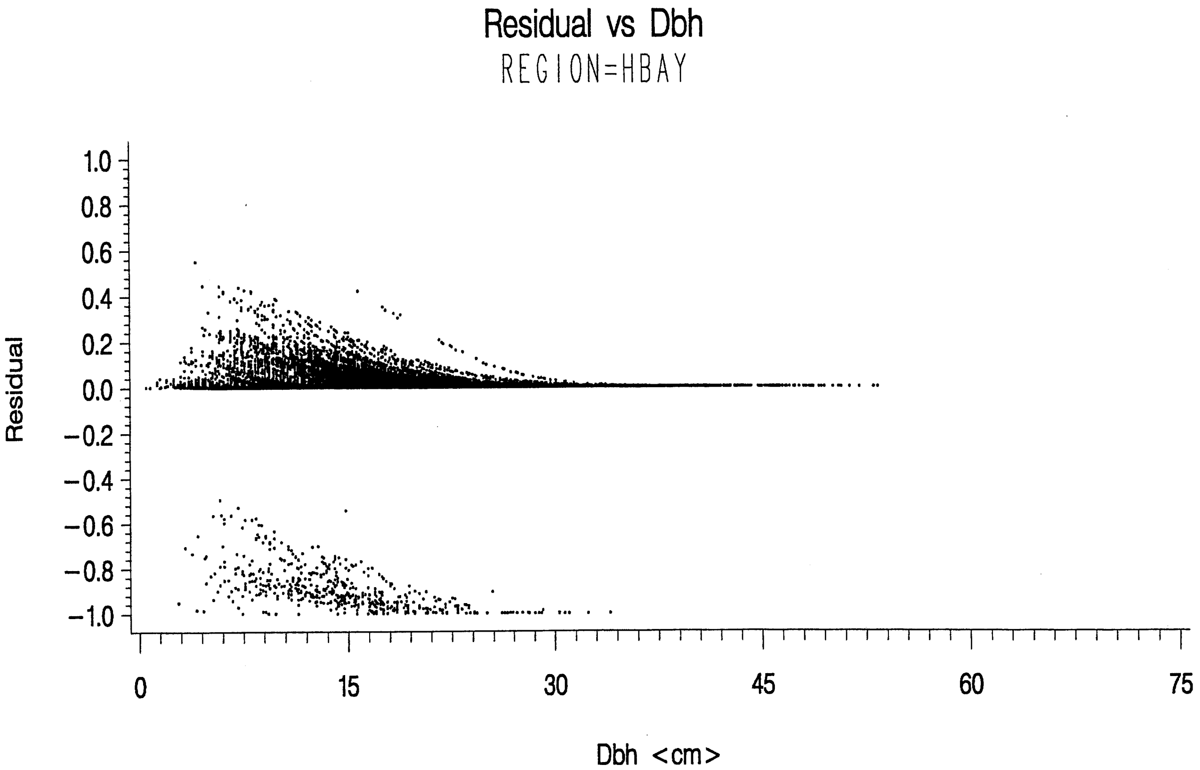


Residual vs Dbh
REGION=CLAYS
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
Residual
0
15
30
45
60
75
Dbh <cm>



Residual vs Dbh
REGION=SANDS
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
Residual
0
15
30
45
60
75
Dbh <cm>

Figure 2.


Residual vs Dbh
REGION=HBAY
Residual
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0
15
30
45
60
75
Dbh <cm>

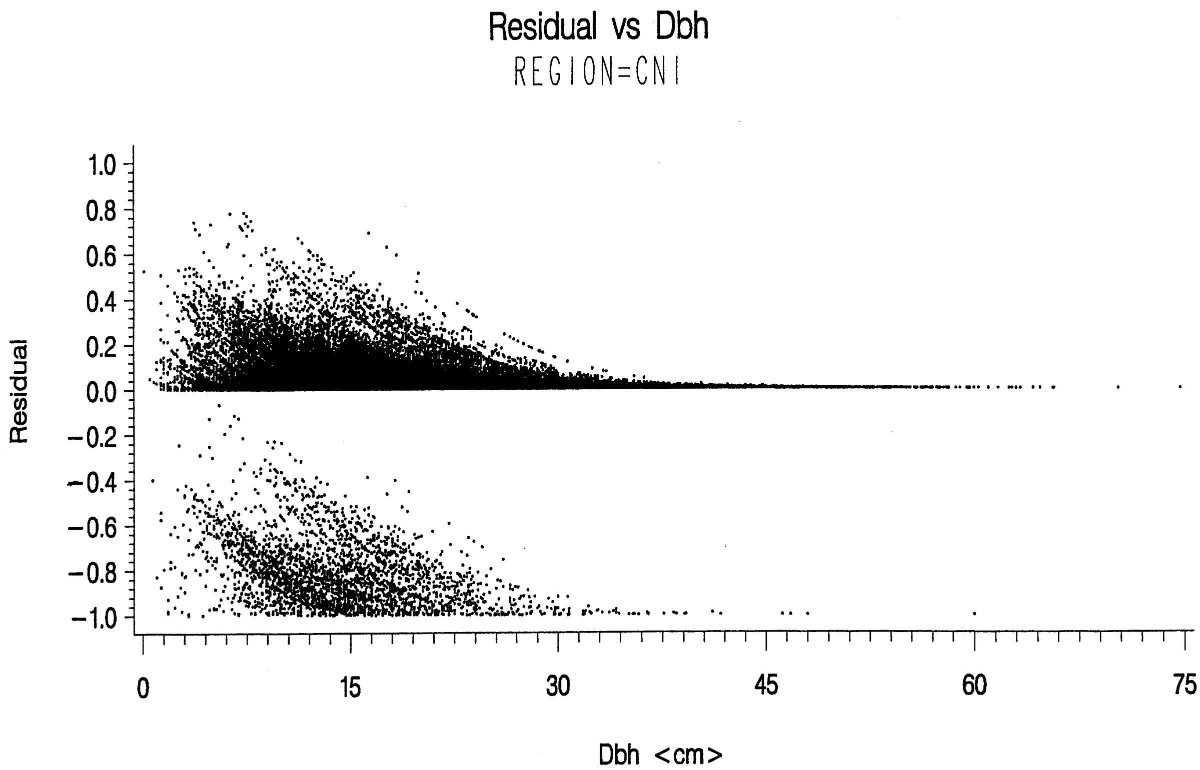
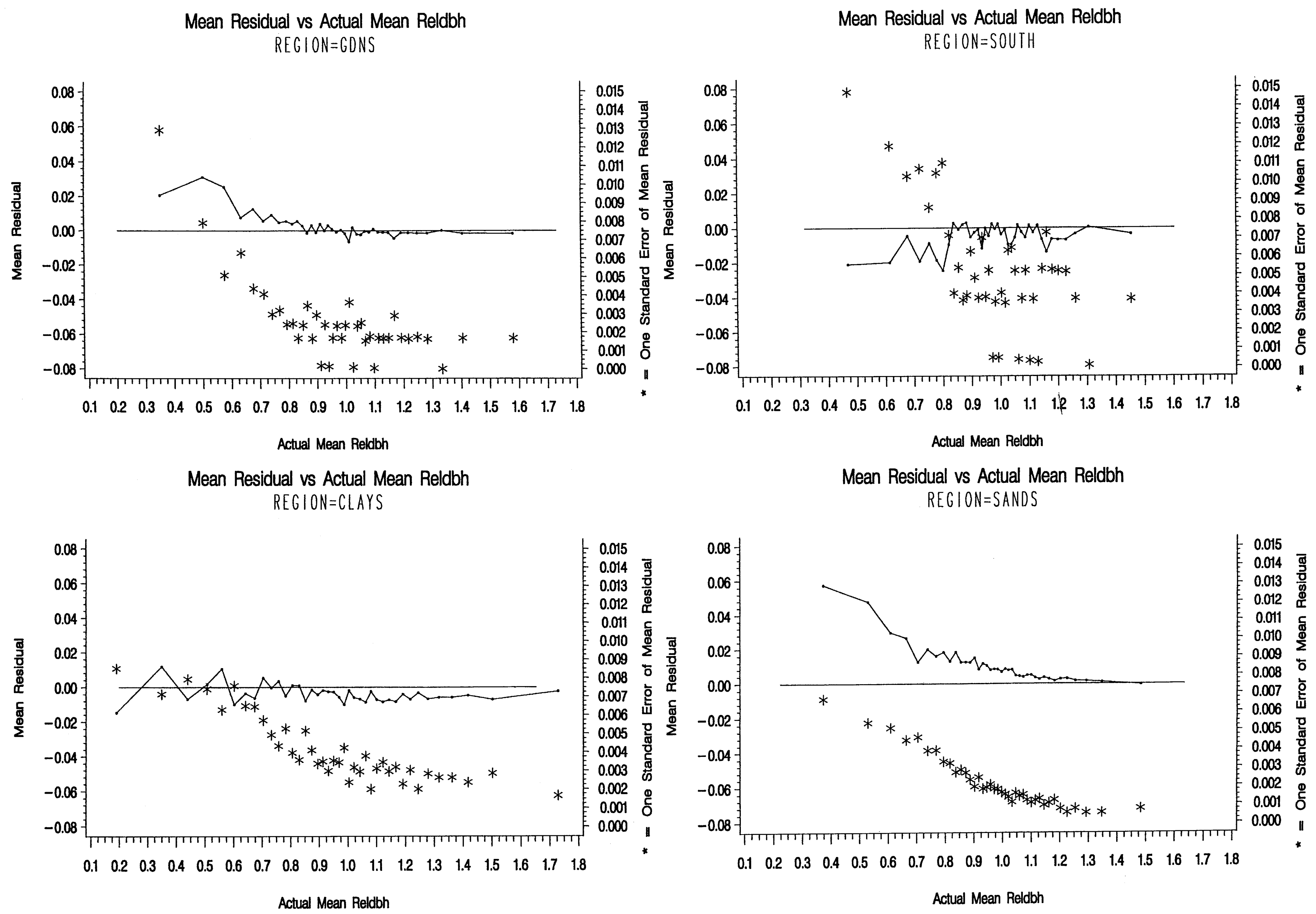

Residual vs Dbh
REGION=CNI
Residual
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
0
15
30
45
60
75
Dbh <cm>

Figure 3.



Mean Residual vs Actual Mean Reldbh
REGION=GDNS
Mean Residual vs Actual Mean Reldbh
REGION=SOUTH
Mean Residual vs Actual Mean Reldbh
REGION=CLAYS
Mean Residual vs Actual Mean Reldbh
REGION=SANDS
Mean Residual
Actual Mean Reldbh
* = One Standard Error of Mean Residual

Figure 4.

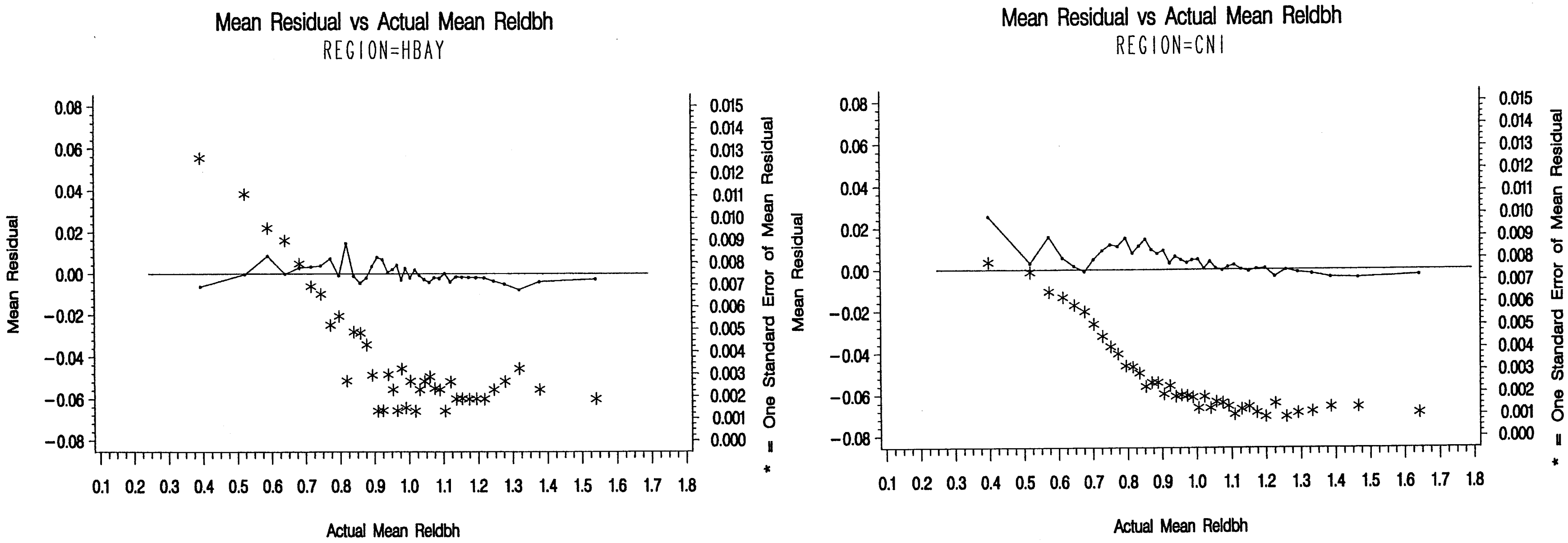

Mean Residual vs Actual Mean Reldbh
REGION=HBAY
Mean Residual
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8
Actual Mean Reldbh
0.015 0.014 0.013 0.012 0.011 0.010 0.009 0.008 0.007 0.006 0.005 0.004 0.003 0.002 0.001 0.000
* = One Standard Error of Mean Residual
Mean Residual vs Actual Mean Reldbh
REGION=CNI
Mean Residual
0.08
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.08
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8
Actual Mean Reldbh
0.015 0.014 0.013 0.012 0.011 0.010 0.009 0.008 0.007 0.006 0.005 0.004 0.003 0.002 0.001 0.000
* = One Standard Error of Mean Residual

Figure 5.

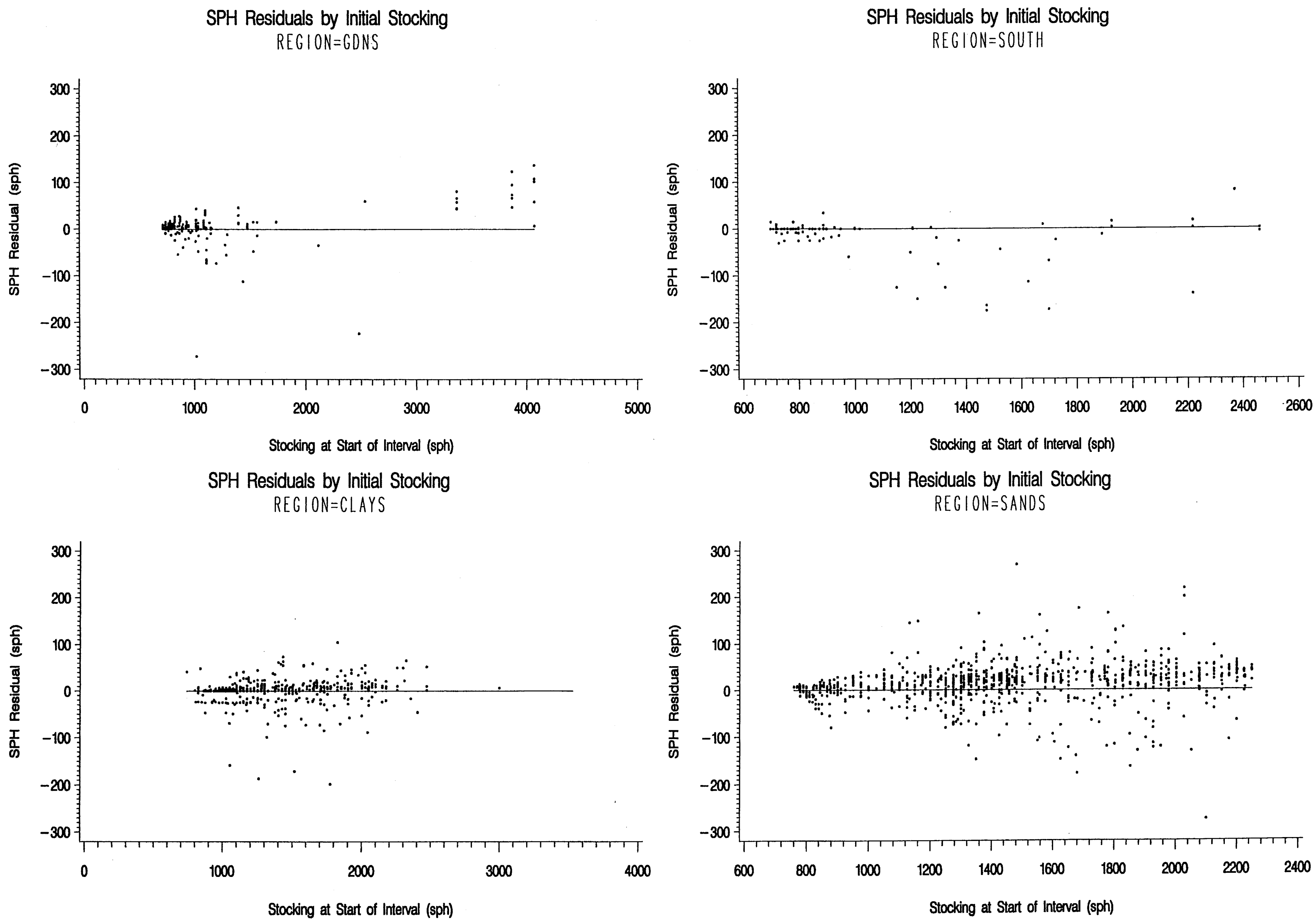

SPH Residuals by Initial Stocking
REGION=GDNS
SPH Residual (sph)
300
200
100
0
-100
-200
-300
0
1000
2000
3000
4000
5000
Stocking at Start of Interval (sph)
SPH Residuals by Initial Stocking
REGION=SOUTH
SPH Residual (sph)
300
200
100
0
-100
-200
-300
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
Stocking at Start of Interval (sph)
SPH Residuals by Initial Stocking
REGION=CLAYS
SPH Residual (sph)
300
200
100
0
-100
-200
-300
0
1000
2000
3000
4000
Stocking at Start of Interval (sph)
SPH Residuals by Initial Stocking
REGION=SANDS
SPH Residual (sph)
300
200
100
0
-100
-200
-300
600
800
1000
1200
1400
1600
1800
2000
2200
2400
Stocking at Start of Interval (sph)

Figure 6.

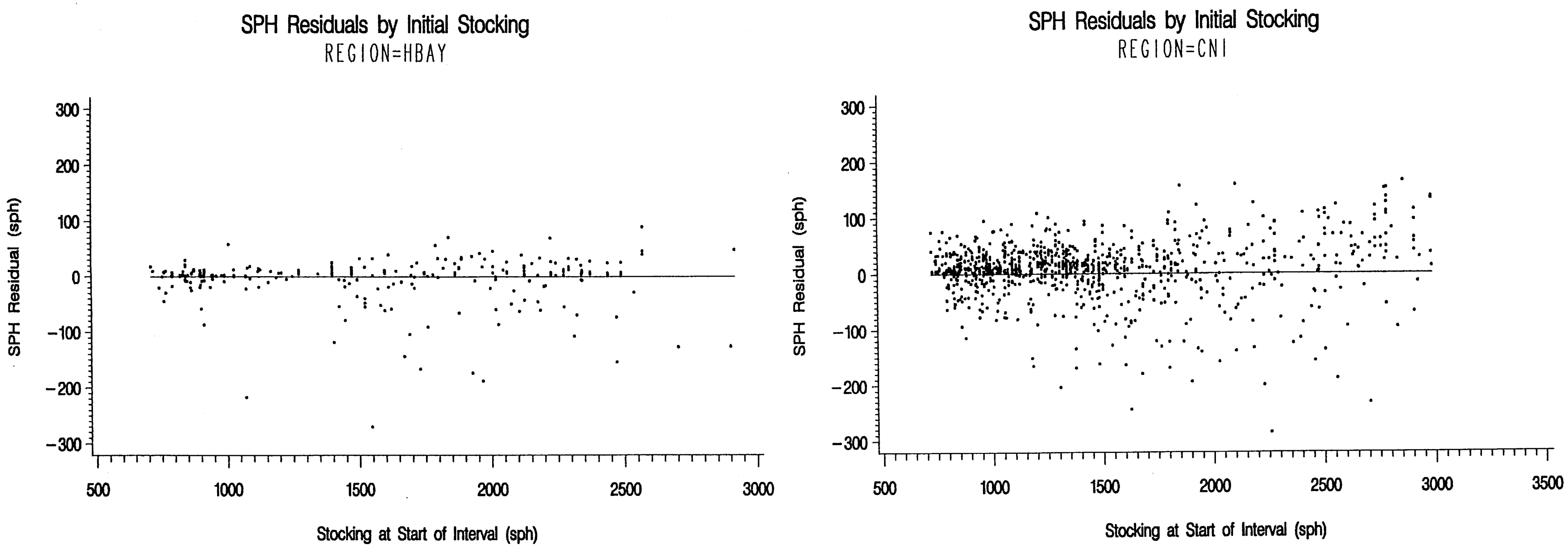

SPH Residuals by Initial Stocking
REGION=HBAY
SPH Residual (sph)
300
200
100
0
−100
−200
−300
500
1000
1500
2000
2500
3000
Stocking at Start of Interval (sph)
SPH Residuals by Initial Stocking
REGION=CNI
SPH Residual (sph)
300
200
100
0
−100
−200
−300
500
1000
1500
2000
2500
3000
3500
Stocking at Start of Interval (sph)

Figure 7.