# VALIDATION OF THE INDIVIDUAL-TREE GROWTH MODEL (ITGM)

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## EXECUTIVE SUMMARY

The Individual-Tree Growth Model (ITGM) is a fully-functional, prototype individual-tree growth model for radiata pine, which implements in combination, tree-level growth and survival equations to project stand- and tree-level growth and yield. ITGM prediction equations require data specific to each of 7 growth modelling regions, and operates on an annual cycle to grow trees from plantation age 15 to rotation age. The ability of this modelling approach has previously been documented using residual analyses with respect to isolated equations, but it has not been validated, as an integrated system of equations, using a fully-functional growth simulator.

During validation, the previously documented modelling approach used to predict static tree height resulted in severely biased prediction of tree height increment. Therefore, a major revision to tree height-growth prediction was undertaken and implemented in ITGM.

During regional tree-level growth and survival analyses, Timberlands West Coast (TWC) was inadvertently overlooked for inclusion. As an interim measure, ITGM was programmed to use Nelson region (GDNS) growth and survival equations. Now, TWC diameter and height growth equations have been fitted.

The objectives of this Report are to document:

- the validation of ITGM to establish the level of confidence at which the ITGM provides useful output and correct inferences about mid-rotation onward growth and yield,
- the new approach for the prediction of tree height increment, and
- the investigation into diameter and height growth equations for TWC.

Regression results confirmed the previous finding, that $R^2$ is poor ($\leq 0.20$) for directly predicting tree height increment. Seven regional dummy variables and 4 explanatory variables were able to explain only 17% ($R^2$) of the variation in tree height increment. Even though the $R^2$ value is low, the validation exercise established that this prediction approach is superior to the use of the tree height / mean top height ratio prediction approach. The utility of regional dummy variables suggests that separate, specific regional tree height increment equations should be investigated. This regional approach may identify regionally specific explanatory variables, and result in improved $R^2$.

Relative to the other regional diameter and height growth equations, the fitted TWC equations have significantly lower $R^2$ values. Despite repeated attempts at uncovering better explanatory variables unique to TWC, explanatory variables similar to GDNS worked best for TWC, but with poorer results. Validation statistics revealed that the TWC predictions had marginally better results via the use of the GDNS growth equations, rather than the directly fit TWC growth equations. This result is counter-intuitive, but accepted. Until further investigations prove otherwise, TWC will continue to be represented with GDNS growth equations in ITGM, as validation results fully support this.

Overall, validation statistics reveal that, on-average, 5 and 10 year tree- and stand-level diameter and height prediction error is generally $\leq 3\%$ (usually over-predicted), while absolute prediction error is generally $\leq 7\%$. Accompanying predicted tree-diameter distributions generally appear reasonable, and skewed and multi-modal diameter distributions (i.e., other than "normal") are accommodated well.

These results indicate that ITGM, as an iterative prediction system for mid-rotation onward tree and stand growth and survival, operates within acceptable error limits without any obvious anomalies or mechanistic mathematical flaws.

# INTRODUCTION

Gordon and Lawrence (1994), Gordon (1996), Lundgren and Gordon (1997), Shula (1997a, b, c) document the development of individual-tree diameter, height, and survival equations applicable to mid-rotation, post-silviculture radiata pine stands, i.e., ≥ 15 years old. Gordon and Shula (1999) document the fully-functional, prototype individual-tree growth model (ITGM), which implements, in combination, the tree-level growth and survival equations to project stand- and tree-level growth and yield.

The individual-tree growth modelling approach has equation forms that are analogous to those used in rotation-age individual-tree growth models (Wykoff et al. 1982; Hann et al. 1997). The ability of this modelling approach has been documented and verified using residual analyses (Shula 1997a, b, c) with respect to isolated equations, but it has not been validated using a fully-functional growth simulator, where the equations work together as a system. The diameter, height, and survival prediction equations require data specific to each of 7 growth modelling regions, and operate on an annual cycle to grow trees from plantation age 15 to rotation age.

During the present validation exercise, the approach and equation form used to predict static tree height (Shula 1997b) subsequently resulted in severely biased prediction of $ht_i$ increment (obtained by subtraction of static tree height at two ages). Therefore, a major revision to tree height-growth prediction was undertaken, implemented in ITGM, and is also described in this Report.

During regional tree-level growth and survival analyses, Timberlands West Coast (TWC) was inadvertently overlooked for inclusion. As an interim measure to represent TWC, ITGM was programmed to use Nelson region (GDNS) growth and survival equations. Now, specific diameter and height growth analyses for TWC have been undertaken, and are also described in this Report.

# OBJECTIVES

The objectives of this Report are to document:

- the validation of ITGM, and to establish the level of confidence at which the ITGM provides useful output and correct inferences about mid-rotation onward growth and yield,
- the new approach for the prediction of tree height increment, and
- the investigation into diameter and height growth equations for TWC.

# NOTATION

| | |
|---|---|
| age | = plantation age (years) |
| $bal_i$ | = sum of basal area of individual trees in a stand larger than tree 'i' |
| $dbh_i$ | = individual-tree, breast-height (1.4 m) diameter (mm) |
| bal_dbh | = $bal_i$ ratio, i.e., ( $bal_i$ / $dbh_i$ ) |
| chg_pdbh | = change in potential $dbh_i$; potential $dbh_i$ growth, as if a MTH tree (Shula 1997a) |
| $dbh_q$ | = stand, quadratic mean breast-height diameter (mm or cm) |
| exp(x) | = $e^x$; e is the base, 2.71828, of the natural logarithm |
| G | = stand, basal area ($m^2$/hectare) |
| $ht_i$ | = individual-tree height (m) |
| hpit | = height potential index of an individual-tree; i.e., $ht_i$ at age 20 (Shula 1997a) |
| ln | = natural base 2.71828 logarithm |
| MTD | = stand, mean top breast-height diameter (mm or cm) |
| MTH | = stand, mean top height (m) |
| N | = stems per hectare (sph) |
| S | = radiata pine site index, base age 20 years (m) |

sqdl_dbh = { [ ln ( $dbh_i$ ) ]$^2$ } (cm)
sqd_ht = $(ht_i)^2$ / 1000 (m)
sph_rdbh = stocking (N) x ($dbh_i$ / $dbh_q$)

# DATA

## Origin

The validation analyses are based on a sub-set of the same regional permanent sample plots (PSPs) used to develop the tree-level growth and survival equations. Nonetheless, the validation is considered quasi-independent because:

1. the datasets for the fitting of growth equations were based on low-intensity random selection (~8%, or some 5,300 of 65,500 observations) of tree-level observations from regional PSPs, while
2. the datasets for the validation analyses (actual versus predicted) are based on a complete selection (100%) of tree-level observations on selected regional PSPs.

Furthermore,

3. the fitting of growth equations was based on point-in-time, annulated growth increments, while
4. the validation analysis is based on iterative, cumulative annual growth and yield prediction starting from an initial point-in-time.

Item 1 resulted in a reduction of the likelihood for correlated regression residuals, while item 2 resulted in the provision of necessary PSP input data (complete tree- and stand-level attributes) required to start an ITGM simulation. Thus, the validation analysis is based on many different individual-trees , than was included in the original regression analysis. Furthermore, item 4 resulted in the investigation of accumulated, cascaded prediction errors, while item 3 resulted in the prediction of growth in annual time-steps.

PSPs to develop growth equations for TWC, and subsequent validation, originated from the same database used to develop a TWC stand-level growth model (Kimberley and Hawke, 1999).

## Description

PSPs and simulation start- and end-ages used in the validation analyses are listed in **Appendix A.** Summaries of plot data (at simulation start-age), including stand- and tree-level mean, and minimum / maximum values are presented in **Tables 1 and 2.**

**Table 1. Summary of plot data, at simulation start-age, providing stand-level mean and (minimum / maximum values).**

| Region | Plots [No.] | Simulation Start-Age [yrs] | $dbh_q$ [cm] | MTD [cm] | G [m2/ha] | N [sph] | MTH [m] | S [m] |
|---|---|---|---|---|---|---|---|---|
| **CNI** | 21 | 16 (15/22) | 28 (17/55) | 36 (28/60) | 43 (17/62) | 1086 (158/2702) | 27 (21/37) | 34 (27/37) |
| **GDNS** | 12 | 16 (15/21) | 26 (21/32) | 33 (27/40) | 32 (11/56) | 681 (180/1630) | 21 (17/24) | 26 (22/30) |
| **HBAY** | 12 | 17 (15/19) | 35 (32/41) | 40 (36/46) | 29 (15/58) | 315 (178/721) | 25 (20/30) | 29 (25/33) |
| **CLAYS** | 13 | 18 (15/25) | 33 (25/40) | 39 (31/46) | 37 (16/78) | 450 (290/1170) | 27 (22/35) | 30 (23/33) |
| **SOUTH** | 10 | 16 (15/17) | 27 (17/35) | 32 (25/39) | 30 (24/68) | 683 (285/2898) | 19 (16/20) | 24 (21/27) |
| **SANDS** | 16 | 19 (15/25) | 30 (16/44) | 34 (19/49) | 22 (9/33) | 322 (109/544) | 23 (16/31) | 24 (20/30) |
| **CANTY** | 5 | 17 (15/20) | 28 (23/34) | 35 (30/40) | 38 (31/46) | 665 (352/950) | 21 (17/23) | 25 (22/27) |
| **TWC** | 6 | 16 (15/19) | 30 (18/41) | 41 (39/44) | 27 (9/48) | 371 (239/553) | 22 (16/29) | 27 (22/30) |

**Table 2. Summary of plot data, at simulation start-age, providing tree-level mean and (minimum / maximum values).**

| Region | Simulation Start-Age [yrs] | No. Observations | | $dbh_i$ [cm] | $ht_i$ [m] |
|---|---|---|---|---|---|
| | | $dbh_i$ | $ht_i$ | | |
| **CNI** | 16 (15/22) | 1662 | 192 | 23 (7/69) | 26 (15/41) |
| **GDNS** | 16 (15/21) | 425 | 105 | 24 (5/44) | 20 (11/27) |
| **HBAY** | 17 (15/19) | 383 | 88 | 34 (7/51) | 24 (17/31) |
| **CLAYS** | 18 (15/25) | 399 | 101 | 31 (12/50) | 26 (13/40) |
| **SOUTH** | 16 (15/17) | 529 | 122 | 23 (5/41) | 18 (9/22) |
| **SANDS** | 19 (15/25) | 612 | 150 | 29 (9/54) | 22 (15/33) |
| **CANTY** | 17 (15/20) | 163 | 38 | 28 (11/43) | 21 (16/26) |
| **TWC** | 16 (15/19) | 333 | 109 | 31 (7/56) | 21 (8/30) |

# METHODS

## Background

Validation is an integral step in the process of building a simulation model (Goulding 1979). Validation addresses the ability of a growth simulator, as a whole, to enable users to make correct inferences regarding operational and/or experimental hypotheses of interest based on simulator output. Sharpe (1990) recognised this approach to validation as performance and refutation, in addition to, goodness-of-fit and mathematical rigour. Performance and refutation, by necessity, follow goodness-of-fit and mathematical rigour to fully evaluate the development of isolated equations and the holistic set of equations that comprise a growth simulator. First, equation form and regression parameter estimates are evaluated for goodness-of-fit (e.g., mean square error, parameter significance, constant standard error, and coefficient of determination). Next, the simulator's collective set of equations is evaluated for mathematical rigour, which involves assessment of the simulator's architecture for suitability, logic, and arithmetic functionality. Finally, performance and refutation evaluate a simulator's accuracy and precision of prediction with respect to the dynamic interaction played-out by the holistic set of equations and explanatory variables.

## Validation approach

The present validation analyses focus on the evaluation of mathematical rigour and performance. To this end, ITGM was used to simulate growth and yield of selected PSPs to check the simulator's architecture for suitability, logic, and arithmetic functionality; and, to compare simulator output with observed PSP data.

ITGM was programmed in batch-mode to accept coma-delimited ASCII input data, and to make iterative annual growth and yield predictions culminating at future PSP stand ages. ITGM simulations were started with initial PSP starting values (tree- and stand-level variables), but thereafter, iterative annual steps to final projection age were re-initiated with predicted tree- and stand-level values. Predicted stand-level values were obtained by the aggregation of predicted tree-level values based upon predicted probabilities of tree-survival and resultant predicted tree-expansion factors. Predicted values at final PSP stand ages that did not result from exact annual projections (e.g., starting-age 22.05 to ending-age 26.65) were obtained by back-adjustment to exact PSP stand ages via interpolation (e.g., annual prediction from age 22.05 to age 27.05, then interpolation back to age 26.65).

The selection of PSPs (and resultant number of observations) for the validation analyses was based on criteria to provide identically paired, 1x- and 2x-term periods of simulation (1x-term, ~ 5 years; 2x-term, ~ twice the 1x-term, or around 10 years), starting at plantation age ≥ 15 years and without thinning interventions. These strict criteria were chosen to provide exact one-to-one comparative estimates of prediction accuracy and precision for 1x- and 2x-simulation periods considered of most interest to mid-rotation onwards inventory projection. These criteria purposely focused the validation analyses, but also, restricted the scale of the analyses because PSP re-measurements meeting the strict criteria were limited in supply.

## Validation attributes and statistics

Validation statistics were calculated for the following stand-level attributes: $dbh_q$, G, N, MTD, and MTH; and tree-level attributes: $dbh_i$ and $ht_i$. There is no single validation statistic that entirely captures model prediction accuracy and precision; therefore, all of the following set of validation statistics were used:

1. R-squared (or modelling efficiency, Soares et al. 1995):

$$R^2 = 1 - [\, \Sigma\, (yact_i - yhat_i)^2 / \Sigma\, (yact_i - ymean_i)^2\, ]$$

2. Mean error (ME):

$$ME = [\, \Sigma\, (yact_i - yhat_i)\, ] / n$$

3. Mean percent error (MPE):

$$MPE = \{\, [\Sigma\, (yact_i - yhat_i / yact_i)\, ] / n\, \} * 100$$

4. Root mean squared error (RMSE):

$$RMSE = [\, \Sigma\, (yact_i - yhat_i)^2 / n\, ]^{0.5}$$

5. Mean absolute error (MAE):

$$MAE = [\, |yact_i - yhat_i| / yact_i\, ] / n$$

6 Mean absolute percent error (MAPE):

$$MAPE = [\Sigma\, |yact_i - yhat_i| / yact_i / n\, ] * 100$$

7. Mean actual or predicted (MA, MP):

$$MA = (\Sigma\, yact_i\, ) / n$$
$$MP = (\Sigma\, yhat_i\, ) / n$$

8. Standard deviation of actual or predicted (STDA, STDP):

$$STDA = \{\, [\, \Sigma\, (yact_i - yact\_mean_i)^2\, ] / n\, \}^{0.5}$$

$$STDP = \{\, [\, \Sigma\, (yhat_i - yhat\_mean_i)^2\, ] / n\, \}^{0.5}$$

where, $yact_i$ = actual value of the variable
$yact\_mean_i$ = actual mean value of the variable
$yhat_i$ = predicted value of the variable
$yhat\_mean_i$ = actual mean value of the predicted variable
$n$ = number of observations in the validation dataset.

Statistics 1 - 3 represent ‘soft’ validation assessors, as positive (+) and negative (-) errors accumulate, but have the opportunity to ‘average out’. Conversely, statistics 4 - 6 represent ‘hard’ validation assessors, as errors (absolute or squared) are accumulated without the opportunity to ‘average out’. Statistic 4 is a particularly ‘hard’ assessor, as the squaring of errors, penalises large errors, especially.

The $R^2$ statistic quantifies the departure of predicted values from actual values relative to the departure of actual values from the mean actual value. This statistic, then, is sensitive to the range in prediction error (variation about zero error) and to the range in the actual data (variation about the mean actual value). A value of 1 identifies a perfect prediction model, while a value $\leq 0$, identifies a prediction model no-better-to-worse than using the mean.

The STDA and STDP statistics quantify the variation about the mean actual and mean predicted values, respectively. The comparison of these validation statistics are particularly meaningful to evaluate tree-level models, as the goal of tree-level models is the accurate projection of the tree-list and tree-size variability in the tree-list.

## Height growth prediction

The first height growth investigation (Gordon 1996) concluded that the prediction of individual-tree height increment was not worthwhile, based principally on poor goodness-of-fit statistics. Further investigation (Shula 1997b) accepted this conclusion, and continued to rely on the indirect prediction of $ht_i$ via the direct, static prediction of height ratio ($ht_i$:MTH), as a power function on diameter ratio ($dbh_q$:MTD). Therefore, predicted $ht_i$ increment was a) dependent on predicted MTH at the end of the prediction period, and b) obtained indirectly by subtraction of predicted $ht_i$ at the start and end of the prediction period. Regional specificity was incorporated through the inclusion of regional dummy variables; adjusted $R^2$ was 0.51.

During the present validation exercise, this height growth modelling approach resulted in severely biased predictions of $ht_i$ increment. This bias was attributed to the inherent reliance on predicted MTH derived from site index, and the instability of the power function on diameter ratio for individual-trees with diameters approaching or greater than stand MTD. To seek a remedy, the first approach to directly model $ht_i$ increment was revisited.

The revised height growth analysis used the same dataset (291 plots) as described in Gordon (1996) and Shula (1997b); however, all observations were utilised (n=13440), rather than separating the dataset into regression and validation datasets (n=5264 and n=8176, respectively) . Gordon 1996 (Table 2, page 3) provides the number of observations, and the range in tree height and height increment by Region for the entire dataset.

SAS (SAS Institute Inc. 1989) non-weighted, non-linear regression procedure, NLIN, (method = marquardt) was used to estimate parameter coefficients ($\alpha \leq 0.05$). The equation form that was fit was a generalised Schumacher (1939) log reciprocal:

- $y = \exp( r_1 + ...+ r7 + a1x_1 +...+ a_nx_n )$ [1]

The dependent variable (y) was annual $ht_i$ increment (m). Where re-measurement did not occur exactly 12 months later, interpolation was used to obtain an annulated observation. Regional specificity was incorporated through the inclusion of regional dummy variables ($r_1 - r_7$). Potential explanatory variables ($x_n$) common to all regions included all those tried in the first investigation (Gordon 1996), and those newly devised, although used previously in growth and survival analyses (Shula 1997a, b, c). 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).

## TWC diameter and height growth equations

The TWC tree-level diameter and height growth analyses started with the same underlying database (812 PSPs) as available for the contractual development of a TWC stand-level growth model (Kimberley and Hawke 1999). Ultimately, the stand-level modelling exercise used a total of 1802 stand-level measurements from 336 PSPs, resulting from the exclusion of PSPs with: site index ≤ 15m, very high stocking, and suspect data.

The present tree-level diameter and height growth analyses selected tree-level data from a total of 13187 measurements from 235 PSPs, resulting from the initial exclusion of PSPs with: site index ≤ 15m, non-annual re-measurements, and suspect data. In the diameter growth analyses, and in keeping with previous analyses (Gordon and Lawrence1994 and Shula 1997a), randomly selected data resulted in 778 tree-level observations from 168 PSPs (**Appendix B**). Summaries of plot data (at initial age), including stand- and tree-level mean, and minimum / maximum values are presented in **Tables 3 and 4**. In the height growth analyses, and in keeping with previous analyses (Shula 1997b), keeping all acceptable height data resulted in 2715 tree-level observations from 188 PSPs (**Appendix C**). Summaries of plot data (at initial age), including stand- and tree-level mean, and minimum / maximum values are presented in **Tables 5 and 6**.

SAS (SAS Institute Inc. 1989) weighted, non-linear regression procedure, NLIN, (method = marquardt) was used to estimate parameter coefficients ($\alpha \leq 0.05$). An equation similar to [1] was fit, with the dependent variable (y) as annual $dbh_i$ and $ht_i$ increment (cm and m, respectively). As TWC data was being fit directly, an intercept parameter ($a_0$) replaced the regional dummy variable ($r_1$). Potential explanatory variables ($x_n$) included all those tried in previous investigations (Shula 1997a, b). To better ensure homogenous variance of residuals, a variety of weighting schemes were investigated, including: the reciprocal (or not) of tree-size attributes (e.g., dbh, height), 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).

**Table 3. TWC diameter growth analyses - summary of plot data, at initial age, providing stand-level mean and (minimum / maximum values).**

| Region | Plots [No.] | Initial Age [yrs] | $dbh_q$ [cm] | MTD [cm] | G [m2/ha] | N [sph] | MTH [m] | S [m] |
|---|---|---|---|---|---|---|---|---|
| **TWC** | 168 | 20 (15/32) | 36 (18/57) | 41 (23/63) | 27 (6/79) | 262 (131/600) | 24 (11/39) | 25 (14/33) |

**Table 4. TWC diameter growth analyses - summary of plot data, at initial age, providing tree-level mean and (minimum / maximum values).**

| Region | Initial Age | No. Observations | | $dbh_i$ | $ht_i$ |
|---|---|---|---|---|---|
| | [yrs] | $dbh_i$ | $ht_i$ | [cm] | [m] |
| **TWC** | 20 (15/32) | 778 | 736 | 38 (7/84) | 23 (5/44) |

**Table 5. TWC height growth analyses - summary of plot data, at initial age, providing stand-level mean and (minimum / maximum values).**

| Region | Plots [No.] | Initial Age [yrs] | $dbh_q$ [cm] | MTD [cm] | G [m2/ha] | N [sph] | MTH [m] | S [m] |
|---|---|---|---|---|---|---|---|---|
| **TWC** | 188 | 20 (15/32) | 35 (18/57) | 40 (23/63) | 26 (6/79) | 260 (120/600) | 23 (11/39) | 24 (14/33) |

**Table 6. TWC height growth analyses - summary of plot data, at initial age, providing tree-level mean and (minimum / maximum values).**

| Region | Initial Age [yrs] | No. Observations dbh$_i$ | No. Observations ht$_i$ | dbh$_i$ [cm] | ht$_i$ [m] |
|---|---|---|---|---|---|
| TWC | 20 (15/32) | 2715 | 2715 | 38 (7/78) | 24 (6/43) |

## RESULTS

### Height growth prediction

Regression results confirmed the previous finding (Gordon 1996), that $R^2$ is poor ($\leq 0.20$) for predicting ht$_i$ increment. Seven regional dummy variables and 4 explanatory variables (all significantly different than 0 or 1) were able to explain only 17% ($R^2$) of the variation in ht$_i$ increment. This indicates that the range in squared prediction error is usually greater than the range in squared observed departure from the mean. **Figures 1a and b** present actual ht$_i$ increment by actual dbh$_i$ for the 7 regions, showing that ht$_i$ increment is largely homogenous across tree-size, and quite variable for a given tree-size. This supports the inability to achieve higher $R^2$ for ht$_i$ increment prediction, i.e., mean ht$_i$ increment is difficult to improve upon via least-squares regression. **Tables 7 and 8** provide fit statistics and parameter coefficients, respectively, from the regression analyses.

**Table 7. Mean residual height increment and standard error by Region from the regression analyses ($R^2$=0.17).**

| Region (no. obs.) | Mean Ht$_i$ Increment Residual (m) | Standard Error (m) |
|---|---|---|
| **CNI** (4449) | 0.00883 | 0.00979 |
| **HBAY** (1365) | 0.00481 | 0.01607 |
| **GDNS** (2538) | -0.00492 | 0.01162 |
| **SOUTH** (1997) | -0.00827 | 0.01153 |
| **CLAYS** (831) | -0.01215 | 0.01950 |
| **CANTY** (301) | 0.00348 | 0.03381 |
| **SANDS** (1959) | -0.01511 | 0.01134 |
| **Combined REGIONS** (13440) | -0.00162 | 0.00507 |

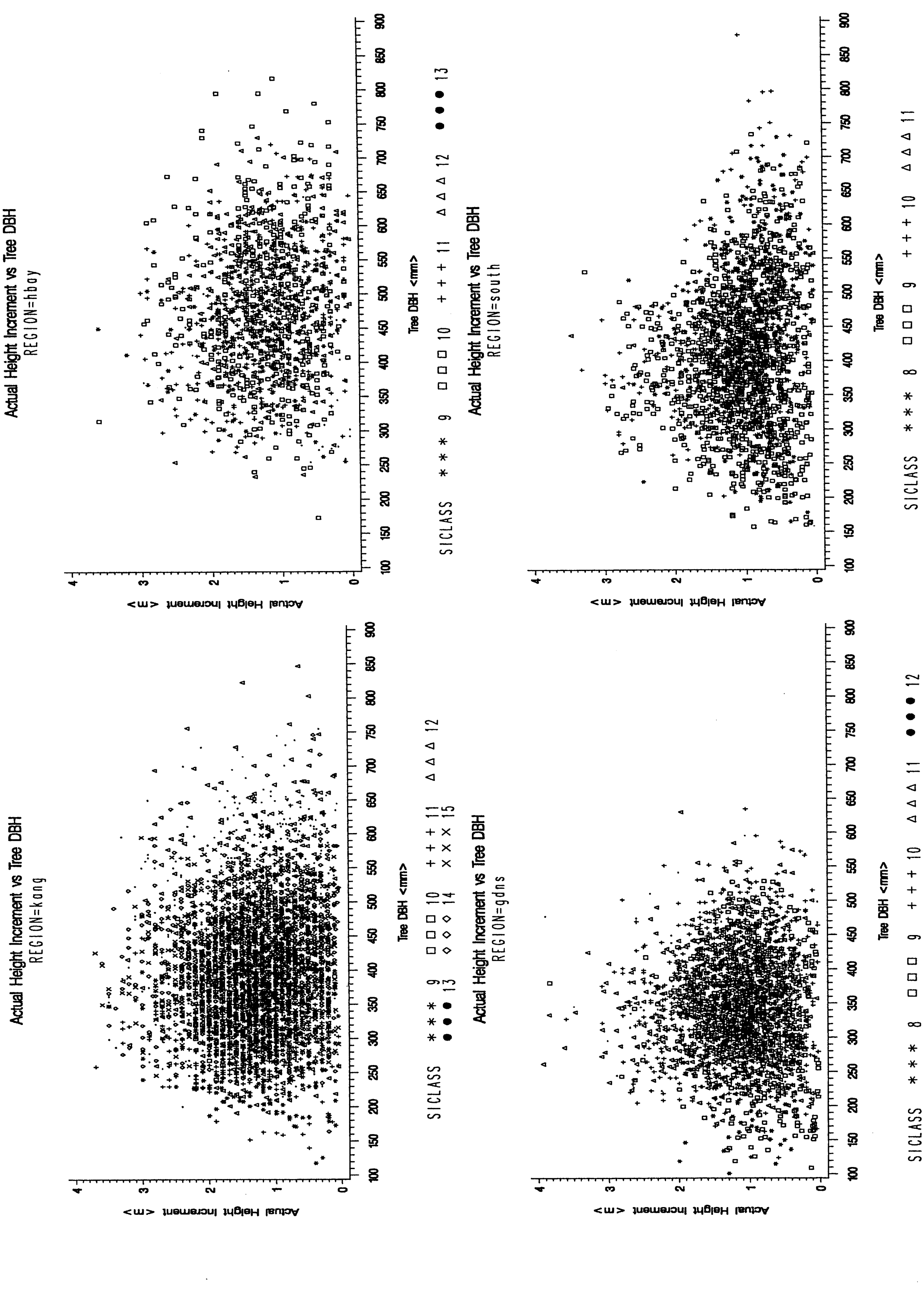



Figure 1a. Actual tree height increment by actual tree dbh for the 7 regions.

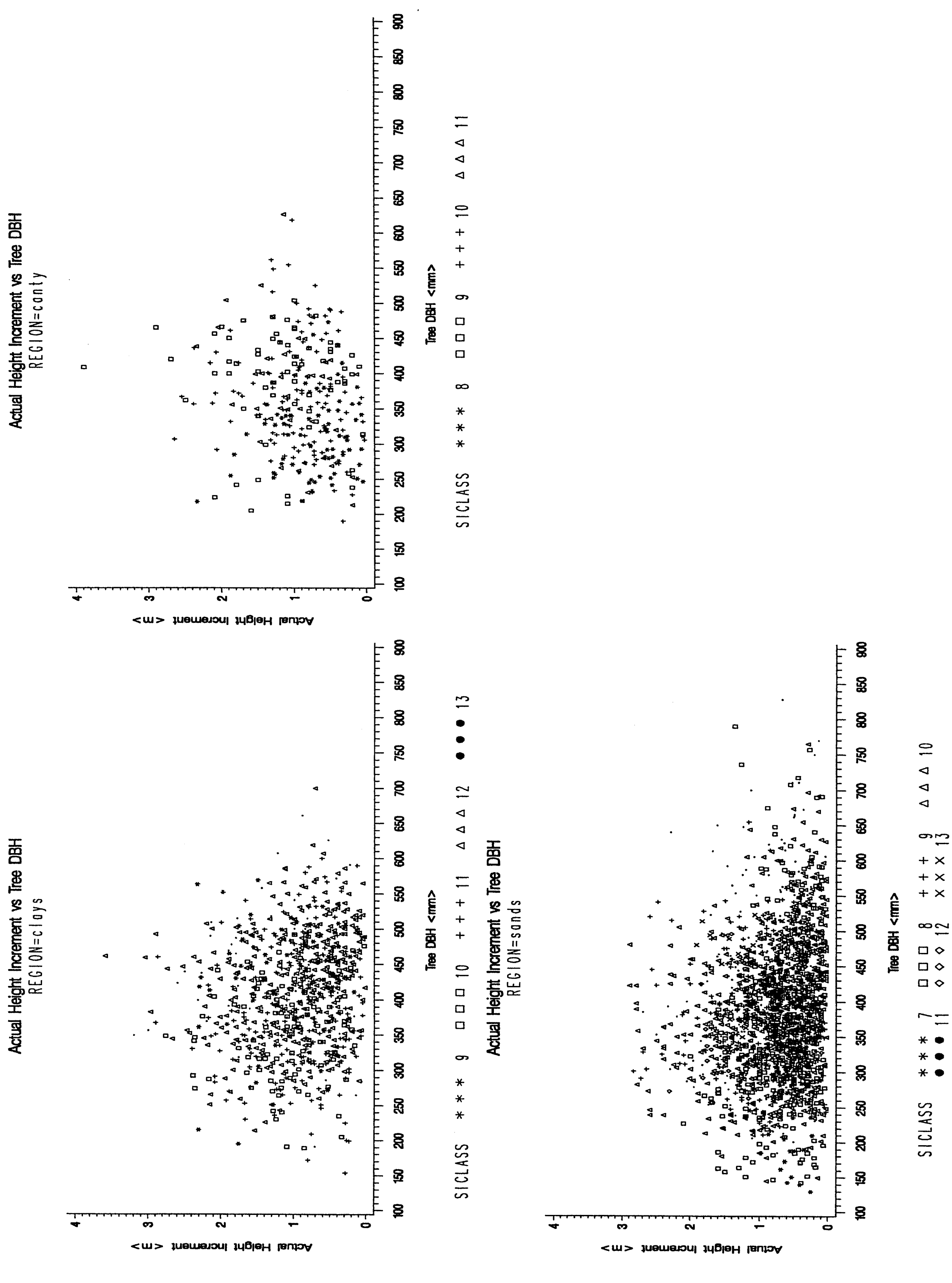



Figure 1b. Actual tree height increment by actual tree dbh for the 7 regions.

**Table 8. Parameters and coefficients by Region from the height increment regression analyses ( $R^2$=0.17 ).**

annual $ht_i$ increment = $\exp( r_1 + \ldots + r_7 + a_1x_1 + \ldots + a_nx_n )$

| Region (no. obs.) | Parameter | Coefficient ($\alpha \leq 0.05$) | Standard Error |
|---|---|---|---|
| **CNI** (4449) | r1 | -0.97793 | 0.12094 |
| **HBAY** (1365) | r2 | -1.07052 | 0.12490 |
| **GDNS** (2538) | r3 | -1.11595 | 0.11640 |
| **SOUTH** (1997) | r4 | -1.14554 | 0.11879 |
| **CLAYS** (831) | r5 | -1.19604 | 0.12201 |
| **CANTY** (301) | r6 | -1.29988 | 0.12276 |
| **SANDS** (1959) | r7 | -1.46447 | 0.11765 |
| **COMMON TO ALL REGIONS** (13440) | sqdl_dbh | 0.02995 | 0.00297 |
| | sqd_ht | -0.73821 | 0.02480 |
| | hpit | 0.02942 | 0.00166 |
| | bal_dbh | -0.36743 | 0.15484 |

The ordering of regions by descending magnitude of the coefficient for the regional dummy variable:

| | dummy coeff. | correspondent $ht_i$ increment (m) |
|---|---|---|
| CNI | -0.98 | 0.38 |
| HBAY | -1.07 | 0.34 |
| GDNS | -1.12 | 0.33 |
| SOUTH | -1.15 | 0.32 |
| CLAYS | -1.20 | 0.30 |
| CANTY | -1.30 | 0.27 |
| SANDS | -1.46 | 0.23 |

provides a ranking of largest to smallest regional $ht_i$ base-increment (by solving the prediction equation with simply the regional coefficient). In practice, these regional $ht_i$ base-increments are, then, adjusted up or down by the other explanatory variables in the equation (i.e., diameter, height, height potential index, relative tree-size) with coefficients common to all regions.

**Figures 2a and b** present $ht_i$ increment residuals by predicted $ht_i$ increment; predictions are unbiased, although residuals range widely about zero error. On average across regions, 62% of the residuals (range, 50% to 70%) are within 0.5m of the actual $ht_i$ increment; while 82% of the residuals (range, 75% to 91%) are within 0.75m of the actual $ht_i$ increment.

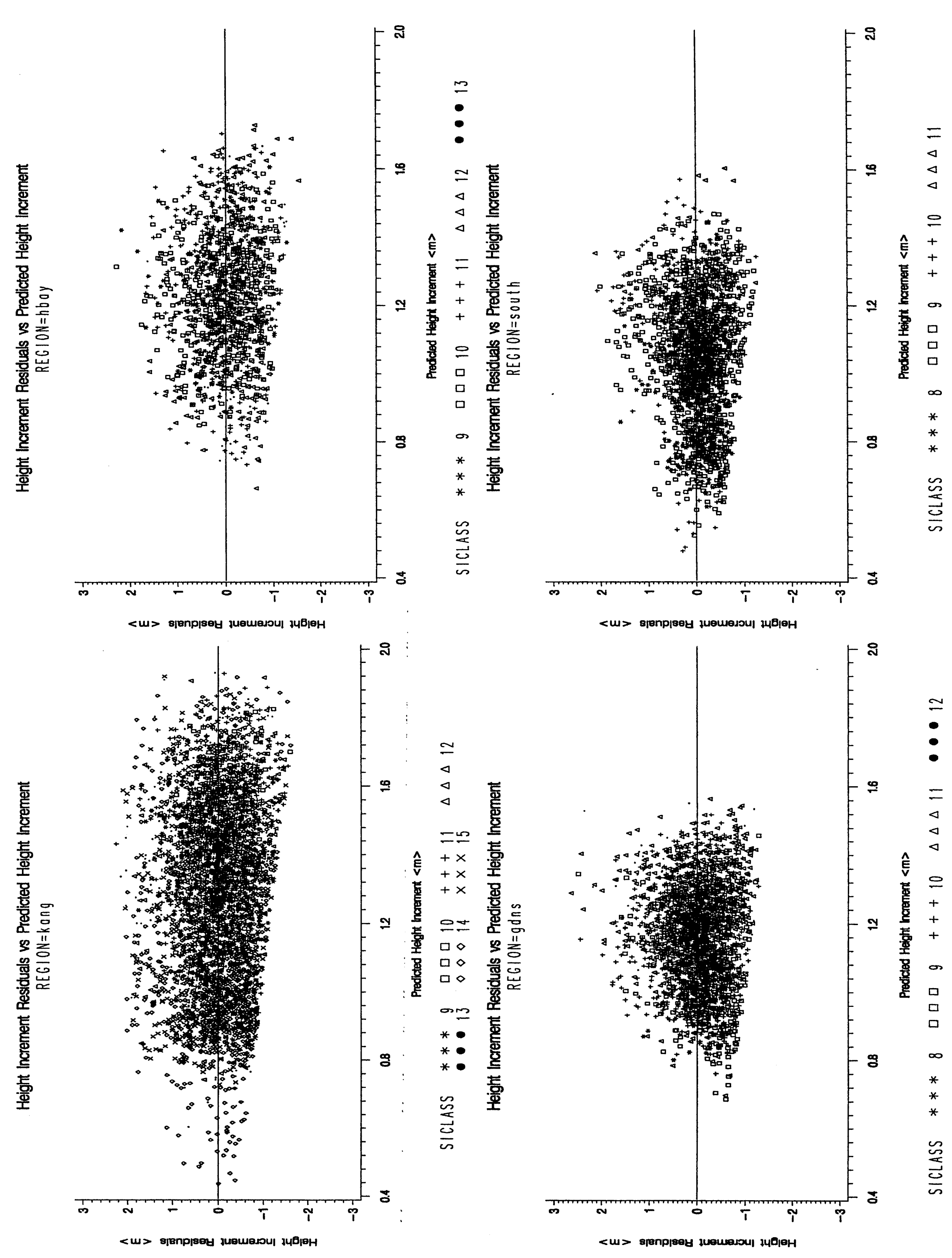



Figure 2a. Tree height increment residuals by predicted tree height increment for the 7 regions.

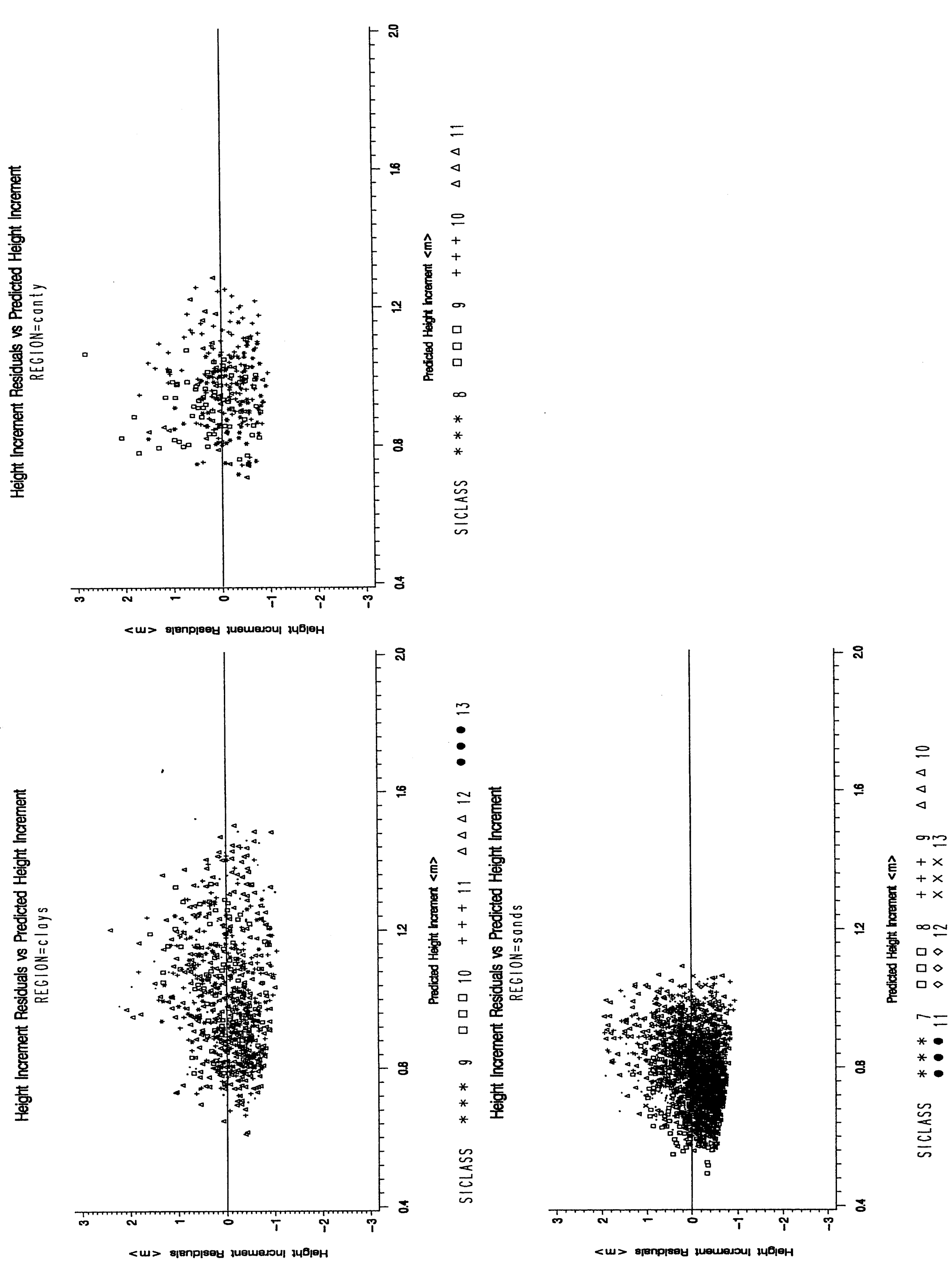



Figure 2b. Tree height increment residuals by predicted tree height increment for the 7 regions.

## TWC diameter and height growth equations

Relative to the other regional diameter and height growth equations (Shula 1997a and1997b), the TWC equations have significantly lower $R^2$ values. For example, the GDNS diameter and height growth equation $R^2$s were 0.56 and 0.17, respectively; but for TWC (**Table 9**), $R^2$s are 0.36, and 0.04, respectively. Despite repeated attempts at uncovering better explanatory variables unique to TWC, explanatory variables similar to GDNS worked best for TWC, but with poorer results. Therefore, it was left to the validation analyses to determine the relative utility to TWC of using either the directly fit TWC equations (Table 9), associated with poorer fit statistics; or in lieu, the GDNS equations (Shula 1997a and1997b), associated with better fit statistics.

**Table 9. TWC diameter and height growth equation parameters, coefficients, and standard errors from the non-linear regression analyses.**

annual $dbh_i$ or $ht_i$ increment = $\exp[\, a_0 + a_1{}^*x_1 + \ldots + a_n x_n \,]$.

| **Attribute** (no. obs.) | **Parameter** | **Coefficient** ($\alpha$=0.05) | **Standard Error** |
|---|---|---|---|
| $dbh_i$ (778) | intercept | 2.14217 | 0.09031 |
| | chg_pdbh | 0.05279 | 0.00416 |
| | bal_dbh | -4.21678 | 0.42323 |
| | sph_rdbh | -0.00041 | 0.00013 |
| | | | |
| $ht_i$ (2715) | intercept | -1.07449 | 0.11331 |
| | bal_dbh$^2$ | -11.07650 | 2.60184 |
| | MTD | 0.02289 | 0.00257 |
| | hpit | 0.03915 | 0.00425 |
| | sqd_ht | -1.05357 | 0.09468 |

**Figures 3 and 4** present $dbh_i$ and $ht_i$ actual increments and residuals by tree size and predicted increments, respectively; predictions are unbiased, although residuals range widely about zero error. For $dbh_i$ and $ht_i$, 62% of the residuals are within 0.5cm of the actual $dbh_i$ increment; while 50% of the residuals are within 0.5m of the actual $ht_i$ increment.

## Validation statistics

Validation statistics revealed that the TWC predictions had marginally better results via the use of the GDNS growth equations, rather than the directly fit TWC growth equations. In this approach, TWC data represented entirely independent data to validate the GDNS equations and to identify the best equations for TWC. While this result is counter-intuitive, the result is accepted, and in the validation statistics that follow, TWC results are based on the ITGM model (as distributed, February 1999) using the GDNS equations, in lieu of, the directly fit TWC equations.

Validation statistics at the stand-level (G, $dbh_q$, N, MTH, MTD) are provided in **Tables 10-14**, and at the tree-level ($dbh_i$ and $ht_i$) in **Tables 15-16**. The tables present validation statistics by Region for identically paired plots at short (about 5 year) and long (about 10 year) projection periods. Because the Regions, CANTY and TWC, only had low numbers of plots (i.e., 5 and 6 plots) available for this identical pairing, **Tables 17-18** (respectively), provide additional validation statistics for these Regions based on the inclusion of all plots (i.e., 11 and 20 plots) suited to a long projection period (i.e., regardless of identical plot pairing with short and long projection periods).

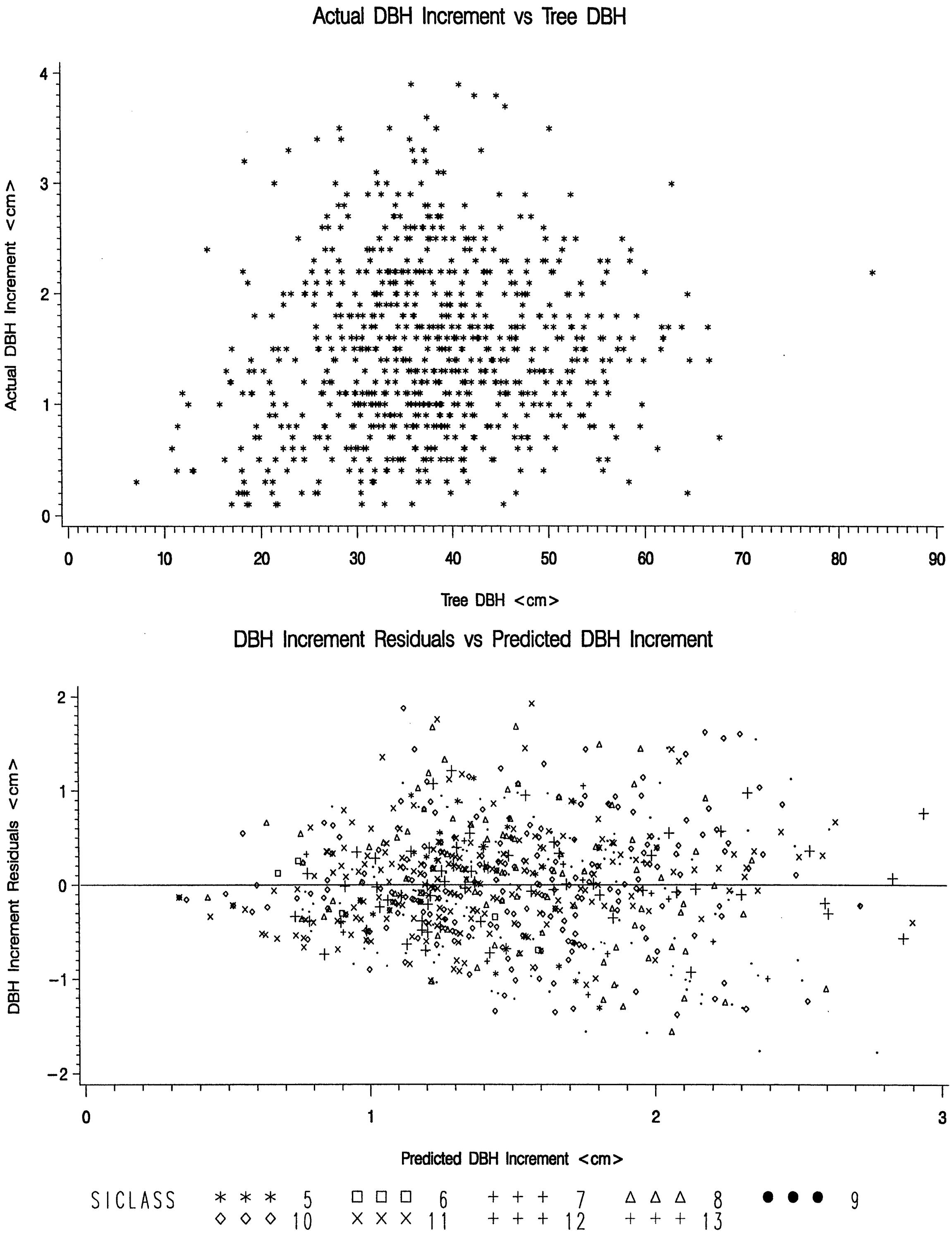



Figure 3. TWC actual tree dbh increments and residuals by tree size and predicted increments.

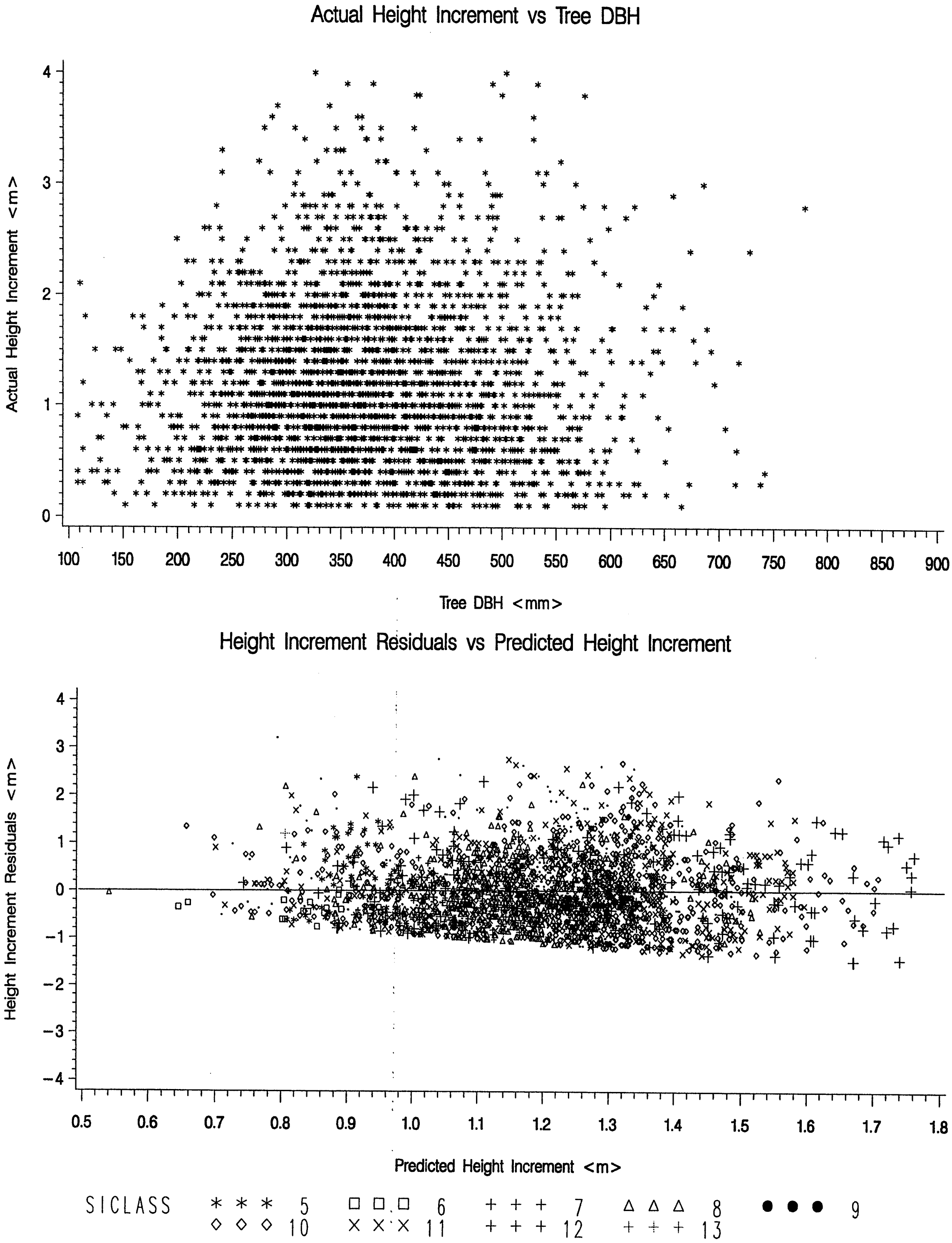



Figure 4. TWC actual tree height increments and residuals by tree size and predicted increments.

<u>Diameter</u>. Generally, tree $dbh_i$ and stand $dbh_q$ (generally, the sub-dominant) are over-predicted, while stand MTD (the dominant) is under-predicted. R-square is usually in the high 80's to mid-90's, and better for the sub-dominant, than for the dominant. Relative to the other Regions, CLAYS and SOUTH, have lower R-square for stand diameter at a long projection period. Mean absolute percent error is usually 3-4% (weighted by the number of plots) for stand diameter, but higher for tree diameter, 5-8% (weighted by the number of trees). In going from the short to long projection period, absolute percent error increases 1-1.5 percent units for stand diameter, but increases 3 percent units for tree diameter. The variability in predicted $dbh_i$ is generally under-represented, but over-represented for MTD.

<u>Height</u>. Generally, tree and stand height are over-predicted. Relative to diameter, R-square is consistently some 20 percent units lower; usually in the low 60's to low-80's, but, better for the dominant (MTH). Relative to the other Regions, CLAYS has a lower R-square for tree $ht_i$ at the long projection period, and a terrible R-square for stand MTH. Mean absolute percent error is usually 3-4% (weighted by the number of plots) for stand MTH, but higher for tree $ht_i$,5-6% (weighted by the number of trees). In going from the short to long projection period, absolute percent error increases $\leq 1$ percent unit for either tree or stand height. The variability in predicted height is increasingly under-represented, in going from the short to long projection period.

<u>Basal Area</u>. Generally, basal area is under-predicted, except for the Regions, CLAYS and CANTY. R-square is usually in the high 80's-90's, but for SOUTH and CANTY at the short projection period, R-square is some 20 percent units lower. At the long projection period, R-square is negative for SOUTH and CANTY. With the inclusion of additional plots, the R-square for CANTY (Table 17) becomes positive (40's), but is still poor. Mean absolute percent error is usually 4-6% (weighted by the number of plots); and in going from the short to long projection period, absolute percent error, generally, doubles. The variability in predicted basal area is increasingly under-represented, in going from the short to long projection period.

<u>Stocking</u>. Generally, stocking is under-predicted, except for the Region, CANTY. (Note: CANTY is the only Region without a survival function, i.e., assumes 100% survival, because mortality was too scarce to warrant modelling.) R-square is usually in the low to high 90's, but for SOUTH, at the long projection period, R-square is in the low 80's. Mean absolute percent error is usually 3-7% (weighted by the number of plots); and in going from the short to long projection period, absolute percent error, generally, doubles. The variability in predicted stocking is decreasingly under-represented, in going from the short to long projection period.

<u>Tree-size Distribution</u>. **Figures 5-12** present actual and predicted diameter distributions of selected plots from the 8 Regions for the short and long projection periods. "Actual" distributions are based only on surviving trees (i.e., actual mortality is excluded), while "predicted" distributions are based on each tree's predicted probability of survival (i.e., predicted mortality is excluded). **Appendix D** provides projection statistics for the selected Regional plots. To represent each Region, plot selection was based on the long projection period using:

a) the plot nearest to a $dbh_i$ variance ratio of 1.0 (i.e., variance of predicted / variance of actual; where, variance = $\Sigma(x_i - xbar)^2 / n$ ), and
b) the plot nearest to a Region's mean $dbh_i$ variance ratio.

These selection criteria were used, as surrogates, to identify:

a) the Regional plot most likely to represent the "best ability" to predict a tree-size distribution, and
b) the Regional plot most likely to represent the "ability on-average" to predict a tree-size distribution.

Note, in Figures 5-12:

- the top set of graphs is the plot nearest to a $dbh_i$ variance ratio of 1.0,
- the left graph is the short projection period,
- the right graph is the long projection period,
- the bottom set of graphs is the plot nearest to the Region's mean $dbh_i$ variance ratio (note: CANTY, one plot represents both, nearest to 1.0 and the mean ratio),
- within any graph, the left and right $dbh_i$ distributions are the actual (a) and predicted (p), respectively,
- the y-axis is stocking (sph) within a $dbh_i$ class, and
- the x-axis is 5 cm $dbh_i$ classes (e.g., 15 cm class is 10 cm < $dbh_i \leq$ 15 cm).

**Table 19** provides mean, standard deviation, minimum, and maximum $dbh_i$ variance ratios by Region, based on the long projection period (9 ≤ period ≤ 13 years). Predicted $dbh_i$ variance is consistently under-represented relative to actual $dbh_i$ variance (except for the Region, CANTY), as indicated by a weighted (by number of plots) mean variance ratio of 0.78 (exclusive of CANTY's ratio, 1.03) and the minimum/maximum variance ratios being skewed slightly towards minimum.

**Table 19. Mean, standard deviation, minimum, and maximum $dbh_i$ variance ratios by Region, based on the long projection period.**

| Region | No. Plots | Long Projection Period (yrs) | Dbh$_i$ Variance Ratio (predicted : actual) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | Std. Dev. | Minimum | Maximum |
| **CNI** | 21 | 13 | 0.77 | 0.18 | 0.48 | 1.14 |
| **GDNS** | 12 | 9 | 0.79 | 0.12 | 0.66 | 1.09 |
| **HBAY** | 12 | 11 | 0.88 | 0.17 | 0.63 | 1.25 |
| **CLAYS** | 13 | 10 | 0.77 | 0.18 | 0.53 | 1.08 |
| **SOUTH** | 10 | 10 | 0.62 | 0.25 | 0.28 | 1.02 |
| **SANDS** | 16 | 11 | 0.80 | 0.25 | 0.40 | 1.32 |
| **CANTY** | 5 | 9 | 1.03 | 0.23 | 0.82 | 1.40 |
| **TWC** | 6 | 10 | 0.81 | 0.12 | 0.62 | 0.94 |

Generally, **Figures 5-12** demonstrate that at low and high stockings, short and long projection periods; the spread in diameter distributions is predicted well. Also, the shape of the distributions are predicted reasonably well, especially with respect to distributions, which start as non-normal, but which become more normally distributed through time (e.g., CNI: Figure 5, top - left to right). The inability to mimic the shape of an actual diameter distribution may be partially attributed to a poor prediction of survival. **Appendix D** reveals that survival is consistently under-predicted (i.e., too much mortality), especially in SOUTH (Figure 9, top-right), where a correspondent inability to mimic the shape of the actual diameter distribution is exhibited.

**Table 10. Validation statistics at the stand-level for basal area ($m^2$/ha) by Region.**

| STATISTIC | CNI | GDNS | HBAY | CLAYS | SOUTH | SANDS | CANTY | TWC |
|---|---|---|---|---|---|---|---|---|
| number of plots | 21 | 12 | 12 | 13 | 10 | 16 | 5 | 6 |
| 1x projection pd. (yrs) | 6 | 5 | 6 | 5 | 5 | 5 | 3 | 5 |
| 2x projection pd. (yrs) | 13 | 9 | 11 | 10 | 10 | 11 | 9 | 10 |
| | | | | | | | | |
| R-square 1x | .96 | .99 | .98 | .99 | .79 | .96 | .72 | .97 |
| R-square 2x | .80 | .97 | .94 | .93 | -.38 | .87 | -.53 | .92 |
| | | | | | | | | |
| Mean error 1x | 1.94 | .59 | .31 | -.36 | 1.46 | .34 | -1.82 | 1.48 |
| Mean error 2x | 3.98 | .93 | 1.84 | -.97 | 2.93 | 1.79 | -4.27 | 2.07 |
| | | | | | | | | |
| Mean % error 1x | 3.20 | .54 | .66 | -.87 | 2.91 | .40 | -3.57 | 4.62 |
| Mean % error 2x | 5.15 | 1.20 | 2.57 | -1.81 | 4.11 | 3.67 | -6.73 | 3.92 |
| | | | | | | | | |
| RMSE 1x | 2.81 | 1.55 | 2.06 | 1.28 | 3.94 | 1.86 | 2.67 | 2.63 |
| RMSE 2x | 6.05 | 3.44 | 4.04 | 2.89 | 7.19 | 3.52 | 6.04 | 4.24 |
| | | | | | | | | |
| Mean abs. error 1x | 2.01 | 1.13 | 1.77 | 1.08 | 3.22 | 1.63 | 2.34 | 2.26 |
| Mean abs. error 2x | 4.43 | 2.50 | 3.12 | 2.43 | 6.30 | 2.98 | 4.89 | 3.64 |
| | | | | | | | | |
| Mean abs. % error 1x | 3.40 | 2.70 | 4.49 | 2.27 | 6.92 | 5.61 | 4.85 | 6.17 |
| Mean abs. % error 2x | 6.15 | 4.48 | 6.39 | 4.22 | 9.66 | 7.26 | 7.88 | 8.39 |
| | | | | | | | | |
| Mean actual 1x | 55.79 | 44.42 | 44.29 | 49.16 | 49.22 | 32.53 | 46.34 | 40.08 |
| Mean predicted 1x | 53.85 | 43.84 | 43.98 | 49.52 | 47.76 | 32.19 | 48.16 | 38.60 |
| | | | | | | | | |
| Mean actual STD 1x | 15.04 | 20.52 | 16.05 | 12.52 | 9.04 | 8.99 | 5.64 | 15.53 |
| Mean predicted STD 1x | 14.14 | 19.71 | 16.35 | 12.19 | 9.66 | 8.78 | 7.65 | 16.50 |
| | | | | | | | | |
| Mean actual 2x | 65.80 | 53.44 | 55.41 | 59.79 | 65.84 | 42.98 | 59.66 | 49.81 |
| Mean predicted 2x | 61.82 | 52.50 | 53.57 | 60.77 | 62.91 | 41.20 | 63.93 | 47.73 |
| | | | | | | | | |
| Mean actual STD 2x | 13.89 | 20.90 | 17.64 | 11.29 | 6.46 | 10.13 | 5.45 | 16.23 |
| Mean predicted STD 2x | 10.83 | 19.77 | 16.89 | 10.57 | 7.36 | 9.50 | 9.60 | 16.73 |

**Table 11. Validation statistics at the stand-level for $dbh_q$ (cm) by Region.**

| STATISTIC | CNI | GDNS | HBAY | CLAYS | SOUTH | SANDS | CANTY | TWC |
|---|---|---|---|---|---|---|---|---|
| number of plots | 21 | 12 | 12 | 13 | 10 | 16 | 5 | 6 |
| 1x projection pd. (yrs) | 6 | 5 | 6 | 5 | 5 | 5 | 3 | 5 |
| 2x projection pd. (yrs) | 13 | 9 | 11 | 10 | 10 | 11 | 9 | 10 |
| | | | | | | | | |
| R-square 1x | .99 | .97 | .93 | .96 | .94 | .95 | .98 | .96 |
| R-square 2x | .98 | .94 | .87 | .70 | .89 | .90 | .96 | .88 |
| | | | | | | | | |
| Mean error 1x | -.25 | -.66 | .13 | -.48 | .56 | -.79 | -.14 | .37 |
| Mean error 2x | -1.00 | -1.24 | .43 | -1.35 | .56 | -1.25 | -.32 | -.15 |
| | | | | | | | | |
| Mean % error 1x | -.76 | -2.08 | .01 | -1.18 | 1.11 | -2.13 | -.55 | 1.13 |
| Mean % error 2x | -2.48 | -3.64 | .44 | -3.04 | .45 | -2.94 | -.92 | -.41 |
| | | | | | | | | |
| RMSE 1x | .83 | .88 | 1.38 | .71 | 1.71 | 1.52 | .54 | 1.37 |
| RMSE 2x | 1.62 | 1.69 | 2.32 | 1.74 | 2.78 | 2.38 | .87 | 2.32 |
| | | | | | | | | |
| Mean abs. error 1x | .67 | .81 | 1.08 | .62 | 1.48 | 1.12 | .50 | 1.23 |
| Mean abs. error 2x | 1.43 | 1.53 | 1.61 | 1.55 | 2.48 | 1.81 | .76 | 2.05 |
| | | | | | | | | |
| Mean abs. % error 1x | 1.91 | 2.61 | 2.38 | 1.60 | 4.23 | 3.03 | 1.57 | 3.57 |
| Mean abs. % error 2x | 3.53 | 4.36 | 3.06 | 3.57 | 6.24 | 4.20 | 2.15 | 5.20 |
| | | | | | | | | |
| Mean actual 1x | 34.6 | 32.2 | 44.5 | 38.5 | 36.1 | 37.1 | 31.0 | 37.9 |
| Mean predicted 1x | 34.9 | 32.9 | 44.4 | 39.0 | 35.6 | 37.9 | 31.2 | 37.5 |
| | | | | | | | | |
| Mean actual STD 1x | 10.8 | 5.5 | 5.3 | 3.5 | 7.6 | 6.9 | 4.8 | 7.8 |
| Mean predicted STD 1x | 10.9 | 5.6 | 4.3 | 3.8 | 7.3 | 7.2 | 4.5 | 8.2 |
| | | | | | | | | |
| Mean actual 2x | 41.1 | 36.9 | 50.5 | 43.2 | 42.8 | 42.9 | 35.6 | 43.5 |
| Mean predicted 2x | 42.1 | 38.2 | 50.1 | 44.5 | 42.3 | 44.2 | 35.9 | 43.6 |
| | | | | | | | | |
| Mean actual STD 2x | 11.0 | 7.0 | 6.8 | 3.3 | 8.8 | 7.8 | 4.7 | 7.4 |
| Mean predicted STD 2x | 11.4 | 6.9 | 5.3 | 4.0 | 8.3 | 8.2 | 4.7 | 7.7 |

**Table 12. Validation statistics at the stand-level for stocking (sph) by Region.**

| STATISTIC | CNI | GDNS | HBAY | CLAYS | SOUTH | SANDS | CANTY | TWC |
|---|---|---|---|---|---|---|---|---|
| number of plots | 21 | 12 | 12 | 13 | 10 | 16 | 5 | 6 |
| 1x projection pd. (yrs) | 6 | 5 | 6 | 5 | 5 | 5 | 3 | 5 |
| 2x projection pd. (yrs) | 13 | 9 | 11 | 10 | 10 | 11 | 9 | 10 |
| | | | | | | | | |
| R-square 1x | .99 | .98 | .99 | .99 | .97 | .98 | .99 | .99 |
| R-square 2x | .91 | .93 | .98 | .98 | .84 | .92 | .91 | .94 |
| | | | | | | | | |
| Mean error 1x | 47 | 41 | 5 | 5 | 31 | 15 | -15 | 8 |
| Mean error 2x | 74 | 64 | 11 | 18 | 67 | 30 | -35 | 17 |
| | | | | | | | | |
| Mean % error 1x | 4.66 | 4.58 | .73 | 1.54 | .63 | 4.58 | -2.02 | 2.47 |
| Mean % error 2x | 9.52 | 7.84 | 1.97 | 4.16 | 2.58 | 9.20 | -4.67 | 4.89 |
| | | | | | | | | |
| RMSE 1x | 68 | 64 | 13 | 11 | 114 | 17 | 19 | 11 |
| RMSE 2x | 105 | 111 | 22 | 20 | 218 | 33 | 49 | 21 |
| | | | | | | | | |
| Mean abs. error 1x | 48 | 41 | 9 | 10 | 45 | 15 | 15 | 8 |
| Mean abs. error 2x | 76 | 64 | 14 | 18 | 86 | 30 | 35 | 20 |
| | | | | | | | | |
| Mean abs. % error 1x | 4.85 | 4.58 | 2.61 | 2.21 | 3.29 | 4.57 | 2.02 | 2.47 |
| Mean abs. % error 2x | 9.84 | 7.84 | 3.95 | 4.16 | 6.81 | 9.20 | 4.67 | 5.93 |
| | | | | | | | | |
| Mean actual 1x | 844 | 654 | 310 | 431 | 632 | 323 | 650 | 356 |
| Mean predicted 1x | 796 | 613 | 305 | 426 | 601 | 308 | 665 | 347 |
| | | | | | | | | |
| Mean actual STD 1x | 581 | 472 | 185 | 159 | 651 | 123 | 205 | 104 |
| Mean predicted STD 1x | 544 | 425 | 174 | 166 | 540 | 118 | 215 | 104 |
| | | | | | | | | |
| Mean actual 2x | 638 | 608 | 303 | 417 | 593 | 322 | 630 | 337 |
| Mean predicted 2x | 564 | 545 | 292 | 400 | 526 | 292 | 665 | 320 |
| | | | | | | | | |
| Mean actual STD 2x | 368 | 424 | 174 | 129 | 565 | 123 | 182 | 96 |
| Mean predicted STD 2x | 310 | 347 | 156 | 124 | 354 | 111 | 215 | 89 |

**Table 13. Validation statistics at the stand-level for MTH (m) by Region.**

| STATISTIC | CNI | GDNS | HBAY | CLAYS | SOUTH | SANDS | CANTY | TWC |
|---|---|---|---|---|---|---|---|---|
| number of plots | 21 | 12 | 12 | 13 | 10 | 16 | 5 | 6 |
| 1x projection pd. (yrs) | 6 | 5 | 6 | 5 | 5 | 5 | 3 | 5 |
| 2x projection pd. (yrs) | 13 | 9 | 11 | 10 | 10 | 11 | 9 | 10 |
| | | | | | | | | |
| R-square 1x | .92 | .88 | .80 | .71 | .73 | .77 | .92 | .86 |
| R-square 2x | .79 | .83 | .77 | .11 | .72 | .66 | .54 | .77 |
| | | | | | | | | |
| Mean error 1x | -.08 | .08 | -.51 | .01 | -.18 | -.30 | -.38 | -.63 |
| Mean error 2x | .15 | -.10 | -.41 | .42 | .33 | -1.11 | .30 | -.32 |
| | | | | | | | | |
| Mean % error 1x | -.31 | -.06 | -1.79 | -.14 | -.98 | -1.28 | -1.69 | -2.15 |
| Mean % error 2x | .25 | -.83 | -1.33 | .76 | .80 | -4.16 | .57 | -.91 |
| | | | | | | | | |
| RMSE 1x | .87 | 1.07 | 1.32 | 1.47 | 1.15 | 1.68 | .71 | 1.03 |
| RMSE 2x | 1.20 | 1.51 | 1.54 | 2.79 | 1.47 | 2.37 | 2.03 | 1.12 |
| | | | | | | | | |
| Mean abs. error 1x | .74 | .87 | 1.09 | 1.18 | .96 | 1.43 | .62 | .77 |
| Mean abs. error 2x | .88 | 1.27 | 1.29 | 2.50 | 1.17 | 2.07 | 1.50 | .88 |
| | | | | | | | | |
| Mean abs. % error 1x | 2.10 | 3.36 | 3.50 | 3.69 | 4.05 | 5.39 | 2.58 | 2.69 |
| Mean abs. % error 2x | 2.05 | 4.30 | 3.56 | 6.78 | 4.03 | 7.04 | 4.77 | 2.70 |
| | | | | | | | | |
| Mean actual 1x | 35.96 | 27.41 | 31.81 | 32.05 | 24.66 | 26.58 | 24.50 | 27.88 |
| Mean predicted 1x | 36.03 | 27.33 | 32.32 | 32.05 | 24.84 | 26.88 | 24.88 | 28.52 |
| | | | | | | | | |
| Mean actual STD 1x | 3.09 | 3.17 | 3.11 | 2.84 | 2.34 | 3.62 | 2.77 | 3.03 |
| Mean predicted STD 1x | 2.81 | 2.51 | 2.68 | 2.64 | 2.05 | 3.75 | 2.51 | 3.56 |
| | | | | | | | | |
| Mean actual 2x | 42.90 | 32.08 | 37.53 | 36.92 | 30.68 | 30.08 | 30.24 | 33.45 |
| Mean predicted 2x | 42.75 | 32.18 | 37.94 | 36.49 | 30.35 | 31.18 | 29.94 | 33.77 |
| | | | | | | | | |
| Mean actual STD 2x | 2.69 | 3.82 | 3.31 | 3.09 | 2.93 | 4.19 | 3.34 | 2.58 |
| Mean predicted STD 2x | 2.19 | 2.79 | 2.53 | 2.47 | 2.41 | 3.78 | 2.31 | 3.04 |

**Table 14. Validation statistics at the stand-level for MTD (cm) by Region.**

| STATISTIC | CNI | GDNS | HBAY | CLAYS | SOUTH | SANDS | CANTY | TWC |
|---|---|---|---|---|---|---|---|---|
| number of plots | 21 | 12 | 12 | 13 | 10 | 16 | 5 | 6 |
| 1x projection pd. (yrs) | 6 | 5 | 6 | 5 | 5 | 5 | 3 | 5 |
| 2x projection pd. (yrs) | 13 | 9 | 11 | 10 | 10 | 11 | 9 | 10 |
| | | | | | | | | |
| R-square 1x | .97 | .96 | .81 | .93 | .80 | .95 | .96 | .96 |
| R-square 2x | .87 | .91 | .71 | .68 | .64 | .91 | .95 | .90 |
| | | | | | | | | |
| Mean error 1x | .56 | -.23 | .08 | .39 | 2.07 | -.41 | -.44 | .80 |
| Mean error 2x | 1.31 | -.00 | .72 | .41 | 3.03 | -.18 | -.16 | .48 |
| | | | | | | | | |
| Mean % error 1x | 1.29 | -.54 | -.03 | .83 | 4.72 | -.91 | -1.21 | 1.75 |
| Mean % error 2x | 2.62 | .07 | .94 | .76 | 5.78 | -.31 | -.36 | .86 |
| | | | | | | | | |
| RMSE 1x | 1.10 | .71 | 1.62 | .82 | 2.86 | 1.51 | .83 | 1.42 |
| RMSE 2x | 2.26 | 1.20 | 2.66 | 1.49 | 4.35 | 2.10 | .83 | 2.04 |
| | | | | | | | | |
| Mean abs. error 1x | .88 | .52 | 1.24 | .70 | 2.17 | 1.19 | .76 | 1.27 |
| Mean abs. error 2x | 1.97 | 1.13 | 1.80 | 1.27 | 3.59 | 1.69 | .64 | 1.58 |
| | | | | | | | | |
| Mean abs. % error 1x | 1.97 | 1.33 | 2.40 | 1.51 | 4.98 | 2.85 | 1.93 | 2.91 |
| Mean abs. % error 2x | 3.70 | 2.49 | 2.97 | 2.47 | 6.87 | 3.43 | 1.37 | 3.29 |
| | | | | | | | | |
| Mean actual 1x | 45.6 | 39.5 | 51.5 | 46.2 | 42.6 | 42.1 | 38.7 | 46.0 |
| Mean predicted 1x | 45.1 | 39.7 | 51.5 | 45.8 | 40.6 | 42.5 | 39.1 | 45.2 |
| | | | | | | | | |
| Mean actual STD 1x | 6.8 | 3.5 | 3.8 | 3.3 | 6.8 | 6.8 | 4.5 | 8.0 |
| Mean predicted STD 1x | 7.1 | 3.8 | 2.7 | 3.2 | 6.6 | 7.1 | 4.3 | 7.9 |
| | | | | | | | | |
| Mean actual 2x | 54.0 | 45.3 | 59.1 | 52.2 | 50.8 | 48.9 | 45.1 | 52.2 |
| Mean predicted 2x | 52.7 | 45.3 | 58.4 | 51.8 | 47.8 | 49.1 | 45.3 | 51.7 |
| | | | | | | | | |
| Mean actual STD 2x | 6.4 | 4.2 | 5.2 | 2.8 | 7.6 | 7.4 | 4.2 | 7.1 |
| Mean predicted STD 2x | 7.5 | 4.7 | 3.4 | 2.9 | 7.7 | 7.8 | 4.3 | 7.1 |

# Table 15. Validation statistics at the tree-level for $dbh_i$ (cm) by Region.

| STATISTIC | CNI | GDNS | HBAY | CLAYS | SOUTH | SANDS | CANTY | TWC |
|---|---|---|---|---|---|---|---|---|
| number of trees | 1352 | 411 | 375 | 384 | 486 | 611 | 160 | 213 |
| 1x projection pd. (yrs) | 6 | 5 | 6 | 5 | 4 | 5 | 3 | 5 |
| number of trees | 1076 | 387 | 368 | 372 | 453 | 610 | 156 | 202 |
| 2x projection pd. (yrs) | 13 | 9 | 11 | 10 | 9 | 10 | 9 | 10 |
| | | | | | | | | |
| R-square 1x | .97 | .96 | .90 | .95 | .95 | .94 | .98 | .94 |
| R-square 2x | .92 | .92 | .82 | .87 | .91 | .85 | .94 | .85 |
| | | | | | | | | |
| Mean error 1x | .00 | -.38 | -.27 | -.41 | .38 | -.43 | -.20 | .44 |
| Mean error 2x | -.18 | -.58 | .23 | -1.04 | .35 | -.50 | -.64 | .09 |
| | | | | | | | | |
| Mean % error 1x | -.23 | -1.57 | -1.07 | -1.41 | .53 | -1.35 | -.88 | .82 |
| Mean % error 2x | -1.14 | -2.58 | -.50 | -3.07 | -.10 | -1.77 | -2.33 | -.68 |
| | | | | | | | | |
| RMSE 1x | 2.06 | 1.59 | 2.83 | 1.73 | 2.45 | 2.01 | .99 | 2.73 |
| RMSE 2x | 4.01 | 2.92 | 4.86 | 3.24 | 4.20 | 3.61 | 2.26 | 4.33 |
| | | | | | | | | |
| Mean abs. error 1x | 1.48 | 1.25 | 2.15 | 1.31 | 1.73 | 1.56 | .80 | 2.10 |
| Mean abs. error 2x | 2.95 | 2.32 | 3.76 | 2.47 | 3.15 | 2.86 | 1.81 | 3.31 |
| | | | | | | | | |
| Mean abs. % error 1x | 4.88 | 4.45 | 5.27 | 3.69 | 5.47 | 4.58 | 2.65 | 6.44 |
| Mean abs. % error 2x | 8.15 | 7.28 | 8.20 | 6.24 | 8.77 | 7.30 | 5.43 | 8.72 |
| | | | | | | | | |
| Mean actual 1x | 30.0 | 29.3 | 41.5 | 37.1 | 29.3 | 35.2 | 30.8 | 36.5 |
| Mean predicted 1x | 30.0 | 29.7 | 41.8 | 37.5 | 29.0 | 35.7 | 31.0 | 36.0 |
| | | | | | | | | |
| Mean actual STD 1x | 12.3 | 8.4 | 9.1 | 7.9 | 11.5 | 8.1 | 7.9 | 10.7 |
| Mean predicted STD 1x | 12.2 | 8.4 | 8.8 | 7.7 | 11.0 | 8.4 | 7.7 | 10.7 |
| | | | | | | | | |
| Mean actual 2x | 37.4 | 33.6 | 46.8 | 41.7 | 34.6 | 40.8 | 35.3 | 42.1 |
| Mean predicted 2x | 37.6 | 34.2 | 46.6 | 42.8 | 34.3 | 41.3 | 35.9 | 42.0 |
| | | | | | | | | |
| Mean actual STD 2x | 14.2 | 10.2 | 11.6 | 8.9 | 13.9 | 9.5 | 9.1 | 11.3 |
| Mean predicted STD 2x | 14.0 | 10.0 | 10.7 | 8.5 | 13.2 | 9.5 | 8.8 | 11.1 |

**Table 16. Validation statistics at the tree-level for $ht_i$ (m) by Region.**

| STATISTIC | CNI | GDNS | HBAY | CLAYS | SOUTH | SANDS | CANTY | TWC |
|---|---|---|---|---|---|---|---|---|
| number of trees | 159 | 85 | 57 | 70 | 107 | 133 | 34 | 57 |
| 1x projection pd. (yrs) | 6 | 5 | 6 | 5 | 5 | 5 | 3 | 5 |
| number of trees | 124 | 81 | 51 | 69 | 72 | 128 | 17 | 47 |
| 2x projection pd. (yrs) | 13 | 9 | 11 | 9 | 10 | 11 | 9 | 10 |
| | | | | | | | | |
| R-square 1x | .83 | .84 | .76 | .74 | .71 | .77 | .78 | .74 |
| R-square 2x | .59 | .77 | .65 | .51 | .66 | .63 | .65 | .51 |
| | | | | | | | | |
| Mean error 1x | -.22 | .05 | -.67 | -.04 | -.04 | .05 | -.22 | .03 |
| Mean error 2x | .17 | -.17 | -.39 | -.36 | .20 | -.76 | .24 | -.05 |
| | | | | | | | | |
| Mean % error 1x | -.82 | -.36 | -2.56 | -.34 | -.65 | -.17 | -1.02 | .44 |
| Mean % error 2x | .11 | -1.63 | -1.56 | -.137 | .14 | -3.34 | .57 | -.23 |
| | | | | | | | | |
| RMSE 1x | 1.65 | 1.53 | 1.78 | 1.89 | 1.49 | 1.83 | 1.23 | 2.02 |
| RMSE 2x | 2.44 | 2.37 | 2.29 | 2.58 | 2.05 | 2.74 | 1.86 | 2.41 |
| | | | | | | | | |
| Mean abs. error 1x | 1.28 | 1.17 | 1.40 | 1.46 | 1.14 | 1.45 | 1.00 | 1.52 |
| Mean abs. error 2x | 1.86 | 1.91 | 1.73 | 2.08 | 1.57 | 2.25 | 1.57 | 1.95 |
| | | | | | | | | |
| Mean abs. % error 1x | 3.79 | 4.80 | 4.76 | 4.77 | 4.99 | 5.50 | 4.27 | 6.00 |
| Mean abs. % error 2x | 4.51 | 6.89 | 4.86 | 5.99 | 5.50 | 7.77 | 5.24 | 6.17 |
| | | | | | | | | |
| Mean actual 1x | 34.81 | 26.12 | 31.03 | 31.00 | 23.40 | 26.58 | 23.92 | 26.74 |
| Mean predicted 1x | 35.03 | 26.07 | 31.70 | 31.05 | 23.44 | 26.52 | 24.15 | 26.71 |
| | | | | | | | | |
| Mean actual STD 1x | 4.07 | 3.81 | 3.65 | 3.74 | 2.78 | 3.84 | 2.64 | 4.04 |
| Mean predicted STD 1x | 3.86 | 3.31 | 3.10 | 3.61 | 2.34 | 3.65 | 2.73 | 4.92 |
| | | | | | | | | |
| Mean actual 2x | 42.02 | 30.59 | 36.83 | 35.18 | 29.24 | 30.17 | 29.64 | 32.89 |
| Mean predicted 2x | 41.85 | 30.76 | 37.22 | 35.54 | 29.04 | 30.93 | 29.40 | 32.94 |
| | | | | | | | | |
| Mean actual STD 2x | 3.83 | 4.95 | 3.91 | 3.73 | 3.54 | 4.48 | 3.27 | 3.50 |
| Mean predicted STD 2x | 3.26 | 3.71 | 2.82 | 3.34 | 2.84 | 3.75 | 3.02 | 4.07 |

**Table 17. Additional validation statistics at the stand- and tree-level for CANTY.**

| STATISTIC | Stand-Level | | | | | Tree-Level | |
|---|---|---|---|---|---|---|---|
| | G ($m^2$/ha) | $dbh_q$ (cm) | N (sph) | MTH (m) | MTD (cm) | $dbh_i$ (cm) | $ht_i$ (m) |
| number of plots or trees | 11 | | | | | 387 | 42 |
| 2x projection pd. (yrs) | 9 | | | | | 9 | 8 |
| R-square 2x | .43 | .97 | .90 | .77 | .89 | .90 | .72 |
| Mean error 2x | -2.86 | -.15 | -24 | .46 | .62 | -.63 | .25 |
| Mean % error 2x | -4.52 | -.41 | -3.66 | 1.13 | 1.24 | -2.62 | .56 |
| RMSE 2x | 5.74 | .72 | 42 | 1.57 | 1.53 | 3.05 | 1.83 |
| Mean abs. error 2x | 4.89 | .62 | 33 | 1.32 | 1.13 | 2.32 | 1.52 |
| Mean abs. % error 2x | 7.58 | 1.68 | 5.11 | 4.07 | 2.29 | 6.74 | 4.91 |
| Mean actual 2x | 64.57 | 37.7 | 596 | 31.83 | 48.4 | 37.0 | 30.87 |
| Mean predicted 2x | 67.43 | 37.9 | 620 | 31.36 | 47.8 | 37.7 | 30.62 |
| Mean actual STD 2x | 8.00 | 4.1 | 142 | 3.42 | 4.7 | 9.4 | 3.51 |
| Mean predicted STD 2x | 9.08 | 4.1 | 161 | 2.53 | 4.8 | 8.8 | 3.21 |

**Table 18. Additional validation statistics at the stand- and tree-level for TWC.**

| STATISTIC | Stand-Level | | | | | Tree-Level | |
|---|---|---|---|---|---|---|---|
| | G ($m^2$/ha) | $dbh_q$ (cm) | N (sph) | MTH (m) | MTD (cm) | $dbh_i$ (cm) | $ht_i$ (m) |
| number of plots or trees | 20 | | | | | 444 | 178 |
| 2x projection pd. (yrs) | 10 | | | | | 10 | 10 |
| R-square 2x | .80 | .86 | .85 | .53 | .82 | .84 | .54 |
| Mean error 2x | . 08 | .22 | -3 | -.92 | .56 | .53 | -.36 |
| Mean % error 2x | -2.10 | .58 | -3.23 | -3.46 | .99 | .85 | -1.65 |
| RMSE 2x | 5.08 | 2.16 | 31 | 2.50 | 2.33 | 4.30 | 2.99 |
| Mean abs. error 2x | 4.44 | 1.74 | 24 | 2.00 | 1.94 | 3.31 | 2.46 |
| Mean abs. % error 2x | 13.00 | 4.28 | 10.71 | 6.72 | 3.99 | 8.86 | 8.51 |
| Mean actual 2x | 38.71 | 43.5 | 265 | 31.18 | 49.8 | 41.9 | 30.24 |
| Mean predicted 2x | 38.63 | 43.3 | 269 | 32.10 | 49.3 | 41.4 | 30.60 |
| Mean actual STD 2x | 11.54 | 5.9 | 84 | 3.73 | 5.6 | 10.7 | 4.41 |
| Mean predicted STD 2x | 10.59 | 6.4 | 78 | 3.11 | 5.4 | 10.9 | 4.35 |

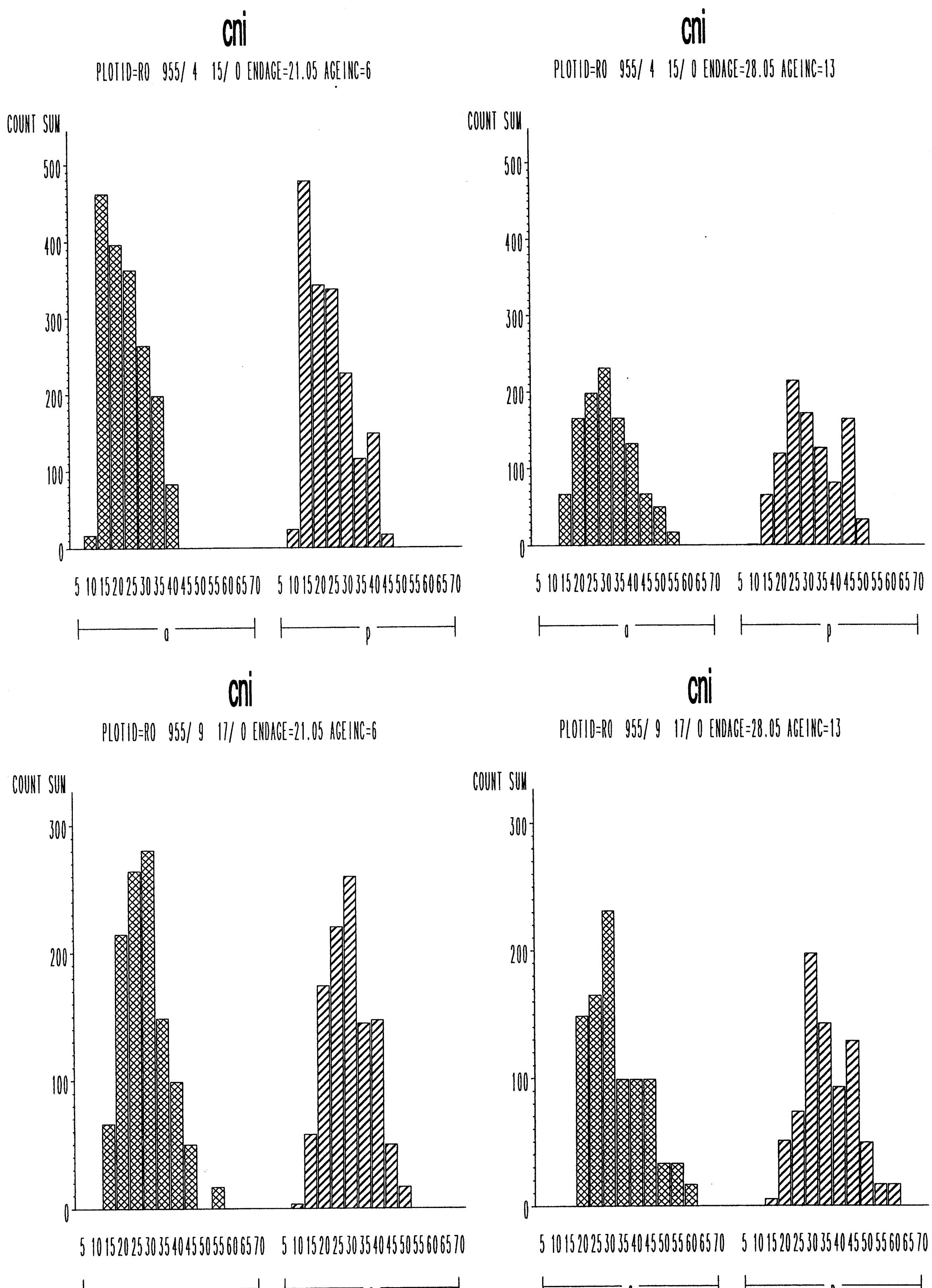



Figure 5. CNI actual (a) and predicted (p) diameter distributions of selected plots for the short and long projection periods. From left to right set: short and long projection periods. From top to bottom set: the plot nearest to a $dbh_i$ variance ratio of 1.0 and the plot nearest to the region's mean $dbh_i$ variance ratio.

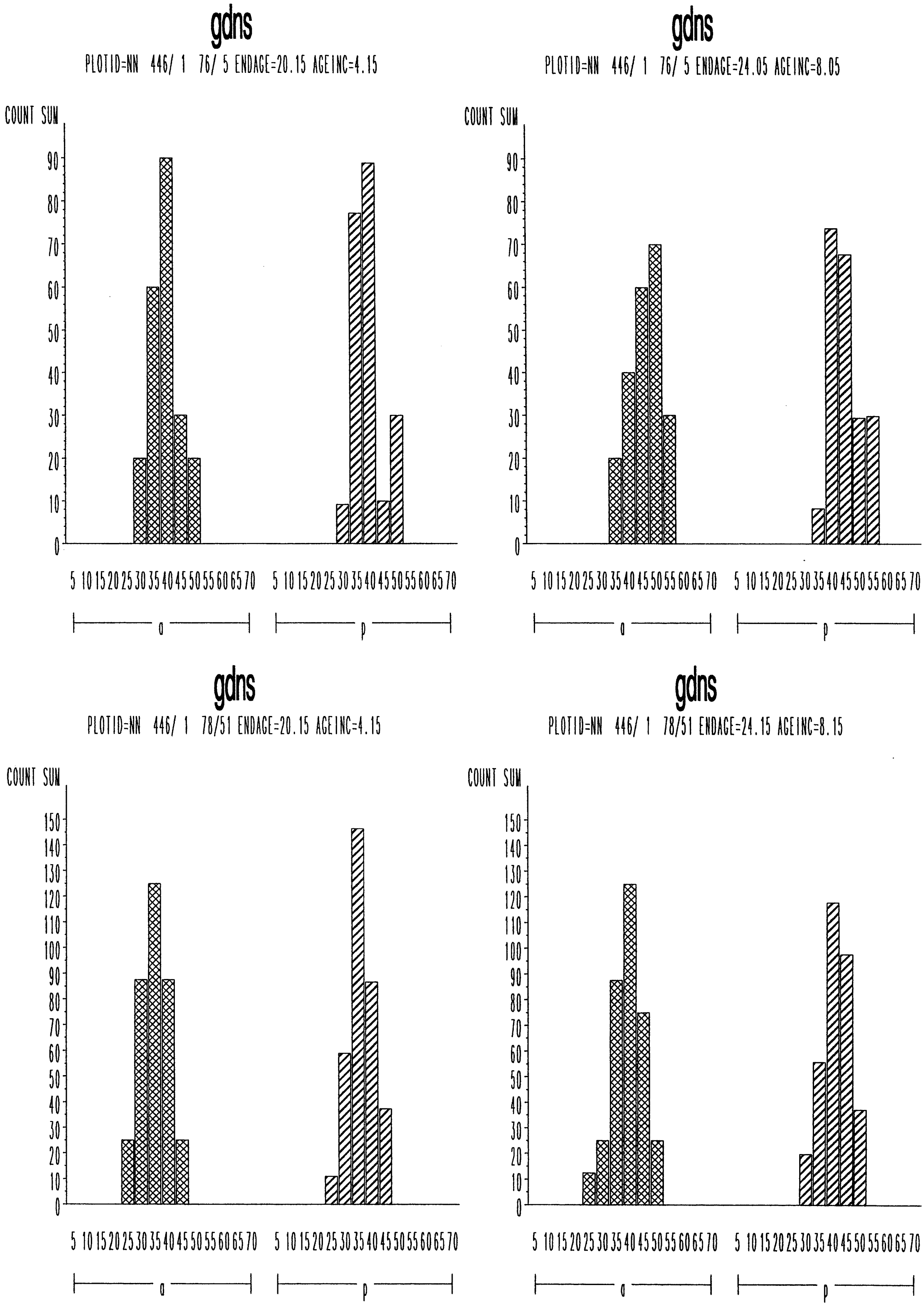



Figure 6. GDNS actual and predicted diameter distributions of selected plots for the short and long projection periods. From left to right set: short and long projection periods. From top to bottom set: the plot nearest to a $dbh_i$ variance ratio of 1.0 and the plot nearest to the region's mean $dbh_i$ variance ratio.

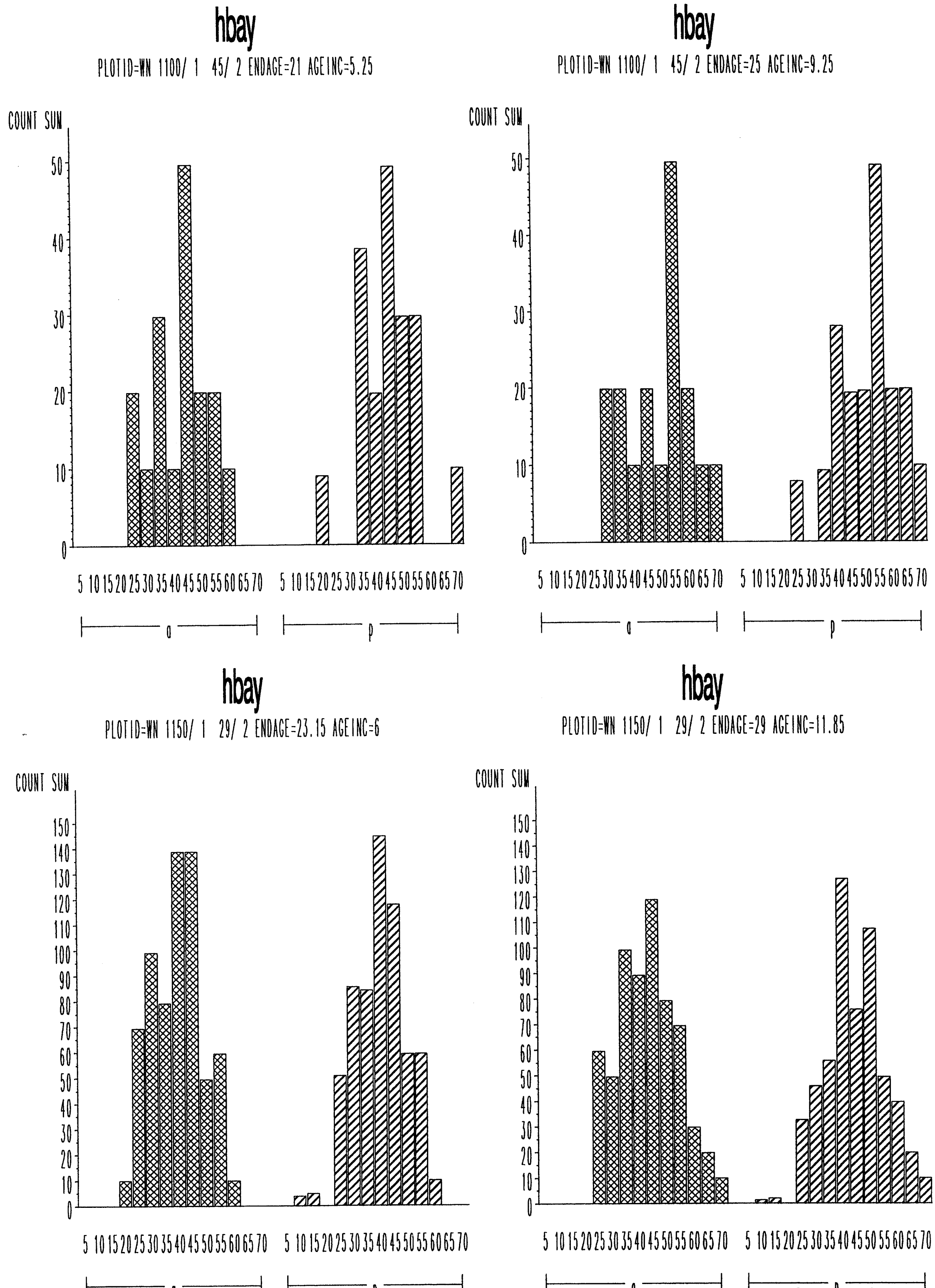



Figure 7. HBAY actual (a) and predicted (p) diameter distributions of selected plots for the short and long projection periods. From left to right set: short and long projection periods. From top to bottom set: the plot nearest to a $dbh_i$ variance ratio of 1.0 and the plot nearest to the region's mean $dbh_i$ variance ratio.

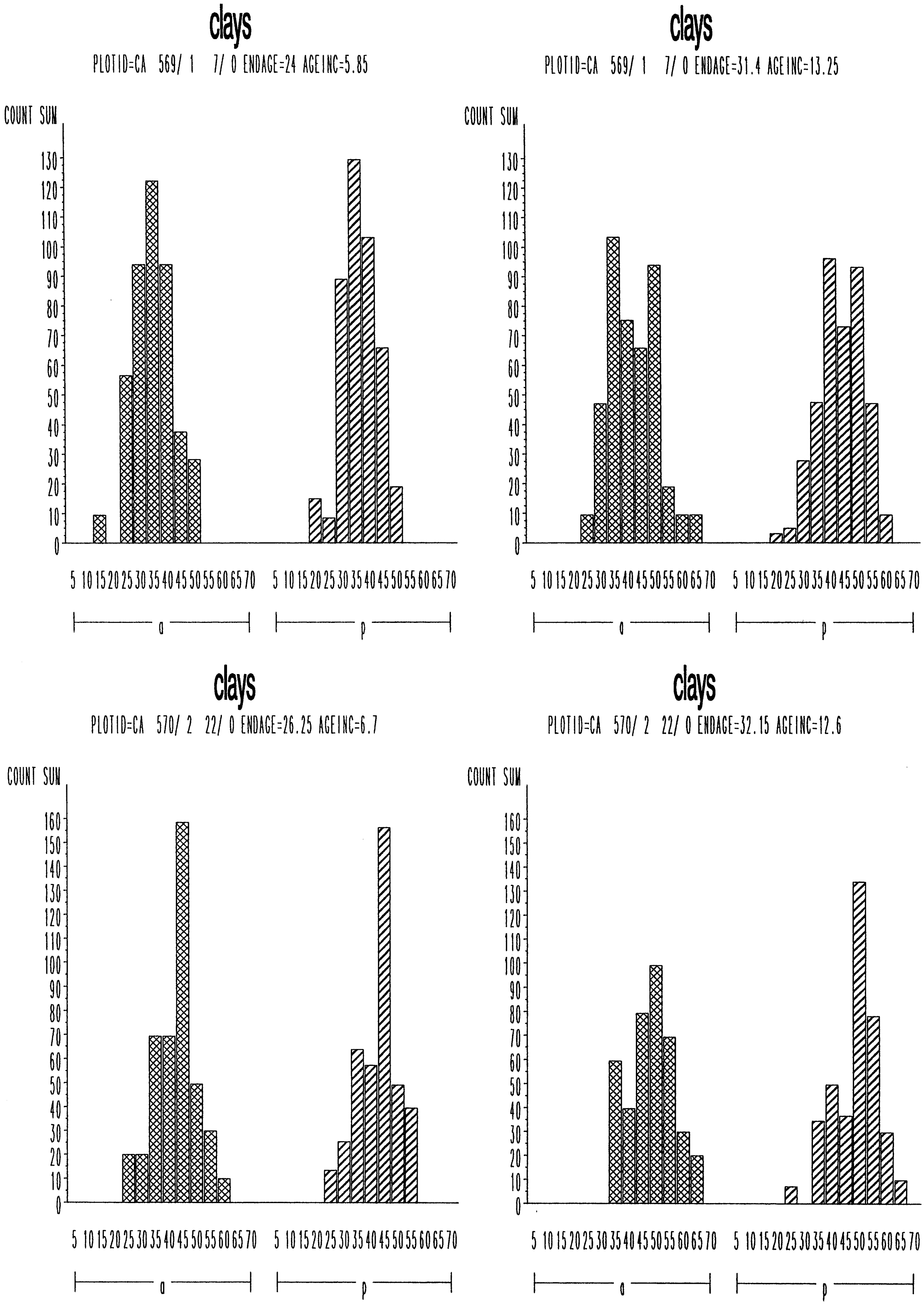



Figure 8. CLAYS actual (a) and predicted (p) diameter distributions of selected plots for the short and long projection periods. From left to right set: short and long projection periods. From top to bottom set: the plot nearest to a $dbh_i$ variance ratio of 1.0 and the plot nearest to the region's mean $dbh_i$ variance ratio.

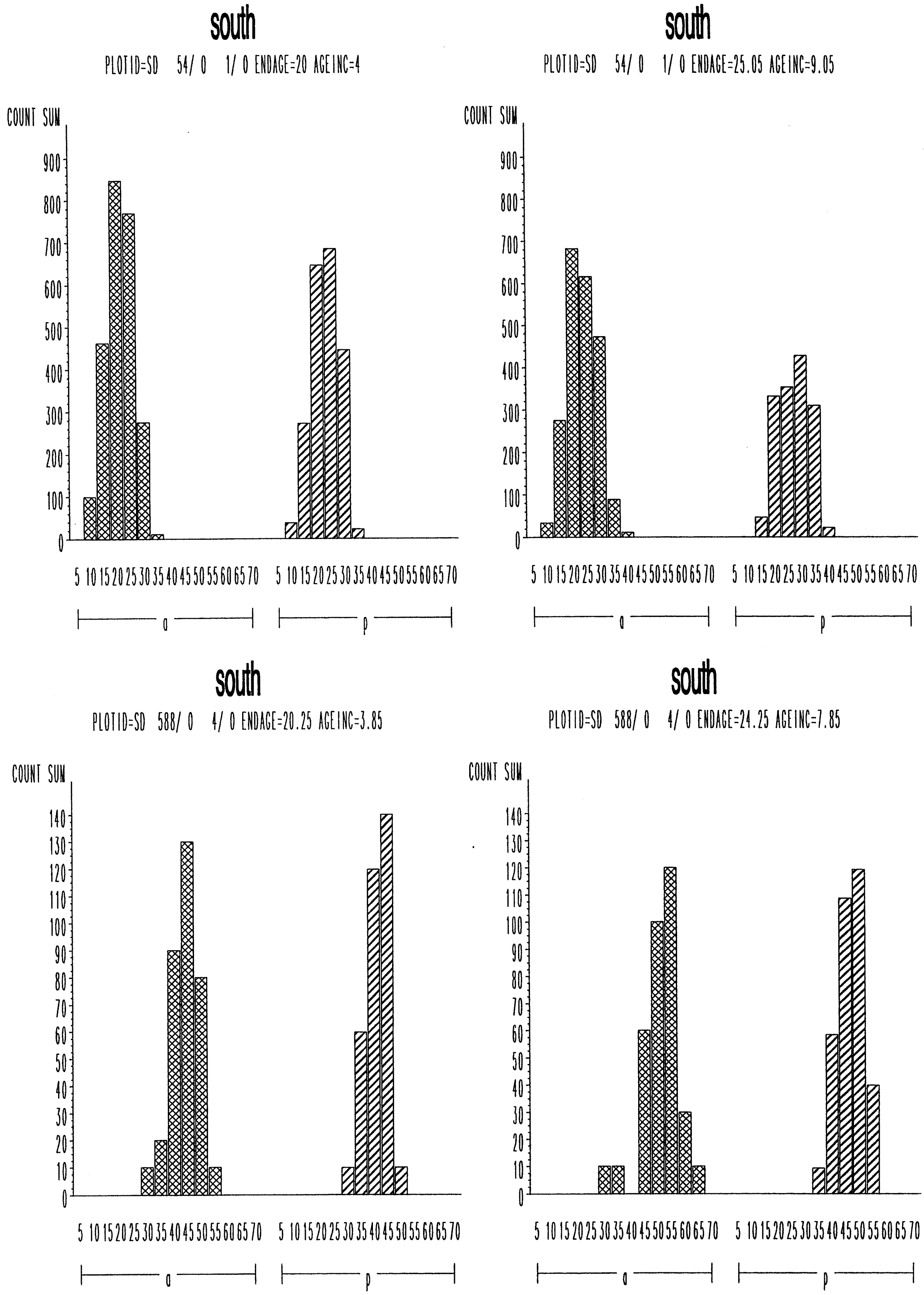



Figure 9. SOUTH actual (a) and predicted (p) diameter distributions of selected plots for the short and long projection periods. From left to right set: short and long projection periods. From top to bottom set: the plot nearest to a $dbh_i$ variance ratio of 1.0 and the plot nearest to the region's mean $dbh_i$ variance ratio.

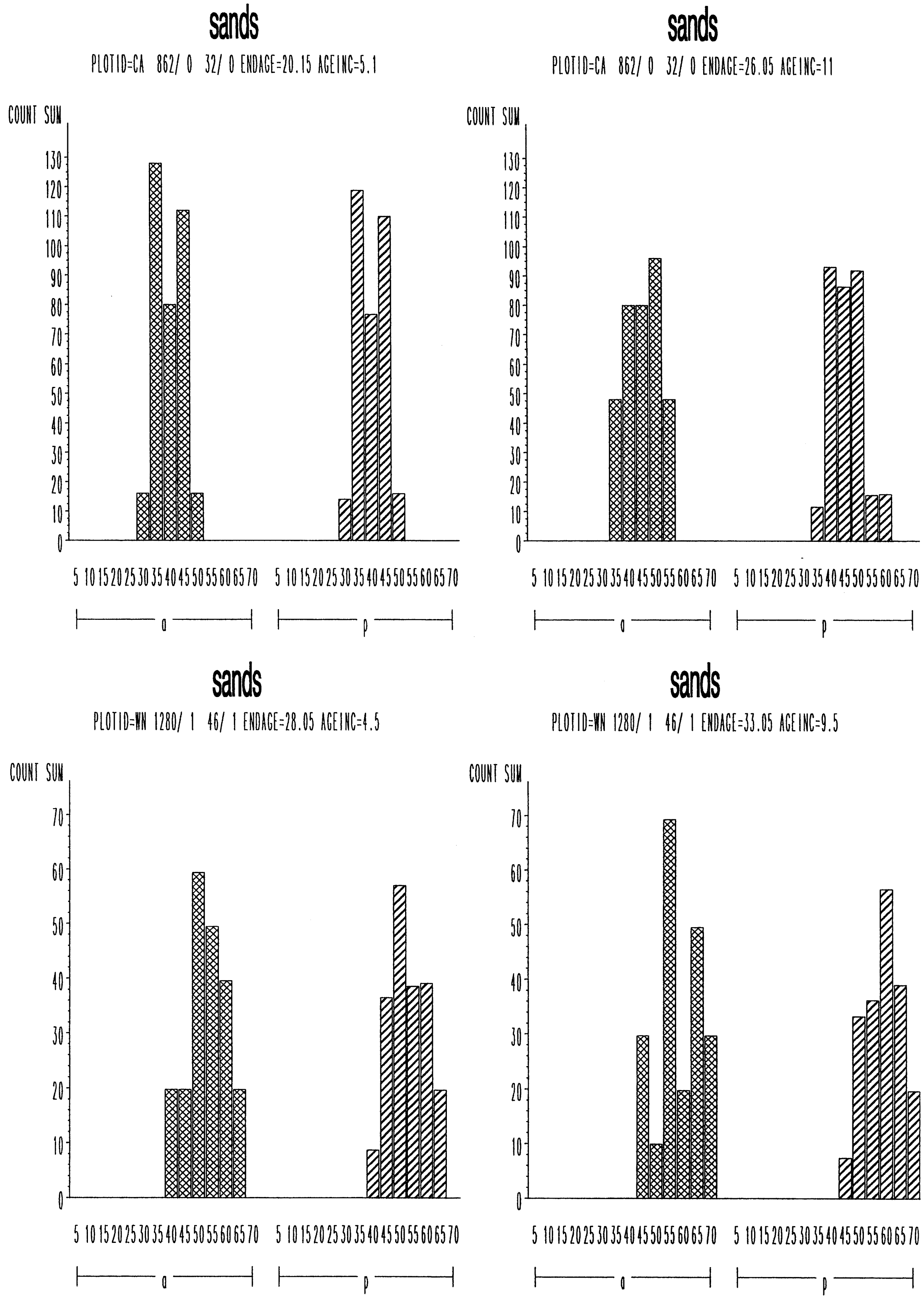
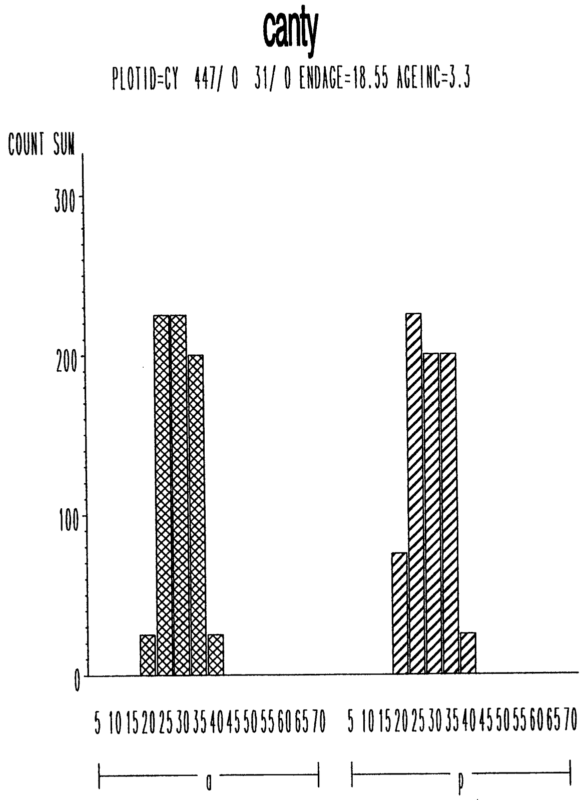



Figure 10. SANDS actual (a) and predicted (p) diameter distributions of selected plots for the short and long projection periods. From left to right set: short and long projection periods. From top to bottom set: the plot nearest to a $dbh_i$ variance ratio of 1.0 and the plot nearest to the region's mean $dbh_i$ variance ratio.



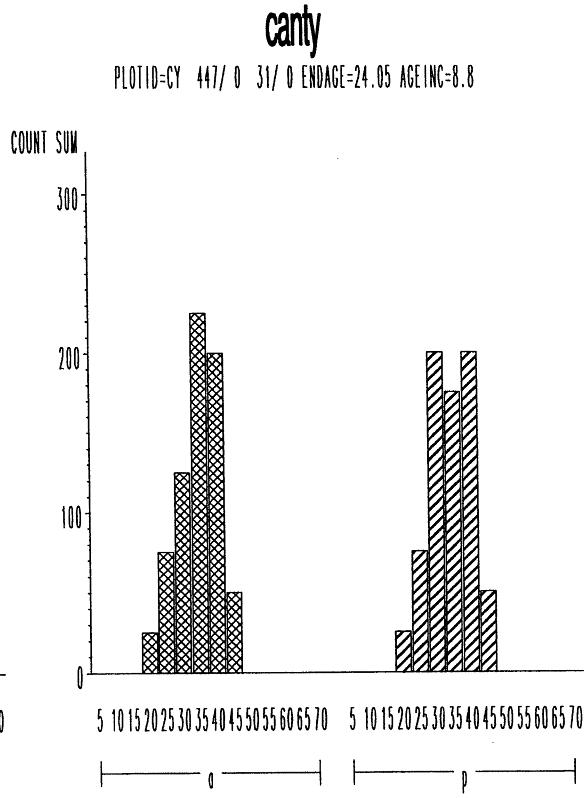




Figure 11. CANTY actual (a) and predicted (p) diameter distributions of selected plots for the short and long projection periods. From left to right set: short and long projection periods. From top to bottom set: the plot nearest to a $dbh_i$ variance ratio of 1.0 and the plot nearest to the region's mean $dbh_i$ variance ratio.

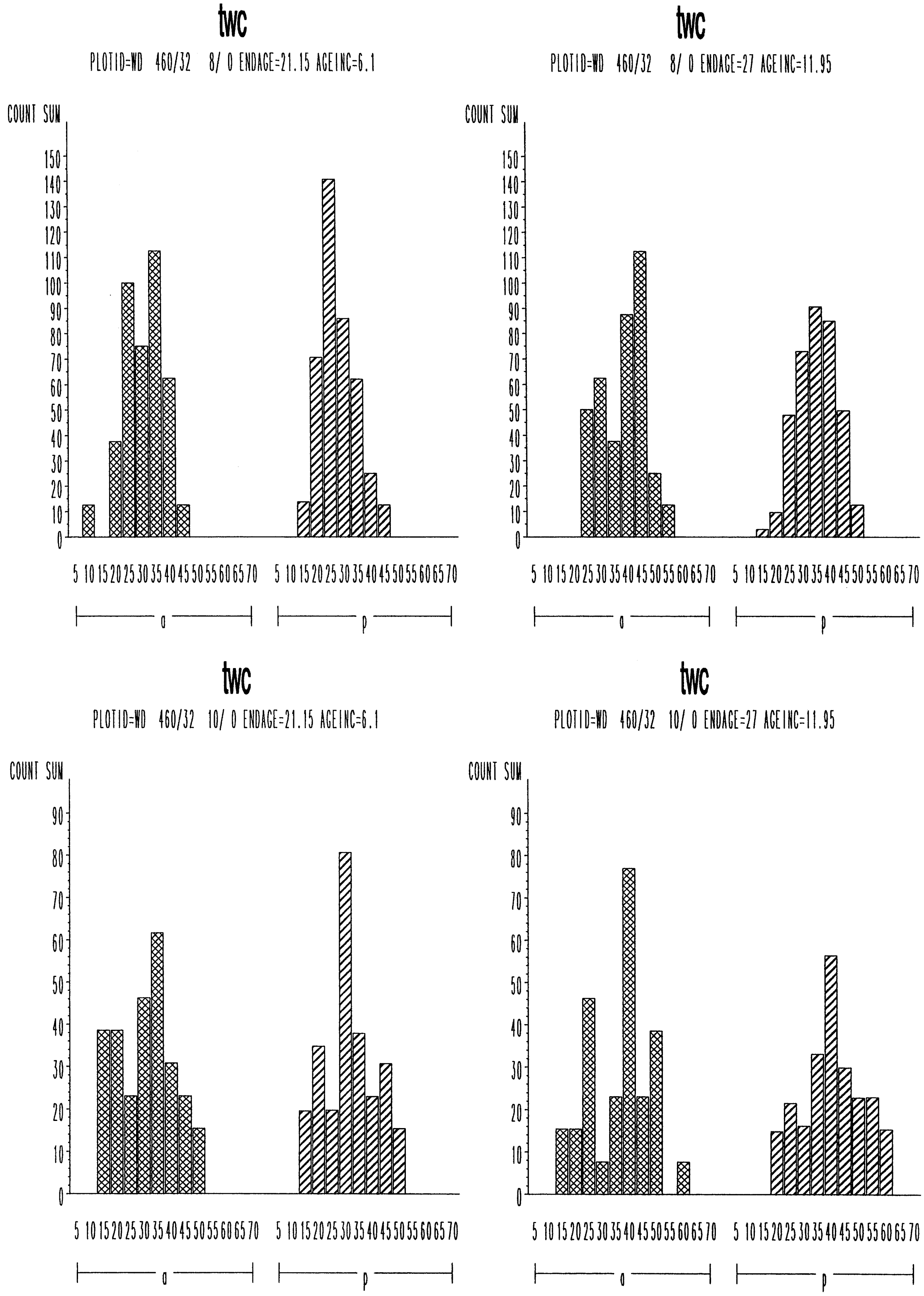



Figure 12. TWC actual (a) and predicted (p) diameter distributions of selected plots for the short and long projection periods. From left to right set: short and long projection periods. From top to bottom set: the plot nearest to a $dbh_i$ variance ratio of 1.0 and the plot nearest to the region's mean $dbh_i$ variance ratio.

# DISCUSSION

## General

The validation exercise, while not strictly "independent", is at least very much quasi-independent. This is because so few observations were used to develop the prediction equations (both in total number and random selection), relative to the observations contributing to the validation exercise. Also, the validation exercise is based on the prediction equations (diameter and height increment, and survival) working as an iterative prediction system, contrary to the original fitting of separate equations at single, points-in-time.

The validation exercise has focused on very discriminate time periods of prediction, i.e., a given "short" time period (say, 5 years), and a strictly complementary "long" time period (say, twice the length of the "short", i.e., 10 years). This approach allows for critical examination of compounded error of prediction, i.e., cascading error, on a strictly one-to-one comparative basis.

## Height prediction

The $R^2$ for the prediction of annual $ht_l$ increment is significantly less, than that from the prediction of static $ht_l$ / MTH ratio, but this is largely a mathematical artefact. A reduction in the variability of the observed (going from $ht_l$ increment to $ht_l$ / MTH ratio) with a corresponding increase in the variability of the predicted (going from $ht_l$ / MTH ratio to $ht_l$ increment) contrives to mathematically produce, by default, a lower $R^2$ value. Unfortunately, the prediction of interest, annual $ht_l$ increment, is by nature, highly variable and less correlated with tree-size attributes, than annual $dbh_l$ increment. Nonetheless, 60-80 percent of predicted observations are within $\pm$ 0.50 to 0.75m of the actual $ht_i$ increment.

Even though the direct prediction of $ht_i$ increment has low $R^2$ values, the validation exercise has established that this prediction approach is superior to the use of the $ht_l$ / MTH ratio prediction approach, which resulted in severely biased $ht_i$ increment predictions.

The utility of regional dummy variables in the $ht_l$ prediction equation, suggests that separate, specific regional $ht_i$ increment equations should be investigated, similar to the regionally specific $dbh_l$ increment equations. This regional approach may identify regionally specific explanatory variables, which may result in improved $R^2$ values.

## TWC equations

The results of directly fitting TWC $dbh_l$ and $ht_l$ increment equations suggest that TWC and GDNS can be modelled similarly (using the same explanatory variables), but with less confidence in Westland. But once again, complete reliance on regression $R^2$ is dodgy, as directly fit TWC equations had significantly poorer $R^2$ than GDNS, but the validation exercise revealed only marginally better validation statistics with the use of GDNS equations, instead of directly fit TWC equations.

Until further investigations prove otherwise, TWC will be represented with GDNS growth equations in ITGM, as validation results fully support this.

## Validation statistics

Validation statistics reveal that, on-average, 5 to10 year tree- and stand-level diameter and height prediction error is generally ≤ 3% (usually over-predicted), while absolute prediction error is generally ≤ 7%. Accompanying predicted tree-diameter distributions generally appear reasonable, and skewed and multi-modal diameter distributions (i.e., other than "normal") are accommodated well. These results indicate that ITGM, as an iterative prediction system for mid-rotation onward tree and stand growth and survival, operates within acceptable error limits without any obvious anomalies or mechanistic mathematical flaws.

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## APPENDIX A:

### Regional PSPs and Simulation Start- and End-ages (short- and long-term)

**CNI**

| plotid | startage | endage1 | endage2 |
|---|---|---|---|
| RO 416/ 0 0/ 0 | 16.00 | 23.00 | 31.00 |
| RO 421/ 0 0/ 0 | 15.15 | 21.05 | 27.05 |
| RO 464/ 0 0/ 0 | 16.05 | 22.00 | 29.00 |
| RO 488/ 0 3/ 0 | 15.40 | 21.40 | 28.25 |
| RO 685/ 2 7/ 0 | 15.25 | 22.25 | 30.15 |
| RO 690/ 0 3/ 0 | 15.15 | 21.05 | 27.05 |
| RO 693/ 0 0/ 0 | 16.00 | 22.00 | 28.00 |
| RO 695/ 1 16/ 0 | 15.15 | 22.15 | 30.15 |
| RO 696/ 1 15/ 0 | 15.15 | 21.15 | 27.15 |
| RO 746/ 0 0/ 0 | 15.15 | 21.15 | 27.05 |
| RO 911/ 1 1/ 0 | 22.05 | 26.65 | 32.25 |
| RO 955/ 4 5/ 0 | 15.05 | 21.05 | 28.05 |
| RO 955/ 4 13/ 0 | 15.05 | 21.05 | 28.05 |
| RO 955/ 4 15/ 0 | 15.05 | 21.05 | 28.05 |
| RO 955/ 6 9/ 0 | 15.05 | 21.05 | 28.05 |
| RO 955/ 6 11/ 0 | 15.05 | 21.05 | 28.05 |
| RO 955/ 6 20/ 0 | 15.05 | 21.05 | 28.05 |
| RO 955/ 7 18/ 0 | 15.05 | 21.15 | 28.00 |
| RO 955/ 7 25/ 0 | 15.05 | 21.15 | 28.00 |
| RO 955/ 9 15/ 0 | 15.05 | 21.05 | 28.05 |
| RO 955/ 9 17/ 0 | 15.05 | 21.05 | 28.05 |

**GDNS**

| plotid | startage | endage1 | endage2 |
|---|---|---|---|
| NN 183/ 0 1/ 0 | 20.55 | 26.40 | 32.05 |
| NN 278/ 1 9/ 0 | 16.15 | 22.00 | 27.00 |
| NN 278/ 1 13/ 0 | 16.15 | 22.00 | 28.00 |
| NN 376/ 0 1/ 0 | 15.05 | 19.00 | 23.05 |
| NN 446/ 1 76/ 5 | 16.00 | 20.15 | 24.05 |
| NN 446/ 1 77/ 1 | 15.00 | 19.25 | 23.05 |
| NN 446/ 1 78/26 | 16.00 | 20.15 | 24.15 |
| NN 446/ 1 78/51 | 16.00 | 20.15 | 24.15 |
| NN 446/ 2 77/ 8 | 15.00 | 20.25 | 26.00 |
| NN 462/ 0 69/ 4 | 16.00 | 20.00 | 24.00 |
| NN 462/ 0 69/ 5 | 16.00 | 20.00 | 24.00 |
| NN 462/ 0 69/10 | 17.00 | 21.00 | 25.00 |

**HBAY**

| plotid | startage | endage1 | endage2 |
|---|---|---|---|
| WN 1100/ 1 35/ 2 | 15.00 | 21.00 | 27.00 |
| WN 1100/ 1 42/ 3 | 19.25 | 22.85 | 26.00 |
| WN 1100/ 1 45/ 1 | 17.75 | 24.00 | 29.00 |
| WN 1100/ 1 45/ 2 | 15.75 | 21.00 | 25.00 |
| WN 1100/ 1 47/ 1 | 16.95 | 20.75 | 24.00 |
| WN 1100/ 1 63/ 1 | 15.75 | 22.00 | 27.00 |
| WN 1150/ 1 29/ 1 | 17.15 | 23.15 | 29.00 |
| WN 1150/ 1 29/ 2 | 17.15 | 23.15 | 29.00 |
| WN 1150/ 1 36/ 7 | 16.15 | 22.05 | 28.00 |
| WN 1150/ 1 39/ 3 | 15.15 | 21.15 | 27.00 |
| WN 1150/ 1 50/ 1 | 15.55 | 21.00 | 27.00 |
| WN 1320/ 1 220/ 1 | 16.75 | 23.00 | 29.00 |

**CLAYS**

| plotid | startage | endage1 | endage2 |
|---|---|---|---|
| AK 286/ 1 5/ 0 | 16.00 | 20.00 | 25.15 |
| AK 286/ 2 3/ 0 | 16.00 | 20.00 | 25.15 |
| AK 286/ 3 5/ 0 | 16.00 | 20.00 | 25.15 |
| AK 286/ 3 6/ 0 | 16.00 | 20.00 | 25.15 |
| AK 401/ 0 7/ 0 | 21.15 | 26.15 | 30.15 |
| AK 401/ 0 9/ 0 | 15.05 | 19.65 | 24.15 |
| AK 401/ 0 11/ 0 | 25.15 | 29.15 | 33.00 |
| AK 458/ 1 3/ 0 | 21.00 | 24.85 | 29.15 |
| AK 501/ 4 5/ 0 | 17.15 | 22.00 | 27.55 |
| CA 569/ 1 7/ 0 | 18.15 | 24.00 | 31.40 |
| CA 570/ 2 22/ 0 | 19.55 | 26.25 | 32.15 |
| CA 656/ 0 8/ 0 | 16.00 | 20.75 | 24.25 |
| CA 656/ 0 20/ 0 | 16.00 | 20.75 | 24.25 |

**SOUTH**

| plotid | startage | endage1 | endage2 |
|---|---|---|---|
| SD 54/ 0 1/ 0 | 16.00 | 20.00 | 25.05 |
| SD 170/ 0 1/ 0 | 15.00 | 21.05 | 27.05 |
| SD 170/ 0 22/ 0 | 15.85 | 20.25 | 26.00 |
| SD 180/ 0 22/ 0 | 16.15 | 21.05 | 26.05 |
| SD 180/ 0 23/ 0 | 16.00 | 20.55 | 26.00 |
| SD 180/ 0 24/ 0 | 16.55 | 23.25 | 29.00 |
| SD 188/ 0 22/ 0 | 15.15 | 21.05 | 27.25 |
| SD 588/ 0 2/ 0 | 16.40 | 20.25 | 24.25 |
| SD 588/ 0 3/ 0 | 16.40 | 20.25 | 24.25 |
| SD 588/ 0 4/ 0 | 16.40 | 20.25 | 24.25 |

**SANDS**

| plotid | startage | endage1 | endage2 |
|---|---|---|---|
| AK 35/ 0 14/ 0 | 18.05 | 22.05 | 27.05 |
| AK 35/ 0 16/ 0 | 15.15 | 22.05 | 30.00 |
| AK 964/ 0 7/ 0 | 24.00 | 30.00 | 37.00 |
| CA 242/ 0 3/ 0 | 24.00 | 27.75 | 31.95 |
| CA 427/ 0 2/ 0 | 25.25 | 29.25 | 33.85 |
| CA 427/ 0 3/ 0 | 25.25 | 29.25 | 33.85 |
| CA 434/ 0 4/ 0 | 17.85 | 24.00 | 31.05 |
| CA 862/ 0 15/ 0 | 15.00 | 20.15 | 26.05 |
| CA 862/ 0 27/ 0 | 15.15 | 20.00 | 26.05 |
| CA 862/ 0 32/ 0 | 15.05 | 20.15 | 26.05 |
| CA 862/ 0 52/ 0 | 15.00 | 19.15 | 23.15 |
| WN 154/ 0 1/ 0 | 16.00 | 20.00 | 25.05 |
| WN 1280/ 1 37/ 6 | 16.65 | 23.15 | 29.00 |
| WN 1280/ 1 46/ 1 | 23.55 | 28.05 | 33.05 |
| WN 1300/ 1 107/ 3 | 15.40 | 21.00 | 26.00 |
| WN 1300/ 1 107/ 4 | 15.40 | 21.00 | 26.00 |

**CANTY**

| plotid | startage | endage1 | endage2 |
|---|---|---|---|
| CY 447/ 0 6/ 0 | 16.25 | 19.55 | 25.05* |
| CY 447/ 0 8/ 0 | 16.25 | 19.55 | 25.05* |
| CY 447/ 0 17/ 0 | 16.25 | 19.55 | 25.05* |
| CY 447/ 0 31/ 0 | 15.25 | 18.55 | 24.05* |
| CY 560/ 2 1/ 0 | 20.00 | 23.00 | 28.00 |
| CY 560/ 2 1/ 0 | 20.00 | 27.00* | - |
| CY 189/ 0 1/ 0 | 20.00 | 29.85* | - |
| CY 432/ 0 1/ 0 | 17.00 | 28.15* | - |
| CY 432/ 0 2/ 0 | 20.05 | 28.15* | - |
| CY 432/ 0 3/ 0 | 17.00 | 28.15* | - |
| CY 432/ 0 4/ 0 | 15.15 | 25.05* | - |
| CY 432/ 0 5/ 0 | 18.05 | 25.05* | - |

**TWC**

| plotid | startage | endage1 | endage2 |
|---|---|---|---|
| WD 98/ 0 0/ 0 | 19.25 | 23.00 | 26.05 |
| WD 369/ 0 1/ 0 | 17.40 | 23.00 | 29.15* |
| WD 417/ 3 4/ 0 | 15.00 | 19.00 | 24.00 |
| WD 417/ 3 4/ 0 | 15.00 | 25.00* | - |
| WD 460/14 83/ 0 | 15.15 | 19.15 | 22.00 |
| WD 460/32 8/ 0 | 15.05 | 21.15 | 27.00* |
| WD 460/32 10/ 0 | 15.05 | 21.15 | 27.00 |
| WD 460/32 10/ 0 | 15.05 | 24.15* | - |
| WD 345/ 0 1/ 0 | 15.15 | 25.25* | - |
| WD 345/ 0 3/ 0 | 15.15 | 25.25* | - |
| WD 345/ 0 4/ 0 | 15.05 | 25.25* | - |
| WD 345/ 0 5/ 0 | 15.05 | 25.25* | - |
| WD 345/ 0 6/ 0 | 16.15 | 25.25* | - |
| WD 345/ 0 7/ 0 | 15.15 | 25.25* | - |
| WD 345/ 0 8/ 0 | 15.15 | 25.25* | - |
| WD 345/ 0 9/ 0 | 15.05 | 25.25* | - |
| WD 370/ 0 1/ 0 | 15.00 | 25.15* | - |
| WD 373/ 0 1/ 0 | 15.15 | 25.25* | - |
| WD 417/ 1 2/ 0 | 19.00 | 29.00* | - |
| WD 417/ 2 2/ 0 | 16.00 | 26.00* | - |
| WD 417/ 4 5/ 0 | 16.00 | 25.00* | - |
| WD 460/32 5/ 0 | 15.25 | 24.25* | - |
| WD 460/32 6/ 0 | 15.25 | 24.25* | - |
| WD 460/32 7/ 0 | 15.25 | 24.25* | - |

* Plot and startage / endage included for greater sample size

## APPENDIX B:

## Diameter Growth Analyses - 168 Timberland West Coast PSPs

| Plot id | Initial Age | Plot id | Initial Age | Plot id | Initial Age |
|---|---|---|---|---|---|
| FR 258/0 1/0 | 18.00 | WD 109/0 8/0 | 30.05 | WD 460/26 13/0 | 26.00 |
| FR 258/0 11/0 | 18.00 | WD 109/0 98/0 | 32.05 | WD 460/26 14/0 | 26.00 |
| FR 258/0 12/0 | 18.00 | WD 109/0 99/0 | 32.05 | WD 460/26 2/0 | 25.15 |
| FR 258/0 13/0 | 18.00 | WD 337/0 1/0 | 24.00 | WD 460/26 3/0 | 25.15 |
| FR 258/0 15/0 | 18.00 | WD 337/0 2/0 | 24.00 | WD 460/26 5/0 | 27.00 |
| FR 258/0 18/0 | 18.00 | WD 337/0 3/0 | 24.00 | WD 460/26 6/0 | 27.00 |
| FR 258/0 19/0 | 18.00 | WD 337/0 4/0 | 24.00 | WD 460/26 7/0 | 27.00 |
| FR 258/0 2/0 | 18.00 | WD 337/0 5/0 | 24.00 | WD 460/26 9/0 | 25.15 |
| FR 258/0 22/0 | 18.00 | WD 337/0 7/0 | 24.00 | WD 460/30 87/0 | 18.15 |
| FR 258/0 23/0 | 18.00 | WD 337/0 8/0 | 24.00 | WD 460/30 89/0 | 18.15 |
| FR 258/0 24/0 | 18.00 | WD 337/0 9/0 | 24.00 | WD 460/30 90/0 | 18.15 |
| FR 258/0 25/0 | 18.00 | WD 345/0 9/0 | 16.15 | WD 460/31 1/0 | 25.00 |
| FR 258/0 26/0 | 18.00 | WD 367/0 1/0 | 24.00 | WD 460/31 118/0 | 15.25 |
| FR 258/0 28/0 | 18.00 | WD 368/0 1/0 | 23.00 | WD 460/31 119/0 | 16.25 |
| FR 258/0 30/0 | 18.00 | WD 369/0 1/0 | 19.00 | WD 460/31 14/0 | 18.00 |
| FR 258/0 31/0 | 18.00 | WD 370/0 1/0 | 17.05 | WD 460/31 15/0 | 18.00 |
| FR 258/0 32/0 | 18.00 | WD 371/0 1/0 | 16.05 | WD 460/31 2/0 | 22.25 |
| FR 258/0 33/0 | 18.00 | WD 372/0 1/0 | 16.05 | WD 460/31 21/0 | 15.00 |
| FR 258/0 35/0 | 18.00 | WD 417/1 2/0 | 19.00 | WD 460/31 24/0 | 19.00 |
| FR 258/0 36/0 | 18.00 | WD 417/1 4/0 | 15.00 | WD 460/31 25/0 | 18.00 |
| FR 258/0 37/0 | 18.00 | WD 417/2 2/0 | 16.00 | WD 460/31 26/0 | 24.00 |
| FR 258/0 38/0 | 18.00 | WD 417/2 3/0 | 15.00 | WD 460/31 30/0 | 16.15 |
| FR 258/0 45/0 | 18.00 | WD 417/3 1/0 | 17.00 | WD 460/31 37/0 | 16.15 |
| FR 258/0 46/0 | 18.00 | WD 417/3 3/0 | 21.00 | WD 460/31 38/0 | 16.15 |
| FR 258/0 47/0 | 18.00 | WD 417/3 4/0 | 15.00 | WD 460/31 5/0 | 29.00 |
| FR 258/0 48/0 | 18.00 | WD 417/3 5/0 | 15.00 | WD 460/32 1/0 | 20.25 |
| FR 258/0 5/0 | 18.00 | WD 417/3 6/0 | 15.00 | WD 460/32 10/0 | 15.05 |
| FR 258/0 50/0 | 18.00 | WD 417/3 8/0 | 21.00 | WD 460/32 108/0 | 21.25 |
| FR 258/0 51/0 | 18.00 | WD 417/3 9/0 | 15.00 | WD 460/32 109/0 | 21.25 |
| FR 258/0 52/0 | 18.00 | WD 417/4 1/0 | 16.00 | WD 460/32 11/0 | 21.25 |
| FR 258/0 53/0 | 18.00 | WD 417/4 3/0 | 20.00 | WD 460/32 110/0 | 21.00 |
| FR 258/0 54/0 | 18.00 | WD 417/4 4/0 | 15.00 | WD 460/32 111/0 | 18.25 |
| FR 258/0 55/0 | 18.00 | WD 417/4 5/0 | 18.00 | WD 460/32 112/0 | 18.25 |
| FR 258/0 56/0 | 18.00 | WD 417/4 6/0 | 15.00 | WD 460/32 2/0 | 19.25 |
| FR 258/0 58/0 | 18.00 | WD 417/4 7/0 | 15.00 | WD 460/32 3/0 | 23.00 |
| FR 258/0 6/0 | 18.00 | WD 417/5 1/0 | 16.00 | WD 460/32 4/0 | 19.25 |
| FR 258/0 60/0 | 18.00 | WD 417/5 2/0 | 15.00 | WD 460/32 5/0 | 16.05 |
| FR 258/0 61/0 | 18.00 | WD 460/19 54/0 | 15.00 | WD 460/32 6/0 | 23.25 |
| FR 258/0 62/0 | 18.00 | WD 460/19 58/0 | 15.00 | WD 460/32 7/0 | 16.05 |
| FR 258/0 63/0 | 18.00 | WD 460/19 60/0 | 16.00 | WD 460/32 8/0 | 15.05 |
| FR 258/0 65/0 | 18.00 | WD 460/19 61/0 | 16.00 | WD 460/33 4/0 | 27.15 |
| FR 258/0 66/0 | 18.00 | WD 460/19 62/0 | 16.00 | WD 460/33 5/0 | 26.15 |
| FR 258/0 67/0 | 18.00 | WD 460/19 64/0 | 18.00 | WD 460/33 7/0 | 24.15 |
| FR 258/0 69/0 | 18.00 | WD 460/19 65/0 | 18.25 | WD 460/33 8/0 | 25.00 |
| FR 258/0 7/0 | 18.00 | WD 460/19 66/0 | 20.15 | WD 460/43 10/0 | 25.15 |
| FR 258/0 70/0 | 18.00 | WD 460/19 67/0 | 16.15 | WD 460/43 11/0 | 25.15 |
| FR 258/0 71/0 | 18.00 | WD 460/19 68/0 | 21.15 | WD 460/43 12/0 | 24.15 |
| FR 258/0 72/0 | 18.00 | WD 460/19 69/0 | 16.25 | WD 460/43 2/0 | 27.15 |
| FR 258/0 73/0 | 18.00 | WD 460/19 70/0 | 18.15 | WD 460/43 47/0 | 21.05 |
| FR 258/0 75/0 | 18.00 | WD 460/19 71/0 | 20.15 | WD 460/43 48/0 | 21.05 |
| FR 258/0 9/0 | 18.00 | WD 460/19 72/0 | 21.15 | WD 460/43 49/0 | 21.05 |
| WD 109/0 12/0 | 30.05 | WD 460/19 73/0 | 21.15 | WD 460/43 50/0 | 18.05 |
| WD 109/0 23/0 | 30.05 | WD 460/19 98/0 | 15.00 | WD 460/43 51/0 | 18.05 |
| WD 109/0 24/0 | 30.05 | WD 460/26 1/0 | 25.15 | WD 460/51 7/0 | 27.05 |
| WD 109/0 71/0 | 32.05 | WD 460/26 10/0 | 26.00 | | |
| WD 109/0 72/0 | 32.05 | WD 460/26 11/0 | 26.00 | | |
| WD 109/0 73/0 | 32.05 | WD 460/26 12/0 | 24.15 | | |

## APPENDIX C:

## Height Growth Analyses - 188 Timberland West Coast PSPs

| Plot id | Initial Age | Plot id | Initial Age |
|---|---|---|---|
| FR 258/0 1/0 | 18.00 | FR 258/0 62/0 | 18.00 |
| FR 258/0 10/0 | 18.00 | FR 258/0 63/0 | 18.00 |
| FR 258/0 11/0 | 18.00 | FR 258/0 64/0 | 18.00 |
| FR 258/0 13/0 | 18.00 | FR 258/0 65/0 | 18.00 |
| FR 258/0 14/0 | 18.00 | FR 258/0 66/0 | 18.00 |
| FR 258/0 15/0 | 18.00 | FR 258/0 67/0 | 18.00 |
| FR 258/0 16/0 | 18.00 | FR 258/0 68/0 | 18.00 |
| FR 258/0 17/0 | 18.00 | FR 258/0 69/0 | 18.00 |
| FR 258/0 18/0 | 18.00 | FR 258/0 7/0 | 18.00 |
| FR 258/0 19/0 | 18.00 | FR 258/0 70/0 | 18.00 |
| FR 258/0 2/0 | 18.00 | FR 258/0 71/0 | 18.00 |
| FR 258/0 20/0 | 18.00 | FR 258/0 72/0 | 18.00 |
| FR 258/0 21/0 | 18.00 | FR 258/0 73/0 | 18.00 |
| FR 258/0 22/0 | 18.00 | FR 258/0 74/0 | 18.00 |
| FR 258/0 23/0 | 18.00 | FR 258/0 75/0 | 18.00 |
| FR 258/0 24/0 | 18.00 | FR 258/0 8/0 | 18.00 |
| FR 258/0 25/0 | 18.00 | FR 258/0 9/0 | 18.00 |
| FR 258/0 26/0 | 18.00 | WD 109/0 100/0 | 32.05 |
| FR 258/0 27/0 | 18.00 | WD 109/0 12/0 | 30.05 |
| FR 258/0 28/0 | 18.00 | WD 109/0 23/0 | 30.05 |
| FR 258/0 29/0 | 18.00 | WD 109/0 24/0 | 30.05 |
| FR 258/0 3/0 | 18.00 | WD 109/0 72/0 | 32.05 |
| FR 258/0 30/0 | 18.00 | WD 109/0 73/0 | 32.05 |
| FR 258/0 31/0 | 18.00 | WD 109/0 8/0 | 30.05 |
| FR 258/0 32/0 | 18.00 | WD 109/0 98/0 | 32.05 |
| FR 258/0 33/0 | 18.00 | WD 109/0 99/0 | 32.05 |
| FR 258/0 34/0 | 18.00 | WD 345/0 2/0 | 16.15 |
| FR 258/0 35/0 | 18.00 | WD 345/0 9/0 | 16.15 |
| FR 258/0 36/0 | 18.00 | WD 367/0 1/0 | 24.00 |
| FR 258/0 37/0 | 18.00 | WD 368/0 1/0 | 23.00 |
| FR 258/0 38/0 | 18.00 | WD 369/0 1/0 | 19.00 |
| FR 258/0 39/0 | 18.00 | WD 370/0 1/0 | 15.00 |
| FR 258/0 4/0 | 18.00 | WD 371/0 1/0 | 16.05 |
| FR 258/0 40/0 | 18.00 | WD 372/0 1/0 | 16.05 |
| FR 258/0 41/0 | 18.00 | WD 417/1 2/0 | 19.00 |
| FR 258/0 42/0 | 18.00 | WD 417/1 4/0 | 15.00 |
| FR 258/0 43/0 | 18.00 | WD 417/2 2/0 | 16.00 |
| FR 258/0 44/0 | 18.00 | WD 417/2 3/0 | 15.00 |
| FR 258/0 45/0 | 18.00 | WD 417/3 1/0 | 17.00 |
| FR 258/0 46/0 | 18.00 | WD 417/3 3/0 | 20.00 |
| FR 258/0 47/0 | 18.00 | WD 417/3 4/0 | 15.00 |
| FR 258/0 48/0 | 18.00 | WD 417/3 5/0 | 15.00 |
| FR 258/0 49/0 | 18.00 | WD 417/3 6/0 | 15.00 |
| FR 258/0 5/0 | 18.00 | WD 417/3 8/0 | 21.00 |
| FR 258/0 50/0 | 18.00 | WD 417/3 9/0 | 15.00 |
| FR 258/0 51/0 | 18.00 | WD 417/4 1/0 | 16.00 |
| FR 258/0 52/0 | 18.00 | WD 417/4 3/0 | 20.00 |
| FR 258/0 53/0 | 18.00 | WD 417/4 4/0 | 15.00 |
| FR 258/0 54/0 | 18.00 | WD 417/4 5/0 | 18.00 |
| FR 258/0 55/0 | 18.00 | WD 417/4 6/0 | 15.00 |
| FR 258/0 56/0 | 18.00 | WD 417/4 7/0 | 15.00 |
| FR 258/0 57/0 | 18.00 | WD 417/5 1/0 | 15.00 |
| FR 258/0 58/0 | 18.00 | WD 417/5 2/0 | 15.00 |
| FR 258/0 59/0 | 18.00 | WD 460/19 54/0 | 15.00 |
| FR 258/0 6/0 | 18.00 | WD 460/19 55/0 | 15.00 |
| FR 258/0 60/0 | 18.00 | WD 460/19 58/0 | 15.00 |
| FR 258/0 61/0 | 18.00 | WD 460/19 60/0 | 16.00 |

| Plot id | Initial Age |
|---|---|
| WD 460/19 61/0 | 16.00 |
| WD 460/19 62/0 | 16.00 |
| WD 460/19 64/0 | 18.00 |
| WD 460/19 65/0 | 18.25 |
| WD 460/19 66/0 | 20.15 |
| WD 460/19 67/0 | 16.15 |
| WD 460/19 68/0 | 21.15 |
| WD 460/19 69/0 | 16.25 |
| WD 460/19 70/0 | 16.25 |
| WD 460/19 71/0 | 20.15 |
| WD 460/19 72/0 | 21.15 |
| WD 460/19 73/0 | 21.15 |
| WD 460/19 98/0 | 15.00 |
| WD 460/26 1/0 | 25.15 |
| WD 460/26 10/0 | 26.00 |
| WD 460/26 11/0 | 26.00 |
| WD 460/26 12/0 | 24.15 |
| WD 460/26 13/0 | 26.00 |
| WD 460/26 14/0 | 26.00 |
| WD 460/26 2/0 | 25.15 |
| WD 460/26 3/0 | 25.15 |
| WD 460/26 5/0 | 27.00 |
| WD 460/26 6/0 | 27.00 |
| WD 460/26 7/0 | 27.00 |
| WD 460/26 9/0 | 25.15 |
| WD 460/30 87/0 | 18.15 |
| WD 460/30 89/0 | 18.15 |
| WD 460/30 90/0 | 18.15 |
| WD 460/30 92/0 | 18.15 |
| WD 460/31 1/0 | 22.25 |
| WD 460/31 118/0 | 15.25 |
| WD 460/31 119/0 | 16.25 |
| WD 460/31 14/0 | 18.00 |
| WD 460/31 15/0 | 18.00 |
| WD 460/31 2/0 | 22.25 |
| WD 460/31 21/0 | 15.00 |
| WD 460/31 23/0 | 19.00 |
| WD 460/31 24/0 | 19.00 |
| WD 460/31 25/0 | 18.00 |
| WD 460/31 26/0 | 24.00 |
| WD 460/31 30/0 | 16.15 |
| WD 460/31 37/0 | 16.15 |
| WD 460/31 38/0 | 16.15 |
| WD 460/31 5/0 | 29.00 |
| WD 460/32 1/0 | 20.25 |
| WD 460/32 10/0 | 15.05 |
| WD 460/32 108/0 | 21.25 |
| WD 460/32 109/0 | 21.25 |
| WD 460/32 11/0 | 21.25 |
| WD 460/32 110/0 | 17.25 |
| WD 460/32 111/0 | 18.25 |
| WD 460/32 112/0 | 18.25 |
| WD 460/32 2/0 | 19.25 |
| WD 460/32 3/0 | 23.00 |
| WD 460/32 4/0 | 19.25 |
| WD 460/32 5/0 | 16.05 |
| WD 460/32 6/0 | 23.25 |
| WD 460/32 7/0 | 16.05 |
| WD 460/32 8/0 | 15.05 |
| WD 460/33 4/0 | 27.15 |
| WD 460/33 5/0 | 26.15 |

| Plot id | Initial Age |
|---|---|
| WD 460/33 7/0 | 24.15 |
| WD 460/33 8/0 | 25.00 |
| WD 460/43 10/0 | 25.15 |
| WD 460/43 106/0 | 19.05 |
| WD 460/43 11/0 | 25.15 |
| WD 460/43 12/0 | 24.15 |
| WD 460/43 2/0 | 27.15 |
| WD 460/43 47/0 | 21.05 |
| WD 460/43 48/0 | 21.05 |
| WD 460/43 49/0 | 21.05 |
| WD 460/43 50/0 | 18.05 |
| WD 460/43 51/0 | 18.05 |
| WD 460/51 7/0 | 27.05 |

## APPENDIX D:

### Projection statistics for the selected Regional plots in Figures 5-12

| Figure Number & Location[a] | Simulation End-Age (yrs) | Projection Period (yrs) | Stocking (sph) Actual | Stocking (sph) Predicted | $Dbh_q$ (cm) Actual | $Dbh_q$ (cm) Predicted | $Dbh_i$ Variance Ratio[b] |
|---|---|---|---|---|---|---|---|
| **CNI** | | | | | | | |
| 5 t-l | 21.05 | 6.00 | 1779 | 1687 | 22.4 | 22.7 | 1.163 |
| 5 t-r | 28.05 | 13.00 | 1087 | 972 | 29.7 | 30.4 | 1.048 |
| 5 b-l | 21.05 | 6.00 | 1137 | 1071 | 27.3 | 27.9 | 0.951 |
| 5 b-r | 28.05 | 13.00 | 923 | 772 | 32.4 | 34.2 | 0.782 |
| **GDNS** | | | | | | | |
| 6 t-l | 20.15 | 4.15 | 220 | 215 | 37.1 | 37.0 | 1.156 |
| 6 t-r | 24.05 | 8.05 | 220 | 209 | 44.2 | 43.0 | 1.091 |
| 6 b-l | 20.15 | 4.15 | 350 | 341 | 33.0 | 33.8 | 0.955 |
| 6 b-r | 24.15 | 8.15 | 350 | 328 | 37.5 | 39.0 | 0.776 |
| **HBAY** | | | | | | | |
| 7 t-l | 21.00 | 5.25 | 178 | 185 | 42.8 | 43.8 | 1.097 |
| 7 t-r | 25.00 | 9.25 | 168 | 182 | 48.2 | 50.2 | 0.989 |
| 7 b-l | 23.15 | 6.00 | 652 | 619 | 38.2 | 38.9 | 1.069 |
| 7 b-r | 29.00 | 11.85 | 623 | 565 | 42.3 | 43.1 | 0.905 |
| **CLAYS** | | | | | | | |
| 8 t-l | 24.00 | 5.85 | 443 | 430 | 33.5 | 34.6 | 0.849 |
| 8 t-r | 31.40 | 13.25 | 433 | 402 | 40.4 | 42.1 | 0.995 |
| 8 b-l | 26.25 | 6.70 | 425 | 405 | 40.6 | 40.9 | 0.859 |
| 8 b-r | 32.15 | 12.60 | 395 | 379 | 46.2 | 46.9 | 0.792 |
| **SOUTH** | | | | | | | |
| 9 t-l | 20.00 | 4.00 | 2459 | 2105 | 19.5 | 21.0 | 1.012 |
| 9 t-r | 25.05 | 9.05 | 2173 | 1491 | 21.8 | 25.4 | 1.015 |
| 9 b-l | 20.25 | 3.85 | 340 | 339 | 41.6 | 38.9 | 0.719 |
| 9 b-r | 24.25 | 7.85 | 340 | 335 | 49.0 | 45.0 | 0.603 |
| **SANDS** | | | | | | | |
| 10 t-l | 20.15 | 5.10 | 352 | 336 | 37.7 | 38.0 | 1.030 |
| 10 t-r | 26.05 | 11.0 | 352 | 315 | 43.5 | 44.2 | 0.940 |
| 10 b-l | 28.05 | 4.50 | 208 | 200 | 51.0 | 50.7 | 0.897 |
| 10 b-r | 33.05 | 9.50 | 208 | 192 | 56.4 | 56.8 | 0.772 |
| **CANTY** | | | | | | | |
| 11 t-l | 18.55 | 3.30 | 700 | 725 | 27.2 | 27.0 | 1.060 |
| 11 t-r | 24.05 | 8.80 | 700 | 725 | 32.9 | 32.2 | 1.020 |
| **TWC** | | | | | | | |
| 12 t-l | 21.15 | 6.10 | 413 | 411 | 29.0 | 26.5 | 0.920 |
| 12 t-r | 27.00 | 11.95 | 388 | 371 | 36.6 | 33.3 | 0.943 |
| 12 b-l | 21.15 | 6.10 | 277 | 262 | 29.8 | 30.7 | 0.823 |
| 12 b-r | 27.00 | 11.95 | 254 | 233 | 35.8 | 39.2 | 0.821 |

a  **t-l** = top left (nearest 1.0[b], short pd.) **t-r** = top right (nearest 1.0[b], long pd.)
**b-l** = bottom left (nearest xbar[b], short pd.) **b-r** = bottom right (nearest xbar[b], long pd.)

b  { variance of predicted $dbh_i$ / variance of actual $dbh_i$ }; variance = $\Sigma(x_i - xbar)^2 / n$