Testing the performance of FORCYTE-11 against results from the Shawnigan Lake thinning and fertilization trials on Douglas-fir

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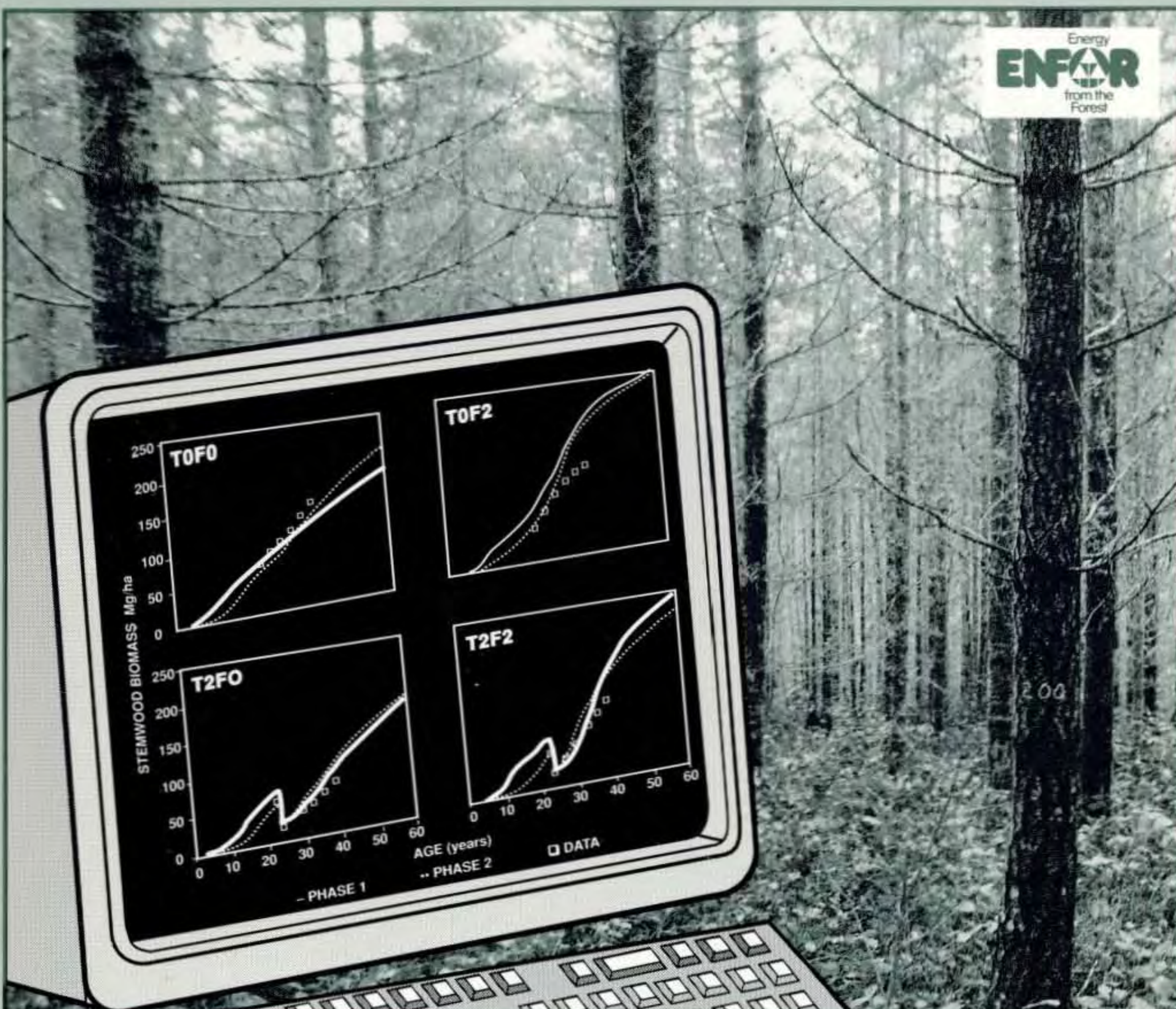
D. Sachs and J. A. Trofymow



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Foreword

ENFOR (ENergy from the FORest) is a contract research and development (R & D) program managed by Forestry Canada. It is aimed at generating sufficient knowledge and technology to realize a marked increase in the contribution of forest biomass to Canada's energy supply. The program was initiated in 1978 as part of a federal interdepartmental initiative to develop renewable energy sources.

The ENFOR program deals with biomass supply matters such as inventory, growth, harvesting, processing, transportation, environmental impacts, and socioeconomic impacts and constraints. A technical committee oversees the program, developing priorities, assessing proposals, and making recommendations. Approved projects are generally carried out under contract.

General information on the operation of the ENFOR program, including the preparation and submission of R & D proposals, is available upon request from:

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Abstract

This project was undertaken to test and evaluate the performance of the FORCYTE-11 model using data from Forestry Canada's thinning and fertilization trials of Douglas-fir at Shawnigan Lake, British Columbia. The project was divided into two distinct phases. In phase I, FORCYTE-11 was run using the standard Vancouver Island Douglas-fir input data provided by the model's authors. The model was used to simulate four treatments at Shawnigan Lake and its performance was evaluated using statistical and graphical techniques on 21 variables. In phase II of the project the model was calibrated using data from the Shawnigan Lake control plots and the simulations and evaluation were repeated for the same four treatments and 21 variables. Additional runs were made for all 15 treatments to compare the model and data rankings of the treatments for three variables.

Phase I results indicated the model was not well calibrated for the Shawnigan Lake site. Simulation of tree growth on the control plots was inaccurate. Foliage biomass increased too rapidly in the simulations for all treatments. At crown closure the model predicted N limitation resulting in an extreme underestimate of foliage biomass on the control plots. Simulation of foliage biomass was more accurate for thinned or fertilized plots. Decomposition processes were not well calibrated. The model predicted humus levels of about 20 Mg ha^{-1} yet actual soils data indicated a humus level in excess of 100 Mg ha^{-1}.

The model was calibrated in phase II of the project using data from the Shawnigan Lake control plots. Salal was added to the simulation as a competitor for the Douglas-fir. Resulting simulations of tree biomass growth were generally improved. Simulation of foliage biomass accumulation was more realistic, but was still underestimated on the control plots. Predictions of density dependent mortality in unthinned treatments improved slightly. The simulation of soil humus levels was more accurate. The calibrated FORCYTE-11 model was able to accurately simulate some of the tree growth responses to thinning and fertilization at Shawnigan Lake. The model's simulations of 15 treatments underestimated stemwood volume and volume increment in treatments with low fertilization. Estimates improved with increasing levels of fertilization although in some cases volume and volume increment were overestimated. This bias was more extreme for unthinned treatments. The model's ability to rank treatments for volume and stem density decreased with the length of the simulation. Model rankings for volume increment were best at the beginning and end of the simulation. At no time did model and data treatment rankings significantly differ from each other (5% level).

FORCYTE-11 was difficult to calibrate, but the calibrated version was relatively easy to use. Model simulations may be improved by incorporating additional stocking, growth, and yield data from higher quality sites. A calibrated version of the model should be useful as both a management simulator and a research tool.

Résumé

Ce projet consistait à expérimenter et à évaluer le modèle FORCYTE-11 à l'aide des données de Forêts Canada sur les essais d'éclaircie et de fertilisation des peuplements de Douglas au lac Shawnigan, en Colombie-Britannique. Le projet se divisait en deux phases distinctes. La première phase consistait à simuler quatre traitements au lac Shawnigan avec des données standard sur les Douglas de l'île de Vancouver fournies par les concepteurs du modèle, et à évaluer la performance du modèle FORCYTE-11 en fonction de vingt-et-une variables au moyen de méthodes statistiques et graphiques. La deuxième phase consistait à étalonner le modèle avec les données issues des parcelles témoins du lac Shawnigan et à répéter la procédure de simulation et d'évaluation sur les quatre mêmes traitements et les vingt-et-une mêmes variables qu'à la phase I. Des cycles d'essai supplémentaires ont été exécutés pour l'ensemble des quinze traitements afin de comparer leur classification selon le modèle et selon les données en fonction de trois variables.

Les résultats de la phase I indiquaient que le modèle n'était pas étalonné correctement pour le site du lac Shawnigan. La simulation de la vitesse d'accroissement des arbres sur les parcelles témoins était inexacte. Elle indiquait notamment un accroissement trop rapide de la biomasse foliaire, et ce pour tous les traitements. A la fermeture du couvert, le modèle prédisait une limite N, sous-estimant gravement la biomasse foliaire des parcelles témoins. La simulation de la biomasse foliaire était plus exacte pour les parcelles éclaircies ou fertilisées. La simulation des processus de décomposition n'était pas étalonnée correctement. Le modèle prédisait un bilan humique d'environ 20 Mg ha^{-1} alors que les données pédologiques recueillies in situ indiquaient un bilan humique de plus de 100 Mg ha^{-1}.

Dans la phase II où le modèle était étalonné avec des données issues des parcelles témoins du lac Shawnigan, des gaulthéria furent ajoutés pour faire concurrence aux Douglas. Les résultats de simulation de l'accroissement de la biomasse foliaire en furent généralement améliorés. L'accumulation de la biomasse foliaire était plus réaliste quoique toujours sous-estimée dans le cas des parcelles témoins et on nota une légère amélioration des predictions de mortalité due à la densité foliaire dans les traitements non-éclaircis. La simulation des bilans humiques était en outre plus exacte. Le modèle FORCYTE-11 étalonné a pu simuler avec exactitude quelques-uns des effets des traitements d'éclaircie et de fertilisation sur la vitesse d'accroisement des peuplements du lac Shawnigan. Les simulations du modèle pour les quinze traitements sous-estimèrent le volume de bois de fût et l'accroissement du volume dans le cas des traitements consistant en un faible taux de fertilisation. Les résultats s'amélioraient toutefois avec l'augmentation du taux de fertilisation bien que dans certains cas le volume et l'augmentation du volume furent surestimés, anomalie qui s'accentuait dans le cas des traitements non éclaircis. L'aptitude du modèle à classifier les traitements selon la densité du volume et du bois de fût décroissait proportionnellemnet à la durée de la simulation. La classification selon le modèle pour ce qui est de l'accroissement du volume était meilleure au début et à la fin du cycle de simulation. Aucun écart significatif (5 %) ne fut enregistré entre la classification des traitements selon le modèle d'une part et selon les données d'autre part.

Le modèle FORCYTE-11 s'est révélé difficile à étalonner, mais la version étalonnée s'est avérée facile à utiliser. On pourrait améliorer la qualité des simulations en incorporant au modèle des données supplémentaires sur le matériel sur pied, la vitesse d'accroissement et la récolte de sites de meilleurs qualité. Une version étalonnée du modèle devrait être utile à la fois comme simulateur de gestion et comme outil de recherche.

1. Introduction

The objective of this project was to evaluate the performance of FORCYTE-11 (Kimmins *et al.* 1990), an ecosystem-based forest simulation model. The model and its predecessors have been used for teaching and research, but have never been validated against an independent data set. A Forestry Canada planning group meeting in Edmonton in 1987 decided that one of the top priorities for the continued development of FORCYTE-11 was a validation study. A feasibility study was commissioned (Godfrey, G.A. 1988. Feasibility study for the calibration, testing and evaluation of the FORCYTE-11 growth simulation model. Contract report to Forestry Canada, Victoria, B.C.) which recommended using the 15 years of data from the Forestry Canada experimental plots at Shawnigan Lake on Vancouver Island, British Columbia (Crown and Brett 1975) to validate FORCYTE-11. This project was designed to implement those recommendations in two distinct phases. In phase I the FORCYTE-11 model was used to simulate the thinning and fertilization trials at Shawnigan Lake using the intial Douglas-fir data sets provided by the model's authors. The model's performance was evaluated against results from a subset of the treatments using both statistical and graphical techniques. In phase II, data from the control plots at Shawnigan Lake was used to calibrate the model. The phase I simulations were then repeated and the calibrated model was evaluated. As a final test in Phase II, simulations of all treatments were made and the model's ranking of the treatments compared with actual results.

2. The Shawnigan Lake experiments

2.1 Background

The Shawnigan Lake experiments were established in 1970 in order to determine the mechanisms of response to thinning and fertilization in Douglas-fir *(Pseudotsuga menziesii)*. The site is located in the very dry maritime Coastal Western Hemlock biogeoclimatic zone (CWHxm), near the transition to the wet Coastal Douglas-fir (CDFb), on very dry, nutrient-poor to medium ecotopes (Klinka *et al.* 1984). The soil, classified as an Orthic Dystric Brunisol, developed on coarse-textured till and has an impermeable compact layer at 55-65 cm. Organic layers are thin (<2 cm) as the site burned twice, once in 1925, prior to logging, and again in 1945. The site was planted to 2-0 Douglas-fir stock in the spring of 1948. Based on breast height site index curves by Bruce (1981), the Douglas-fir site index is 25 m at 50 years. The main experiment, which began at a stand age of 24 years, consists of a 3x3 factorial treatment design with three levels of thinning and three of fertilization. Each treatment combination was replicated twice in two successive years, 1971 and 1972 for a total of 36 plots (Crown and Brett 1975). In 1981, 9 years after the first fertilization, the 1972 plots were refertilized at the same initial rates. The levels of thinning and fertilization are listed in Table 1.

2.2 The test data set

The feasibility study identified 24 candidate variables from the Shawnigan Lake data sets which could be used to evaluate FORCYTE-11. Sufficient data were available for both graphical and statistical analyses of 21 of the candidate variables. These included:

- six stand level biomass (Mg ha^{-1}, 1 Mg = 10^3 kg) variables –
  stemwood, periodic annual stemwood increment, stembark, foliage, branch and total aboveground biomass;
- three individual tree biomass (kg) variables–
  smallest, average, and largest tree
- four height (m) variables –
  canopy top, smallest tree, canopy bottom, canopy depth;
- six stand level stocking (number ha^{-1}) and mortality variables –
  stem density, mortality, mortality rate (%), mortality biomass (kg ha^{-1}), base mortality rate (non-density-dependent), shade mortality rate (density-dependent);
- two foliar assimilation and loss rate variables –
  Net assimilation rate (kg total biomass per kg foliage per yr), foliar litterfall (kg (ha yr)$^{-1}$).

Two additional variables, foliage increment and foliage nitrogen, could only be examined graphically due to the limited number of data points.

Biomass data were based on a biomass sampling at Shawnigan lake 9 years after the initial treatment for which Barclay *et al.* (1986) developed regression equations for foliage, stemwood, bark, branch and total aboveground biomass for the T0F0, T0F2, T2F0 and T2F2 treatments. They reported biomass estimates at establishment and 9 years

Table 1. Levels of thinning and fertilization in the Shawnigan Lake experiment.

Symbol	Treatment
Thinning	
T0	Unthinned
T1	About 1/3 initial basal area removed
T2	About 2/3 initial basal area removed
Fertilization	
F0	Unfertilized
F1	224 kg urea N ha^{-1}
F2	448 kg urea N ha^{-1}
F1-1	224 kg urea N ha^{-1} applied twice
F2-2	448 kg urea N ha^{-1} applied twice

post-treatment. To generate biomass values for other years, the regression equations were applied to stand table data for each treatment plot (R. de Jong, Forestry Canada, Victoria, unpublished data). All trees in the stand tables were used for calculating the biomass values regardless of species. Control plot equations were used for the year of treatment and the individual treatment equations were applied to data from subsequent years. Extrapolation of the foliar biomass equations beyond the 9-year range of data used to generate them produced unreasonable values. Foliage biomass at ages 36 and 39 showed no sign of reaching any limit. Therefore points for ages 36 and 39 were excluded from the graphical and statistical analyses. Data that were used in statistical calculations are shown on the graphs.

Average stemwood biomass for the smallest and largest tree variables were calculated by applying the biomass regression equations from Barclay *et al.* (1986) to stand table data for each treament plot (R. de Jong, Forestry Canada, Victoria, upublished data). Average tree stemwood biomass was calculated using quadratic mean diameters reported by Gardner (1990).

Tree and canopy height and stem density and mortality values were from stand table data for each treatment plot (R. de Jong, Forestry Canada, Victoria, unpublished data) as reported by Gardner (1990).

Net assimilation rate was defined as the production of aboveground tree biomass per unit foliage biomass. Data were from a study by Brix (1983) which measured net assimilation rate on codominant trees for the 9 years after the initial treatments. Data on litterfall mass were from a study by Trofymow *et al.* (Trofymow, J.A., Barclay, H.J.; McCullough, K.M. Annual rates and elemental concentrations of litterfall in thinned and fertilized Douglas-fir. manuscript in preparation). Since the T2F2 plots were refertilized at age 30, data for subsequent years were excluded.

Brix (1983) reported foliage increment for each of his codominant trees, but no stand level estimates. A stand level estimate for the 9-year period following treatment was reported by Barclay *et al.* (1986). Their estimate does not include litterfall.

Stand level estimates of foliar N content and concentrations, nine years post- treatment, were reported by Pang *et al.* (1987). These foliar N concentrations were applied to the stand table biomass estimates described above for data from the 12-year report (Barclay and Brix 1985) to calculate estimates of foliar N, 12 years after treatment. This assumes that foliar N concentrations were similar 9 and 12 years after treatment.

3. The FORYCTE-11 model

3.1 Background

To familiarize the reader with some of the FORCYTE-11 terms used in this report, the following is a brief description of the model and the names and functions of the different programs and data files. The overall structure and relationship of the model components is shown in Figure 1. Further information on FORCYTE-11 is available in the user's manual (Kimmins *et al.* 1990) and scientific documentation (Kimmins 1991).

FORYCTE-11 is described by its authors as a "hybrid, stand-level simulation model" which makes predictions of the effects of management on biomass and nutrient accumulation over time in various plant components and soils (Kimmins *et al.* 1990). The model requires empirical data to be supplied by the user (TREEDATA, PLNTDATA, BRYODATA and SOILDATA) on historical patterns of plant growth, plant chemistry and on soils and soil processes for two to five sites that differ in site quality. Site quality is defined primarily in terms of soil fertility.

Since user supplied data will not be complete for all years for each site, the initial "setup" programs, TREEGROW, PLNTGROW, BRYOGROW and FORSOILS use the empirical data provided to extrapolate between years and generate trend files TREETRND, PLNTTRND, BRYOTRND, and SOILTRND of decomposition rates and biomass and nutrient accumulation curves for all plant and soil components for each site specified.

MANAFOR is the ecosystem process and management simulator. The program uses output files from the setup program (TRND files) and an initial ECOSTATE file (defined below) combined with a file, MANADATA, which specifies the type of management to be simulated. MANAFOR then simulates plant growth and soil processes, scheduling the management intervensions such as fertilization, thinning, fire, rotation length and harvest intensity, specified in the MANADATA file. MANAFOR uses the TREETRND files along with indices of light and nutrient availability to simulate the growth of one or more tree species. Availability of nutrients is controlled through the processes of litter decomposition, humus formation, and nutrient adsorption, desorption and loss. Light availability is determined by foliar mass, canopy depth, and canopy height. If the appropriate input data are provided, MANAFOR can also disaggregate total tree biomass into individual trees and simulate herb, shrub and moss growth.

After the initial setup and prior to the management simulations, an initial state file, ECOSTATE, must be created which defines the initial contents of all plant and soil state variables to be simulated by MANAFOR. This file is generated by first running MANAFOR with an empty ECOSTATE file (no plant or soil biomass or nutrients) and with nutrient feedback control of plant growth switched off. Growth is then simulated as described by the input TRND data for a specific site without regard to nutrient limitation. The intent is to "create" nutrients based on the demands as determined by historical plant growth. An ENDSTATE file is produced describing the contents of all plant and soil state variables. The ENDSTATE file is then used as the initial ECOSTATE file for subsequent management simulations with nutrient feedback switched on. Several unmanaged rotations are usually simulated to ensure the forest floor is initially in steady-state (Kimmins *et al.* 1990).

Output from MANAFOR includes MANATRND files for use by the FORECAST program and VIEWGRAF data files for graphical display by PROBE. FORECAST produces summaries of biomass and nutrient input and outputs as well as economic and energy analyses. PROBE is a separate software package that assists the user in the setup, execution, and graphical analysis for multiple FORCYTE-11 simulations (Apps *et al.* 1988, MacIsaac *et al.* 1989). To examine the effects of alternative initial conditions or management regimes in FORCYTE-11, plant, tree, soil or management input DATA files must be edited and changed for each model run. Often only a single line is changed. Instead of editing and making a copy of the input DATA file each time a new model run is required, PROBE allows the user to create a file containing only the lines changed for each simulation. For each simulation or case, the appropriate lines are then replaced in the default input data file. Thus, the user creates a file describing changes in the input data files for each case which is then used by PROBE to execute multiple runs of FORCYTE-11. PROBE also contains a routine to compress the VIEWGRAF files from each FORCYTE-11 run to save disk space. These files are used for graphical display by the DISPLAY program.

3.2 Creation of initial state file

An initial ECOSTATE file was created which attempted to match the stand history as described in the Shawnigan Lake establishment report (Crown and Brett 1975). Site index was set at 25 and the model was run for 200 years. A harvest was then simulated which left all material on the forest floor. This was repeated twice to build a forest floor in steady state. The model was then run for 200 years followed by a moderate burn killing approximately half of the trees. Next, a salvage logging was simulated followed by natural regeneration of 5000 Douglas-fir seedlings per hectare. The new stand was allowed to grow for 15 years and then an extremely hot burn was simulated which killed all trees and consumed much of the decomposing material in the forest floor. Three annual applications of 5 kg N ha^{-1} of fertilizer were added following the burn to simulate the N-fixation input of the invading lupins. This state was used as the starting state for the simulation of the experiment. Data files are presented in Appendix I.

3.3 Simulations

Four treatments, T0F0, T0F2, T2F0 and T2F2 at Shawnigan Lake were simulated using FORCYTE-11 and comparisons were made with data for 23 variables described previously. In the last part of Phase II, all 15 treatments were simulated but only three variables were compared (stemwood biomass, stemwood increment, stem density). At Shawnigan Lake, the average number of trees in each treatment differed at the start of the experiment. Therefore to have the appropriate stocking level at the start of the experiment, year 24, a series of initial model runs were made to determine number of seedlings that had to have initially regenerated in each treatment at year 0 in FORCYTE-11.

All simulations were run for 120 years. Only 60 years of data are shown in the figures to provide better resolution for comparison with the actual Shawnigan Lake data. The PROBE supervisory program was used to make multiple simulations with FORCYTE-11 and interpret the output graphically (Apps *et al.* 1988; MacIsaac *et al.* 1989).

4. Methods to compare model and data fit

4.1 Overall comparisons

All statistical analyses were completed using SYSTAT microcomputer software (Wilkinson 1988). Summary statistics comparing model predictions and data were done for each variable averaged across all treatments and all times (Table 2). For each of the 21 variables analyzed, the difference between predicted and observed values for each treatment and age was calculated and the overall mean difference and its variance determined. The probability that these differences were normally distributed was determined using the Kolmogorov-Smirnov test with the Lilliefors option (Lilliefors 1967). The probability that the mean difference was zero was determined using a paired two-tailed t-test. In addition, a linear regression of predicted vs. observed values was fitted and the coefficient of determination calculated (r^2).

The accuracy of the model predictions were determined using the technique described by Freese (1960) as modified by Reynolds (1984) and used to calculate the critical errors, e^* and e^{**}. The critical

Table 2. Statistics[a] comparing the overall fit of model and data in Phase I of the FORCYTE-11 evaluation.

Variable	Mean Diff.	σ^2 Diff.	r^2	Prob. Norm.	Prob. f=0	ANOVA p values Thin	Fert	T x F	α=0.05 e^*	e^{**}	α=0.20 e^*	e^{**}
Stemwood Biomass (Mg ha^{-1})	11.42	20.36	0.77	0.05	0.01	0.01	0.00	0.00	36.55	59.26	26.53	33.93
Stemwood PAI (Mg (ha yr)$^{-1}$)	0.83	2.26	0.13	1.00	0.12	0.06	0.00	0.08	3.68	6.26	2.69	3.53
Stembark Biomass (Mg ha^{-1})	-1.84	3.67	0.62	0.00	0.02	0.00	0.00	0.00	6.42	10.42	4.66	5.96
Foliage Biomass (Mg ha^{-1})	-0.29	2.34	0.46	1.00	0.63	0.07	0.00	0.00	3.49	6.35	2.59	3.51
Branch Biomass (Mg ha^{-1})	3.88	4.72	0.34	0.24	0.00	0.00	0.00	0.00	9.60	15.56	30.70	39.27
Total Biomass (Mg ha^{-1})	5.00	26.67	0.77	0.45	0.37	0.00	0.00	0.00	42.30	68.59	30.70	39.27
Largest Tree (kg)	-107.18	79.59	0.14	0.01	0.00	0.00	0.00	0.01	210.84	341.89	153.03	195.75
Average Tree (kg)	7.38	9.40	0.97	0.00	0.00	0.09	0.13	0.53	18.77	30.44	13.62	17.43
Smallest Tree (kg)	-6.10	5.49	0.96	0.53	0.00	0.10	0.05	0.20	12.94	20.98	9.39	12.01
Density (# ha^{-1})	0.31	264.36	0.98	0.00	0.99	0.00	0.00	0.01	411.78	667.73	298.87	382.30
Mortality (# ha^{-1})	-41.67	79.87	0.64	0.00	0.03	0.36	0.00	0.02	138.10	234.96	101.14	132.5
Mortality Rate (%)	-3.42	0.78	0.58	0.00	0.07	0.25	0.00	0.01	1.33	2.26	0.97	1.27
Canopy Top Height (m)	-2.08	3.63	0.20	0.00	0.01	0.00	0.00	0.00	6.82	11.06	4.95	6.33
Smallest Tree Height (m)	1.87	1.63	0.84	1.00	0.00	0.00	0.15	0.01	4.14	6.72	3.01	3.85
Canopy Bottom Height (m)	4.43	1.11	0.54	0.02	0.00	0.03	0.87	0.54	7.42	12.62	5.43	7.12
Canopy Depth (m)	-6.55	3.43	0.04	0.03	0.00	0.00	0.00	0.00	11.98	20.38	8.77	11.49
Mortality Biomass (kg ha^{-1})	1042.1	1471.1	0.52	0.01	0.01	0.34	0.24	0.47	2773.03	4178.03	2030.88	2661.48
Base Mortality Rate (%)	0.14	0.06	0.16	0.50	0.00	0.46	0.02	0.26	0.24	0.41	0.18	0.23
Shade Mortality Rate (%)	-0.46	0.80	0.51	0.00	0.02	0.39	0.00	0.00	1.42	2.41	1.04	1.36
NAR[b] (kg (kg foliage yr)$^{-1}$)	0.05	0.49	0.30	0.06	0.60	0.12	0.84	0.70	0.82	1.29	0.59	0.75
Litterfall (kg (ha yr)$^{-1}$)	-225.96	498.05	0.37	0.27	0.01	0.01	0.00	0.01	902.16	1296.48	639.50	769.46

[a]Mean Diff. - Mean difference
σ^2 Diff. - Variance of differences
r^2 - Simple correlation coefficient of model to data fit
Prob. Norm. - Probability the differences are normally distributed
Prob. f=0 - Probability the mean difference is 0
ANOVA p value - Probabilities resulting from two-way ANOVA of differences
e^*, e^{**} - Reynold's critical values calculated at 5% or 20% (α) error levels. Values are in the same units as the variable. e^* assumes the model is most accurate, e^{**} assumes the data are most accurate
[b]NAR - Net assimilation rate

error, e^*, can be interpreted as the smallest error level, in absolute terms, which will lead to the acceptance of the null hypothesis (i.e. that the model is within e^* units of the true value) at the given a level. With this test the model is judged to be accurate unless there is strong evidence to the contrary. A more conservative approach places the burden of proof on the model. It uses the test statistic e^{**}, which is based on the lower tail of the Chi-square distribution and accepts the model only if there is strong evidence that it is at least as accurate as required. Both critical error tests were done at α=0.05 and α=0.20 (Table 2).

4.2 Individual treatment comparisons

Tests of model and data fit were also done for each variable for each treatment. These results are shown on the individual graphs (Figures 2 - 22). First, the mean difference, d, between predicted and observed values was calculated. Wald-Wolfowitz tests (runs) were performed to detect a run or serial patterns in the difference between model and data (Wilkinson 1988). Probabilities less than 0.05 were used as evidence that the sequence of model to data differences were non-random. The critical values from three Freese tests were also calculated. The first (fn) assumes no bias in the model. The second (fc) tests after correcting for constant bias which is assumed to be equal to the mean difference between the estimated and true values. The third (fv) tests after correcting for variable bias by fitting a linear regression of the predicted on the observed values. These critical values can be interpreted as the maximum absolute error that could be tolerated to accept the hypothesis that the model is accurate under the given assumptions and with an α level of 0.05. There are two numbers shown for each statistic on each graph. The first number refers to the phase I results and the second refers to phase II.

4.3 Comparison of treatment rankings

An alternative approach in testing a model is to examine how well the model predicts the relative ranking of a number of treatments. Therefore, at the end of Phase II the calibrated model was used to simulate the results for all 15 treatments (Table 1) as reported in the 15-year report (Gardner 1990). Spearman's rank correlation coefficients (r_s) tests how well the model's relative ranking of the 15 treatments compare with the actual results (Snedecor and Cochran 1976). Because of degrees of freedom limitations, at least six treatments must be examined in order to test for significance. The rank correlation can range from -1 (complete disconcordance) to +1 (complete concordance). Values of r_s below a critical value indicate the model and data rankings of the treatments significantly differ. Significance levels of r_s for 15 treatments (13 df) are 0.514 at α= 0.05 or 0.641 at α= 0.01 (Snedecor and Cochran 1976, p.557)

5. Phase I results

5.1 Overall fit of model to data

The distribution of the differences between predicted and observed values differed significantly from a normal distribution (α=0.05) for 12 of the 21 variables (Table 2). Only stemwood periodic annual increment, foliage biomass, branch biomass, total biomass, smallest tree biomass and height, base mortality rate, net assimilation rate and foliage litterfall showed normal distributions. The mean difference was significantly different from zero for 15 of the 21 variables (Table 2). These results indicate that the Freese (fn, fc, fv) and Reynolds critical error (e^*, e^{**}) values should be interpreted with caution.

Since the differences for several variables were not normally distributed it may indicate that the differences come from more than one sub-population. This would occur if the fit of model and data differs with treatment. Sub-populations for one or more treatments may themselves be normally distributed. To examine for variation between treatments an analysis of variance (ANOVA) was performed on the population of differences to test for the effects of thinning, fertilization and their interaction. It should be recognized that because FORCYTE-11 is a deterministic model and the data points for each treament are not independent, ie., serial data are being used, the results of the AOV should be treated with caution. The calculated p values should be treated simply as indices of the effects of treatment and not as measures of significance. In most cases if the overall population of differences was not normally distributed then at least one of the effects or the interaction had high p values, providing strong evidence that more than one population of differences exists for that variable (Table 2). This suggests that comparisons of model and data fit should be made for each treatment.

5.2 Fit of model to data for individual treatments

5.2.1 Stand level biomass. The FORCYTE-11 model underestimated total stemwood biomass for the control plots (T0F0) (Figure 2). The addition of fertilization caused an overestimate of stemwood biomass for T0F2. Stemwood biomass estimates for both thinning treatments were very close to the actual data early in the simulation, but the model overestimated stemwood biomass during the last few measurement periods (Figure 2). Predicted periodic annual increment of stemwood biomass was underestimated in the control and overestimated for the three treatments (Figure 3). The model underestimated bark biomass in the control plots, but was reasonably close to the data on the treated plots (Figure 4). Predicted branch biomass was much higher than reported values for the T0F0 and T0F2 plots (Figure 5). Model predictions were much closer to reported values for the thinned plots.

In control plots, FORCYTE-11 predicted that foliar biomass had plateaued at age 15 and therefore after year 24 consistently underestimated foliar biomass (Figure 6). The model overestimated foliage biomass in the T0F2 plots at treatment but was close to the measured values 6 and 9 years after treatment. Simulations of foliage biomass were most accurate for the thinned plots. The model showed a maximum foliage biomass of 7 - 8 Mg ha^{-1} when no fertilization was simulated (T0F0, T2F0). Maximum foliage biomass was increased to about 12 Mg ha^{-1} with simulated fertilization. Predicted total aboveground biomass followed the pattern for stemwood biomass with the best fit occurring on the thinned treatments (Figure 7).

In the actual Shawnigan Lake data, many of the treated plots started with substantially lower stem volumes (and therefore stemwood biomass) than the control (Gardner 1990). Although the FORCYTE-11 runs were initiated so that, at the time of treatment, each treatment started with the correct number of trees, the model predicted that the starting biomass in each treatment was similar. Hence, there was a built in bias in biomass predictions at the start of the simulation. This initial bias was worst in the T0F2 treatment and not as important in the other treatments since they were heavily thinned immediately at treatment. There was no way of overcoming this initial bias problem in FORCYTE-11 without providing a different calibration data set for each treatment.

5.2.2. Individual tree biomass. FORCYTE-11 greatly underestimated the biomass of the largest trees in the unfertilized treatments and slightly underestimated maximum size in the fertilized treatments (Figure 8). The step function nature of the actual data on the graphs was due to calculations of stemwood biomass based on stand tables. In the Shawnigan data set, a tree remains in the same size class for several measurement periods and then suddenly jumps to the next size class. Simulations of average and smallest tree size were generally accurate for all treatments (Figures 9,10).

5.2.3. Heights. FORCYTE-11 generally predicted a narrower range of tree heights than was actually measured at Shawnigan Lake, especially in the control plots. Simulation of canopy top height (Figure 11) was reasonably accurate for all treatments except the control, where FORCYTE-11 predicted considerably shorter dominant trees. The model also overestimated the height of the smallest trees in all treatments except T2F0 (Figure 12). The bottom of the canopy was lower in all treatments at Shawnigan Lake than simulated values (Figure 13). Simulated canopy depth (Figure 14) was consistently lower than the data due to the general overestimate of canopy bottom height.

5.2.4. Stocking and mortality. The model accurately predicted stocking for T0F0 and the two thinning treatments, but overestimated the number of trees following fertilization alone (Figure 15) due to an underestimate of fertilizer induced mortality in T0F2 (Figure 16). The initial difference in stem density for the T0F0 treatment (Figure 15) was due to the use of treatment average (1971 and 1972 plots) stem density data to initiate the model and the individual treatment stand table data used in the figure and statistics. Prior to the Phase II simulations, individual stand treatment table data were used to initiate the model and for all model to data comparisons.

Simulated mortality in the control plots matches the data reported by Gardner (1990). Although no mortality occurred at Shawnigan Lake after thinning (T2), the model predicted very low but measurable mortality after thinning (Figures 16,17) and underestimated mortality in both the unthinned treatments. However, the stemwood biomass of mortality was overestimated by FORCYTE-11 (Figure 18). The base (density-independent) mortality rate was overestimated by FORCYTE-11, especially in the thinned plots where no mortality actually occurred after treatment (Figure 19). The model underestimated the shade-induced (density-dependent) mortality rate in the unthinned plots, but correctly predicted no shade-induced mortality after thinning (Figure 20).

5.2.5. Net assimilation rate and litterfall. The model slightly underestimated net assimilation rate in the control plots (Figure 21). A slight underestimate was expected since Brix (1983) measured only codominant trees and so his estimates of net assimilation rate should be slightly higher than model predictions which are based on the whole stand. FORCYTE-11 also underestimated the effect of fertilization on net assimilation rate, and slightly overestimated the effect of thinning.

Even given the great deal of annual variation in litterfall at Shawnigan Lake, FORCYTE-11 underestimated foliage litterfall in the control plots (Figure 22). The model more accurately predicted litterfall in the treatment plots, but the model tended to overestimate litterfall at the time of treatment and underestimate following treatment. The T2F2 treatment plot was refertilized at age 33 and therefore data for subsequent years were excluded. Since the litterfall collected in the traps at Shawnigan Lake was 90 to 95% foliage by weight but was not routinely sorted from fine twigs and cones (Trofymow *et al.* manuscript in prep.) the Shawnigan data may slightly overestimate actual foliar litterfall.

5.2.6. Foliar N content and increment. FORCYTE-11 underestimated foliar N content for control plots due to its underestimate of foliage biomass (Figure 23). The model overestimated foliage N on the T0F2 treatment 9 years after treatment (at age 33 years), but was very close to the stand table estimate at year 12 (at age 36 years). Predictions for treatments T2F0 and T2F2 were reasonably close to reported values and estimates from the stand tables.

For all treaments, the model predicted lower foliar increments than those observed (Figure 24). The greatest underestimate was for control plots for which the model predicted a net decrease in foliage biomass after 9 years and thus negative net foliar production.

6. Phase I conclusions

The FORCYTE-11 model accurately simulated some of the treatment responses at the Shawnigan Lake plots, but simulation of growth on the control plots was inadequate. Thinned treatments were simulated most accurately. The model underestimated growth on the control plots due to nutrient limitations. Nitrogen demand exceeded availability in the simulation starting at about age 10 and this caused site quality to decline. Since, site quality in FORCYTE-11 is simply an index of nutrient (in this case N) availability with respect to demand (Kimmins *et al.* 1990), when N availability exceeds tree demand then the site quality begins to increase. When demand for N exceeds availability, site quality declines.

All three treatments but especially fertilization caused an increase in site quality when applied at age 24. As growth continues, available soil N was depleted and the trees' demand increased thus causing site quality to decline. Site quality increased after age 70 when tree growth slowed and demand decreased. This late increase in site quality was exacerbated by a positive feedback in the model. In the initial Douglas-fir SOILDATA file, sites of three qualities are defined (Appendix I). The poor, medium, and good sites receive annual inputs of 1, 2, and 3 kg N ha^{-1}, respectively, from fixation by non-symbiotic organisms. Therefore, as site quality increases, the model predicts higher annual N inputs causing site quality to increase further. When nitrogen was not severely limiting, FORCYTE-11 appeared to simulate stand growth more accurately.

The treatments that included thinnings were simulated most accurately because thinning brought the number of stems per hectare within the range of the initial model calibration data. The TREEDATA file specifies a maximum of 1800 stems ha^{-1} (Appendix I). The thinning treatments take a stand of at least 4000 - 5000 stems ha^{-1} and thin it down to approximately 900 stems ha^{-1}. FORCYTE-11 gives unpredictable results when operated outside the range of its calibration data. The poorest simulations were of unthinned stands which were less uniform. The stand at Shawnigan Lake became established over several years and contains many smaller suppressed trees (Crown and Brett 1975). The TREEDATA input file specifies a stand in which the trees were planted or naturally regenerated all in one year and the size class data are based on a fairly uniform stand of 1800 stems ha^{-1}; therefore, the model does not simulate the wide variation in tree size found at Shawnigan Lake.

One major area of model weakness involves the simulation of decomposition. At 36 years, simulated soil organic matter (humus in FORCYTE-11) levels for the entire soil system were about 20 Mg ha^{-1}. The actual soils data indicate a soil organic matter capital of 100 - 120 Mg ha^{-1} (J.A. Trofymow, unpublished data). This discrepancy occurs because, in the default FORCYTE-11 data set for the FORSOILS program, less than 1% of the original mass of decomposing materials eventually becomes humus.

7. Calibration of FORCYTE-11 for Phase II

Phase II of the project involved calibrating the FORCYTE-11 model using data from the Shawnigan Lake experiment to improve the simulation of the control plots. Attempts were made to address some of the weaknesses observed in phase I. A number of changes were made in the SOILDATA, TREEDATA, and PLNTDATA files (Appendix I). In the discussion that follows, the letters in parenthesis refer to the parts of Appendix I. Shaded lines in the Appendix indicate changes made prior to the Phase II simulations.

The simulation of soil processes was modified by editing the SOILDATA file. In an attempt to increase the amount of humus and available N in the simulation the decomposition rates for all detritus were set to release 15% of the original detrital mass to the soil humus pool at the end of decomposition (Appendix Ic). Decomposition times were not changed. The humus decomposition rates were adjusted to maintain a humus pool of 100 - 120 Mg ha^{-1} which is consistent with Shawnigan Lake data (Appendix I b,e). Humus decomposition rates were set to remain constant following clearcutting (Appendix I b,e). The original data increased humus decomposition after harvest by a factor of 1.5 - 2.0 after a delay of several years.

The N concentration in humus was set to increase slightly with site index (Appendix I b,e). It was constant in the original data set. Increasing humus N concentration with site index buffers the available N pool. As available N increases so does site quality. This causes more N immobilization by decomposing materials which must reach a higher final N content on better sites to become humus. Increased immobilization by the forest floor results in less available N for tree growth and, consequently, lower site quality. This effectively simulates an active microbial pool which increases in size as N availability increases even though the FORCYTE-11 model does not include the simulation of any microbial component.

Nitrogen inputs in precipitation remained fixed at 5 kg N ha^{-1} yr^{-1}. The N input due to fixation by non-symbiotic organisms was set at a constant 0.5 kg N ha^{-1} yr^{-1} and N input from seepage was removed (Appendix I a,d,e). The site quality increase due to positive feedback mentioned earlier no longer occurred.

An initial attempt was made to simulate growth of a second cohort of Douglas-fir trees under the planted stand to mimic natural regeneration. This strategy was abandoned after several trials. The second cohort could be made to survive by increasing its shade tolerance, but the size class distribution was the same as the overstory so there was little change in the overall size class distribution of the stand. This problem could be addressed by having different size class distributions for the two cohorts. However, data were not available and adjusting the model for two shade tolerances and size class distributions was beyond the scope of this project. Instead it was assumed that all trees were established the first year and exhibited the wide range of size classes on the Shawnigan Lake control plots.

In addition to the changes to the TREEDATA file for size class distribution, stand density and plant detailed below, five changes to the biomass and height data were also made: 1) The concentrations of N in all biomass components in the original low site data were changed to eliminate the relatively minor discrepancies between it and the Shawnigan Lake data (Appendix I h,l). 2) The biomass of all aboveground tree components on the low site were also set to match the Shawnigan Lake control plot data (Appendix I f). 3) To improve the fit of the model, the amount of expected foliage biomass of the medium and high sites were lowered and the times to reach the maximum values were increased so that foliage biomass would not increase as rapidly with site quality improvement as seen at the beginning of the simulation. 4) Tree height data was also changed to match Shawnigan Lake data on the low site (Appendix I g). 5) Canopy top heights for the medium and high sites were left unchanged, but the heights of the smallest trees and the canopy bottom heights were reduced (Appendix I i,k).

Tree size class distributions were changed to match Shawnigan data on the low site at ages 23, 33, and 39 (Appendix I g). No size class distributions were specified for any other ages due to a lack of data. The model applies the shape of these distributions to younger and older stands if no distributions are specified for other ages. Size class distributions were also changed on the other two sites to give stemwood biomass distribution curves with shapes similar to the low site (Appendix I i,k). In general these curves are now skewed to the left. There are more trees in the smaller size classes.

The expected number of trees was increased on all three sites (Appendix I g,i,j). The original data called for a maximum of 1800 trees ha^{-1}, which meant the model was operating outside the range of its calibration data. The MANAFOR module could not reproduce the TREEGROW tree biomass and height growth with nutrient feedback off. The new data predicts a maximum of 6000 trees ha^{-1} on all sites and there is now good agreement in the control plots between biomass and height growth predicted by TREEGROW and that predicted by MANAFOR with nutrient feedback off.

A major change in the calibration dataset was the addition of salal as a competitor with Douglas-fir to slow down the initial increase in site quality in the simulation (Appendix I m,n). The PLNTDATA file was modified to simulate growth of salal as plant number two. Data for salal growth was provided by Christian Messier (University of British Columbia, unpublished data). The model dataset was adjusted so that salal provides relatively little light competition for Douglas-fir, but it does compete for nitrogen. Salal took up about 6-7 kg N ha^{-1} annually for the first 10 years of the simulation.

8. Phase II results

In general, simulations of tree biomass growth at Shawnigan Lake were improved using the calibrated FORCYTE-11 model. However, simulation of tree mortality in unthinned plots was worse. The height and biomass of the smallest trees were also not simulated correctly. Simulations of other variables were either unchanged or only slightly improved.

8.1 Overall fit of model to data

The statistical analyses from phase I were repeated (Table 3) with similar results. The distribution of the differences between predicted and observed values was not normal (α=0.05) for 13 of the 21 variables, compared to 12 of 21 variables in phase I. Variables for which the distribution of differences was normal in phase I, but not in phase II included bark, branch and total biomass, smallest tree height and base mortality rate. The distribution of differences for stemwood biomass, stemwood periodic annual increment, average tree biomass, and canopy depth were normal in phase II, but not in phase I. The mean difference differed significantly from zero for 15 of the 21 variables in phase II. An equal number differed significantly from zero in phase I. Again, this indicates that Freese and Reynolds critical values should be interpreted with caution. The results of the ANOVA indicated sub-populations may exist for one or more treatments.

A comparison of the overall Reynolds critical values (e^*, e^{**}) for phases I and II shows that simulations of biomass growth and net assimilation rate were better in phase II as indicated by the lower Reynolds values. Overall simulation of the largest tree size improved, but simulations of average and particularly the smallest tree sizes were worse. Simulations of density and mortality were generally worse except for base mortality rate and the biomass of mortality which improved slightly in phase II. Tree height simulations improved except for smallest tree height which was much worse. When compared to phase I, most of the biomass and height r^2 values increased and several of stocking and mortality r^2 values decreased.

8.2 Fit of model to data for individual treatments

8.2.1 Stand level biomass. Simulations of stand biomass variables were improved in phase II. The simulation of stemwood biomass was slightly improved on all treatments (Figure 2). Simulation of periodic annual increment was improved on all treatments except T0F2 where it was marginally worse (Figure 3). The model still underestimated bark biomass on the control plots, but the fit was better than in phase I (Figure 4). Simulated bark biomass was virtually unchanged for the other treatments. Predictions of branch biomass were greatly improved in all treatments except T2F2 where the model estimate continued to be low (Figure 5). Foliage biomass simulation was much improved over phase I for all treatments (Figure 6) with the peak in foliage biomass predicted at approximately the correct age for all treatments. The rapid early rise in foliage biomass from phase I was no longer seen. There was still some N limitation on the control plots as evidenced by the underestimate of foliage biomass. The accuracy of total aboveground biomass simulation was relatively unchanged (Figure 7).

8.2.2 Individual tree biomass. Tree size class simulations improved slightly. The simulation of stemwood biomass of the largest tree (Figure 8) improved on all but the T2F2 treatment; it was still underestimated in the T0F0 treatment but was overestimated in the T2F2 treatment. Simulation of average tree biomass (Figure 9) remained unchanged.

Table 3. Statistics[a] comparing the overall fit of model and data in Phase II of the FORCYTE-11 evaluation.

Variable	Mean Diff.	σ^2 Diff.	r^2	Prob. Norm.	Prob. f=0	ANOVA p values			α=0.05		α=0.20	
						Thin	Fert	T x F	e*	e**	e*	e**
Stemwood Biomass (Mg ha^{-1})	10.01	19.55	0.76	0.13	0.02	0.00	0.00	0.00	34.37	55.73	24.94	31.91
Stemwood PAI (Mg $(ha\ yr)^{-1}$)	1.18	1.74	0.38	0.04	0.01	0.30	0.00	0.04	3.24	5.51	2.37	3.11
Stembark Biomass (Mg ha^{-1})	-1.07	3.41	0.68	0.07	0.14	0.00	0.00	0.01	5.58	9.05	4.05	5.18
Foliage Biomass (Mg ha^{-1})	-0.24	1.36	0.81	0.65	0.50	0.00	0.00	0.00	2.05	3.72	1.52	2.06
Branch Biomass (Mg ha^{-1})	-0.75	2.86	0.70	0.05	0.21	0.40	0.34	0.03	4.61	7.47	3.34	4.28
Total Biomass (Mg ha^{-1})	-0.28	22.96	0.81	0.00	0.95	0.00	0.00	0.00	35.76	57.99	25.95	33.20
Largest Tree (kg)	-23.18	121.32	0.18	0.18	0.36	0.00	0.00	0.12	192.53	312.21	139.74	178.75
Average Tree (kg)	8.55	11.46	0.98	0.29	0.00	0.00	0.11	0.37	22.45	36.41	16.30	20.85
Smallest Tree (kg)	-32.06	22.70	0.81	0.03	0.00	0.06	0.79	0.51	62.06	100.64	45.05	57.62
Density (# ha^{-1})	151.60	317.49	0.97	0.00	0.03	0.62	0.00	0.01	550.24	892.26	399.37	510.86
Mortality (# ha^{-1})	-75.05	104.54	0.40	0.00	0.01	0.03	0.01	0.07	197.92	336.74	144.95	189.96
Mortality Rate (%)	-0.67	0.99	0.43	0.00	0.01	0.05	0.00	0.02	1.83	3.12	1.34	1.76
Canopy Top Height (m)	1.47	2.53	0.58	0.00	0.01	0.00	0.00	0.00	4.59	7.44	3.33	4.26
Smallest Tree Height (m)	-4.12	3.03	0.84	0.05	0.00	0.00	0.02	0.74	8.08	13.11	5.87	7.50
Canopy Bottom Height (m)	-1.05	1.11	0.65	0.00	0.00	0.94	0.09	0.28	2.35	4.00	1.72	2.25
Canopy Depth (m)	2.63	3.11	0.29	0.19	0.00	0.00	0.00	0.00	6.27	10.67	4.59	6.02
Mortality Biomass (kg ha^{-1})	-494.78	798.46	0.49	0.00	0.01	0.06	0.29	0.44	1442.30	2453.93	1056.30	1384.29
Base Mortality Rate (%)	0.0114	0.06	0.08	0.00	0.53	0.06	0.02	0.10	0.10	0.16	0.07	0.09
Shade Mortality Rate (%)	-0.66	0.98	0.37	0.00	0.01	0.08	0.00	0.01	1.82	3.10	1.33	1.75
NAR[b] (kg (kg foliage $yr)^{-1}$)	0.13	0.34	0.50	0.08	0.05	0.43	0.27	0.65	0.58	0.91	0.42	0.52
Litterfall (kg $(ha\ yr)^{-1}$)	-276.07	527.72	0.43	0.10	0.00	0.02	0.01	0.47	980.97	1416.09	696.00	839.39

[a]Mean Diff.	- Mean difference
σ^2 Diff.	- Variance of differences
r^2	- Simple correlation coefficient of model to data fit
Prob. Norm.	- Probability the differences are normally distributed
Prob. f=0	- Probability the mean difference is 0
ANOVA p value	- Probabilities resulting from two-way ANOVA of differences
e^*, e^{**}	- Reynold's critical values calculated at 5% or 20% (α) error levels. Values are in the same units as the variable. e^* assumes the model is most accurate, e^{**} assumes the data are most accurate
[b]NAR	- Net assimilation rate

The calibrated model's estimate of smallest tree biomass for all treatments was much worse than in Phase I (Figure 10).

8.2.3 Heights. The simulation of all canopy height variables except smallest tree height improved. Simulated canopy top height was much more accurate for T0F0 in phase II (Figure 11). Simulated smallest tree height was also better for T0F0, but greatly underestimated for all other treatments in phase II (Figure 12). Canopy bottom height was slightly underestimated on all treatments, but the fit was much improved over phase I (Figure 13). Simulation of canopy depth was accurate for the control plots (Figure 14), but was overestimated in the other treatments due to the underestimate of smallest tree height and canopy bottom height.

8.2.4 Stocking and mortality. The simulations of stem density, mortality and mortality rate (Figures 15-17) were worse for unthinned plots in phase II due to a lack of shade-induced mortality before after age 33 (Figure 20). Simulations of the thinned plots were unaffected. Predictions of stemwood biomass of mortality were improved in phase II, but were underestimated for unthinned treatments (Figure 18). The simulation of the base mortality rate improved in phase II (Figure 19).

8.2.5 Net assimilation rate and litterfall. The more accurate simulation of foliage biomass improved the simulation of net assimilation rate in phase II (Figure 21). However, simulation of litterfall did not improve much except for the T2F2 treatment (Figure 22).

8.2.6 Foliar N content and increment. Predictions of foliar N were improved on the control plots (Figure 23). The negative net foliage production for T0F0 seen in phase I was corrected (Figure 24).

8.3 Model's fit and ranking of all treatments

Most of the tests of the model in Phase I and II concentrated on how accurately FORCYTE-11 could predict treatment effects. An alternative approach in testing a model is to examine how well the model predicts the relative ranking of a number of treatments. Indeed, the latter approach has been suggested by the model's authors (Kimmins and Scoullar 1989) as FORCYTE-11's primary purpose and is reflected as such in the model's full name - FORest nutrient Cycling and Yield Trend Evaluator.

The calibrated model was run to simulate the results for all 15 treatments (Table 1) (Gardner 1990). The model's predictions and data from the Shawnigan site were compared graphically, and comparisons of predicted and actual rankings were made by Spearman's rank correlation (r_s). Variables examined included total stemwood volume, stem density, 3-year volume increment (PAI), 0-9 year increment, 9-15 year increment, 0-15 year increment and 15-year adjusted stemwood volume. The adjusted volume had been corrected by covariate analysis for the initial differences in pretreatment plot volumes (Gardner 1990). A wood density of 0.42 g cm^{-3} was used to convert FORCYTE-11 stemwood biomass values to stemwood volumes.

Model estimates of stemwood volume in unthinned, lightly fertilized treatments were low but improved in treatments with higher rates of fertilization (Figure 25). The model consistently overestimated volume in heavily thinned plots at all levels of fertilization. The model's ranking of the treatments was good at each measurement period but declined over time and differed from actual treatment rankings only at year 9 if a 1% significance level was used (Table 4). The model's predictions of adjusted 15-year volumes slightly improved (Figure 26) as did the model's ranking of treatments (r_s unadjusted volume = 0.754, r_s adjusted volume = 0.818).

Since the model tended to underestimate mortality, FORCYTE-11 increasingly overestimated stem density in unthinned plots (Figure 27). The model failed to emulate the effects of increasing fertilization on stem densities which declined more rapidly as the rate of fertilization increased. In heavily thinned plots no mortality occurred and stem density levels were correctly predicted to remain constant. As expected, model rankings of treatment were initially exact (the model was initiated with actual data) and then worsened but at no time did the predicted rankings differ significantly from actual rankings (Table 4).

Table 4. Spearman's Rank correlation coefficients[1] comparing model to data ranking of stemwood volume, density and 3-year periodic annual volume increment (PAI).

Years since treatment	Stemwood Volume	Stem Density	3-year PAI
0	0.865	1.000	-
3	0.896	1.000	0.842
6	0.711	0.996	0.753
9	0.536	0.988	0.682
12	0.682	0.975	0.953
15	0.754	0.971	0.852

[1]critical values for significance
0.514 at α= 0.05
0.641 at α= 0.01

At all thinning levels the model went from underestimating PAI at low fertilization levels to overestimating PAI at high fertilization levels (Figure 28). Although the lowest value of Spearman's rank correlation coefficient occurred at 9 years, at no time did the model treatment rankings significantly differ from actual rankings (Table 4). FORCYTE-11 predictions of PAI for the 0-9 year period (Figure 29), 9-15 year period (Figure 30) and 0-15 year period (Figure 31) again reflected the bias the model had in underestimating growth in unthinned treatments at low fertilization levels and overestimating the growth response to increasing fertilization levels at all thinning levels. Although model rankings of PAI never significantly differed from actual rankings, Spearman's rank correlation coefficient for the 9-15 year PAI, the period with the greatest bias, was lower (0.861) than for either the 0-9 year PAI (0.936) or the 0-15 year PAI (0.958).

9. Phase II conclusions

The calibrated model was generally more accurate than the original phase I model. The new calibration data were more representative of the actual stands at Shawnigan Lake. FORCYTE-11 was used within the range of its calibration data as was the intent of its authors. Problems with the calibration data set which affect model behavior still exist. More data are needed on height, stocking, and size class distributions of stands on better sites. These stands should preferably be located on Vancouver Island, but data from the lower mainland could be used. Size class and height simulations in FORCYTE-11 are directly dependent upon the data for better sites. The mortality simulation is also dependent not only on the number of trees, but also the height of the canopy and smallest trees.

Site data for medium and high sites in the calibrated model remain relatively unchanged from that supplied with the model, but the number of trees was approximately tripled and the height and size class data were broadened. This reflects a difference in data set design philosophy. The original data set simulated a relatively uniform stand which was established in one year, as would be the case in a planted forest. The stand at Shawnigan Lake, although planted, had a much wider variation in tree diameter and height due to the establishment of natural regeneration over the next 5 to 10 years. In the phase II data set, we attempted to address this variation. The changes made were not completely successful and further changes in the calibration data set are needed. For example, on medium and high sites the smallest tree height is now too low and there are too many small trees. These problems could be addressed by incorporating inventory data, such as that available from permanent sample plots, from other sites in the same region. Such changes should improve the simulation of mortality, tree height, and size class distribution.

The model still predicted rapidly increasing site quality for the first 15 to 20 years of the simulation. The addition of salal and its N demand improved the simulation, but there was still a great excess of available N early in the simulation and the control plots became very N-limited after crown closure. The simulation of N availability is directly tied to forest floor decomposition. More data are needed on the decomposition of forest floor materials, particularly materials which are resident in the forest floor for long periods of time such as large woody debris. There are problems with the simulation of decomposition in FORCYTE-11, but the current structure has not been thoroughly tested due to lack of data.

10. General conclusions

This project was the first validation trial of FORCYTE-11 against a known data set. The model simulated the Shawnigan Lake experiment reasonably well considering that it is still not well calibrated for Vancouver Island. The model could be better calibrated using inventory data from permanent sample plots and then re-evaluated. Perhaps by then more decomposition data will be available and the model could be more thoroughly tested.

FORCYTE-11 showed promise as a management simulator. It predicted some of the tree growth responses to fertilization and thinning in a Douglas-fir stand on Vancouver Island with reasonable accuracy. However, the model is sensitive to the calibration data. Calibration of the model was difficult, requiring a large amount of time and detailed information on biomass growth, yield, stocking and nutrient content of the both the overstory and major understory species under consideration. Information on decomposition and soil processes for the local area are necessary. After calibration, the model should then be validated against an independent data set for that area. Presumably, if these steps are accomplished, FORCYTE-11 could be a valuable management tool to assist in long-range planning for the area in question. However, the uncalibrated model should not be used to make forest management decisions or be used to extrapolate results beyond the region of calibration. For example, a version of FORCYTE-11 calibrated for coastal Douglas-fir should not be used to simulate interior Douglas-fir stands.

The FORCYTE-11 model also has great value as a research and teaching tool. It can be used to help define research questions and test hypothesis. FORCYTE-11 is probably most valuable as part of a general research program to understand the structure and function of forest ecosystems. Such a program must include process research, simulation modelling, and long-term validation trials (Sollins *et al.* 1982).

The FORCYTE-11 model is extremely large and complex. However, recent advances in personal computer technology have made it relatively inexpensive to acquire the hardware and software required to run the model. The development of the PROBE supervisory programs (Apps *et al.* 1988 and MacIsaac *et al.* 1989) have greatly simplified the operation of the model and interpretation of results, but any user should expect to spend several weeks becoming familiar with the model's operation. A major limitation to the use of FORCYTE-11 is the length of time and the skill level required to calibrate it; a great deal of experience is required. However, once a calibrated version is available for an area, FORCYTE-11 could be run by individuals with relatively little microcomputer experience.

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Figures

For figures 2 - 22, statistics on each graph indicate the mean difference (d) between model and data, probability values for the Wald-Wolfowitz runs test (runs) where a $p<.05$ indicates consistent under or overestimates by the model, and Freese e^* values for no bias (fn), or corrected for constant bias (fc) or variable bias (fv). Freese e^* values can be interpreted as the absolute error (in the same units as shown on the vertical axis of the graphs) that can be tolerated to accept the accuracy of the model at $\alpha=0.05$. For each test a pair of numbers are shown, the first refers to Phase I of the evaluation and the second refers to Phase II, after the model was calibrated with data for the Shawnigan Lake site. The SYSTAT statistical package was used for all analyses.

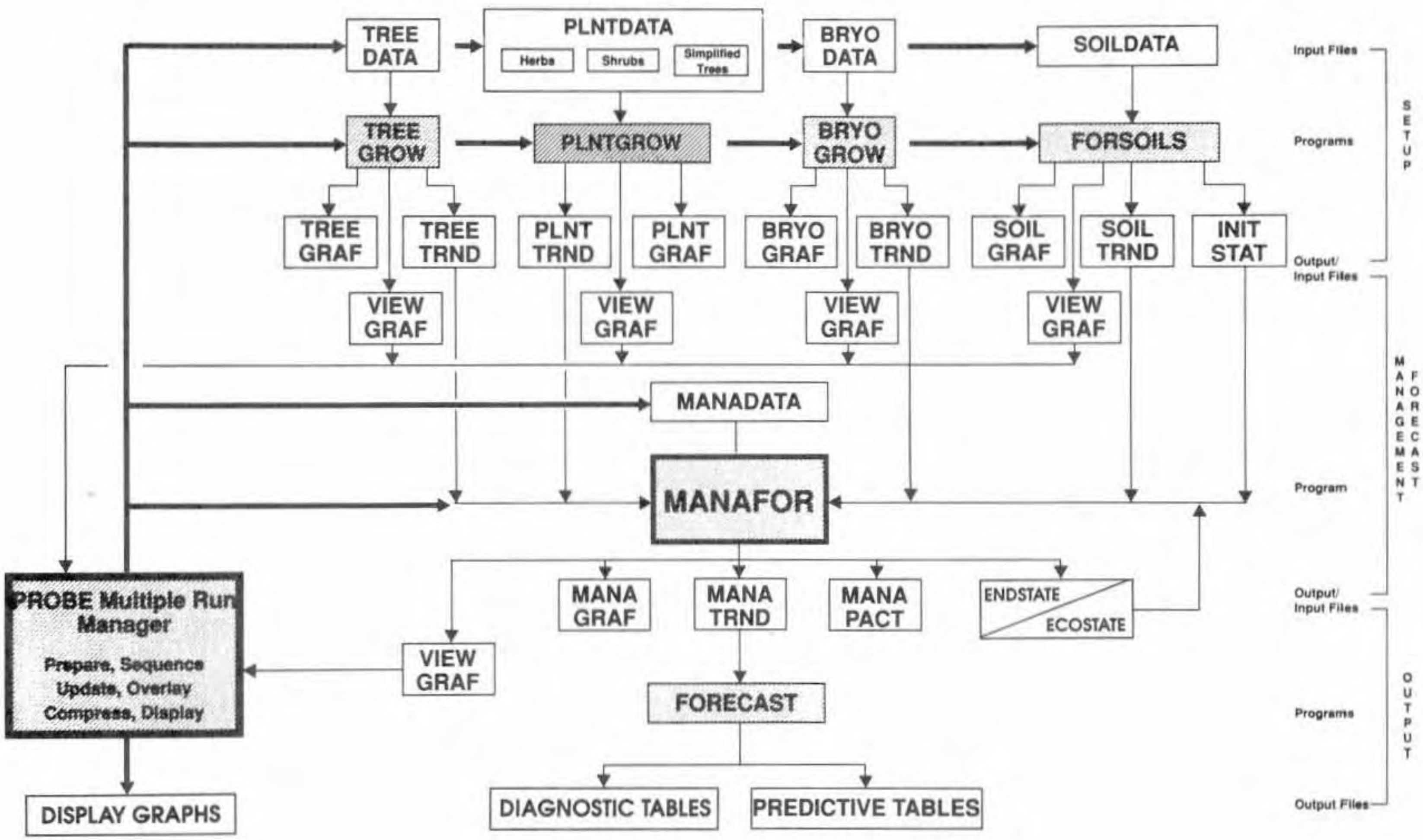


Figure 1. Overall structure of FORCYTE-11. The model is divided into three major sections. The first, data setup, is divided into several plant modules and a soils module. Individual programs may be run separately, or under the control of the multiple run manager, PROBE (Apps *et al.* 1988; Kurz *et al.* 1988; MacIsaac *et al.* 1989). The user selects which setup modules are used in a particular model run. This will determine the complexity of the ecosystem that is to be simulated in MANAFOR. (from Kimmins *et al.* 1990).

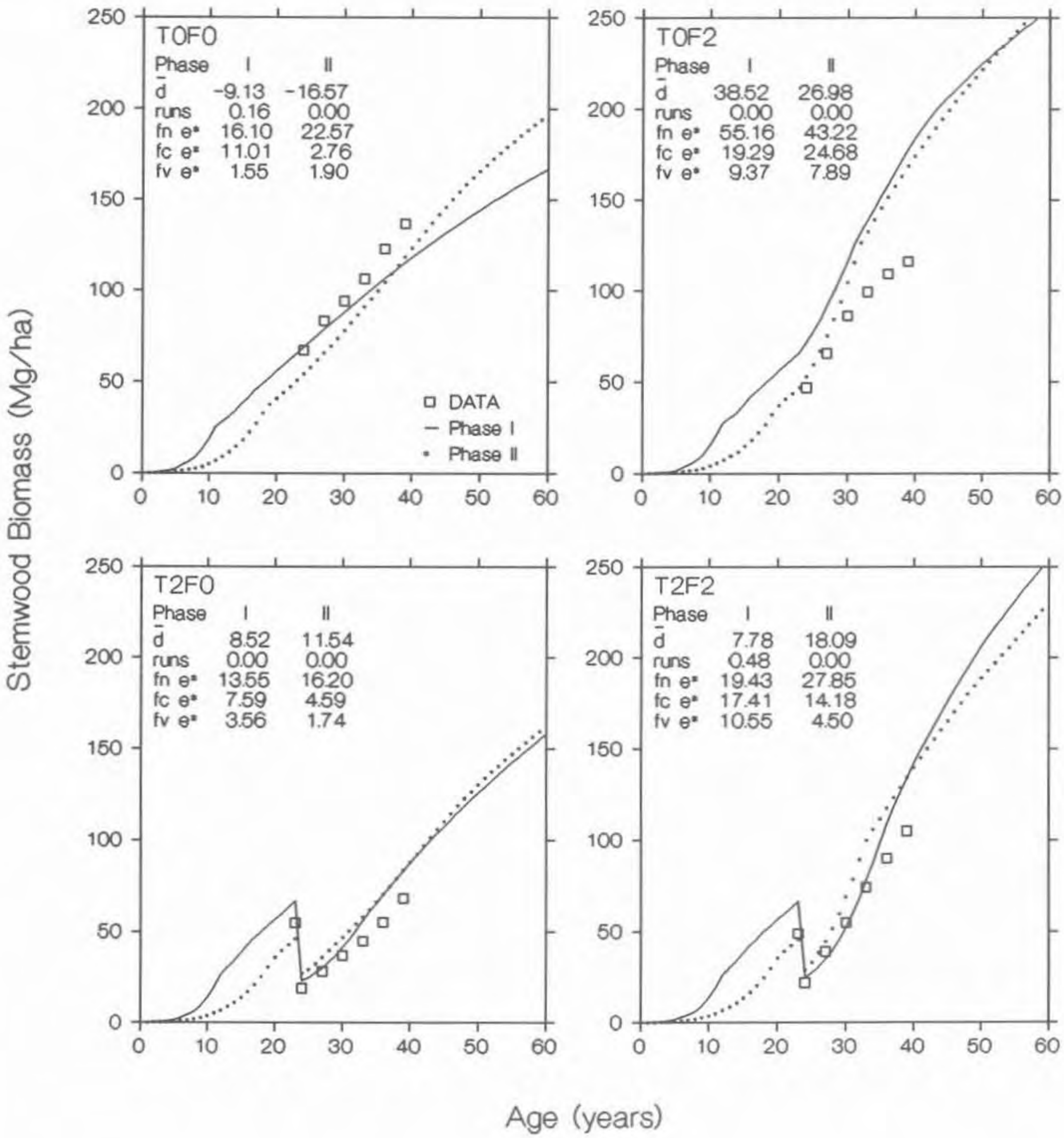


Figure 2. Predicted and measured stemwood biomass under four thinning and fertilization treatments at Shawnigan Lake.

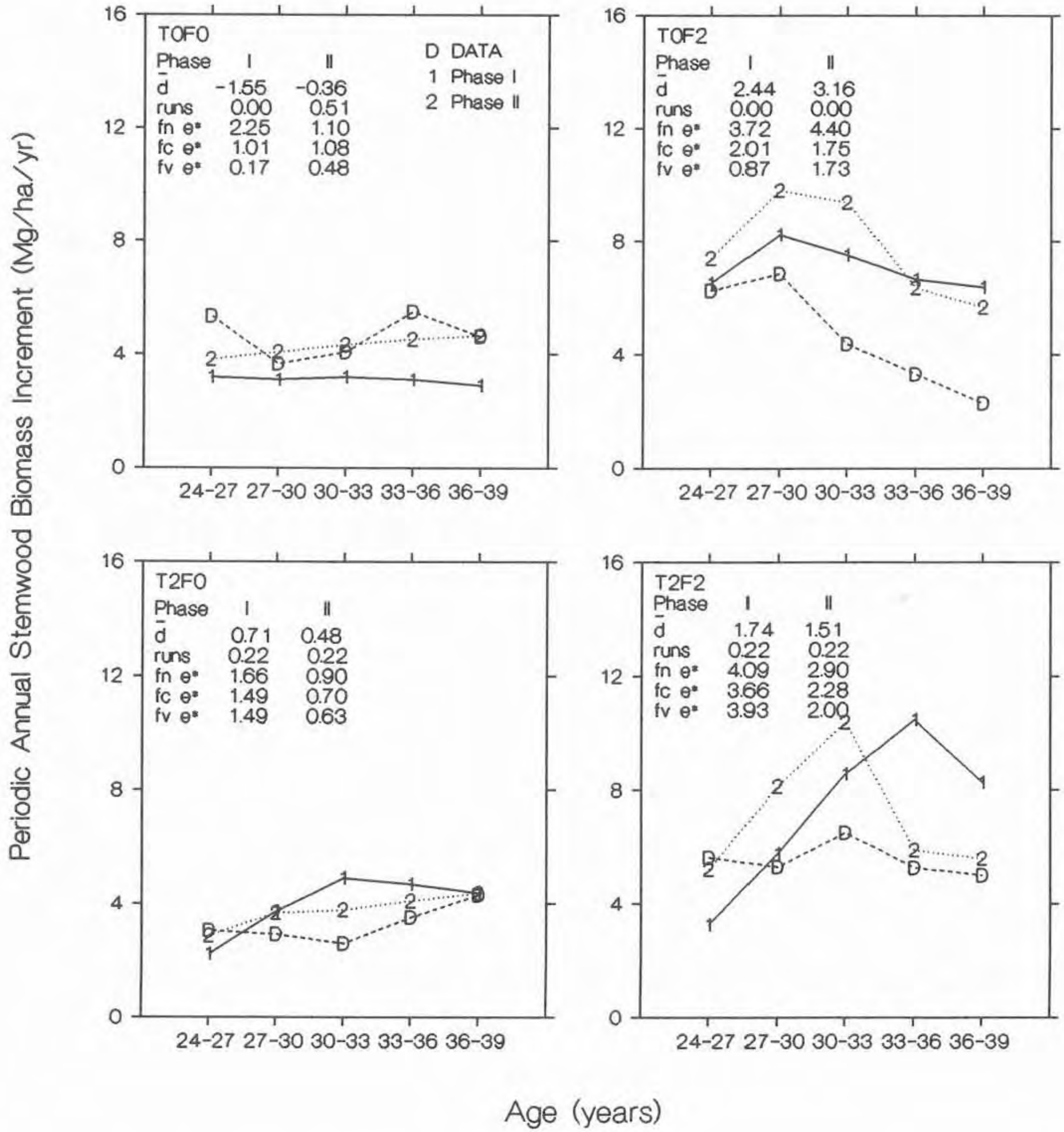


Figure 3. Predicted and measured stemwood biomass periodic annual increment under four thinning and fertilization treatments at Shawnigan Lake.

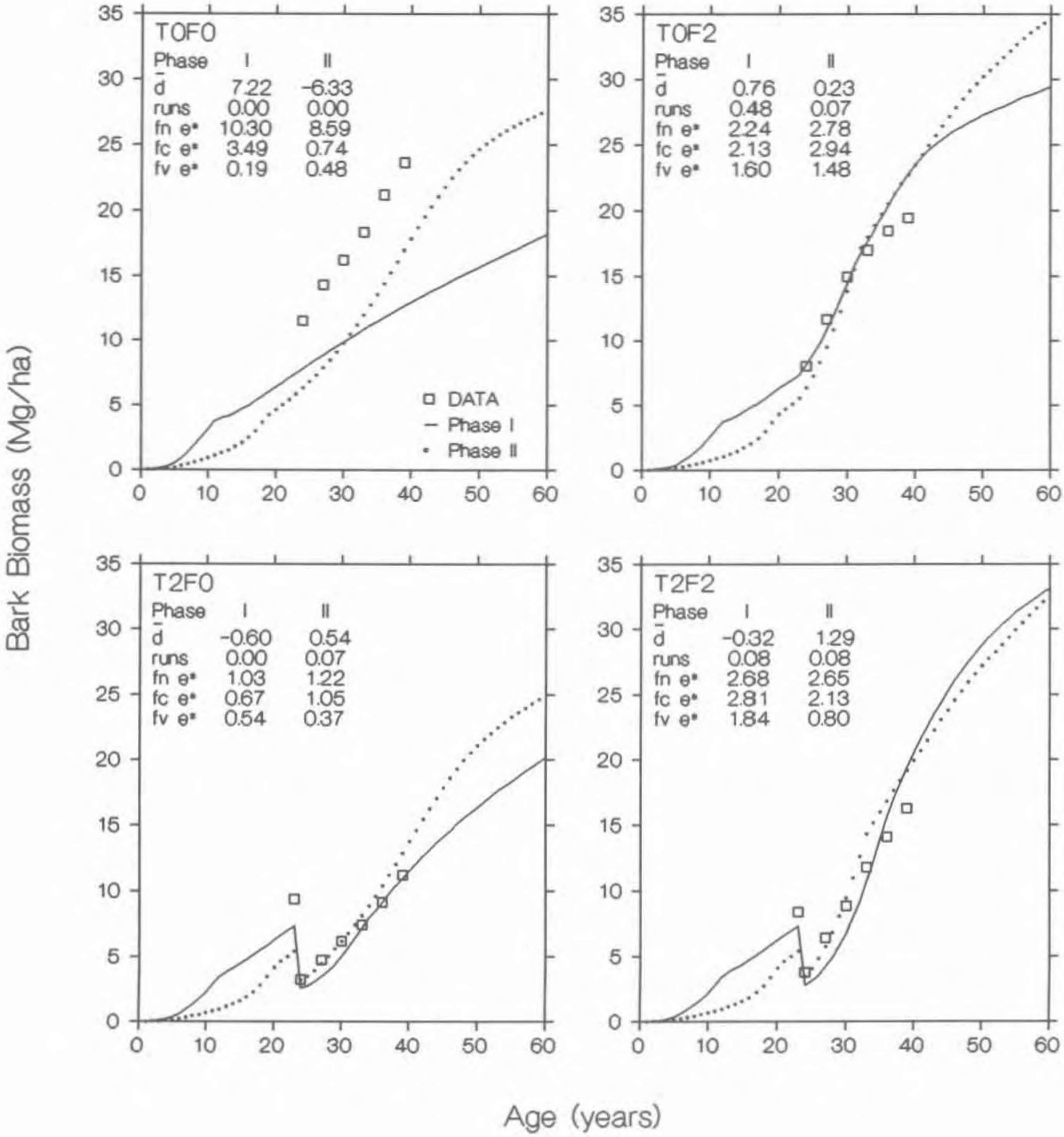


Figure 4. Predicted and measured bark biomass under four thinning and fertilization treatments at Shawnigan Lake.

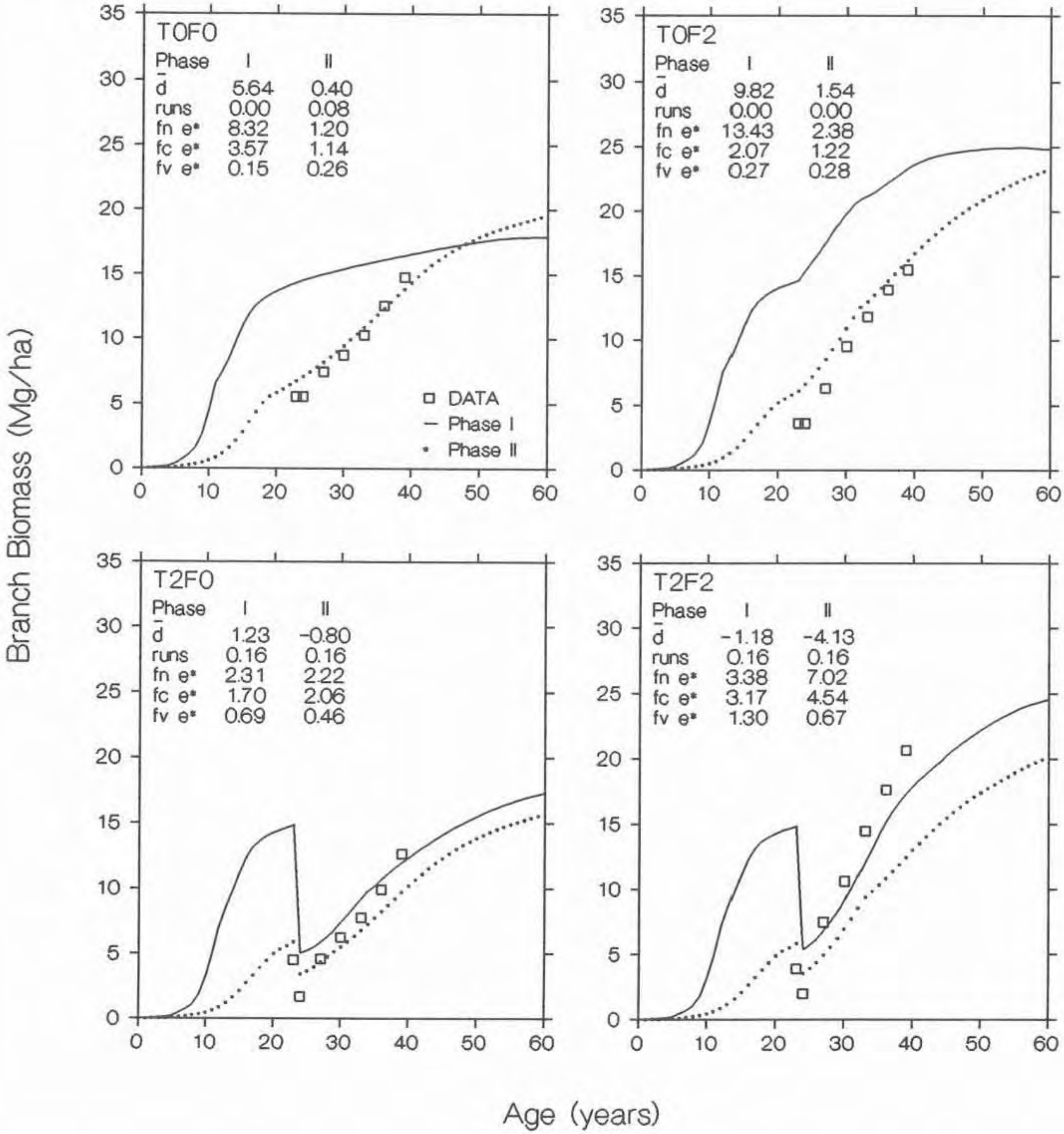


Figure 5. Predicted and measured branch biomass under four thinning and fertilization treatments at Shawnigan Lake.

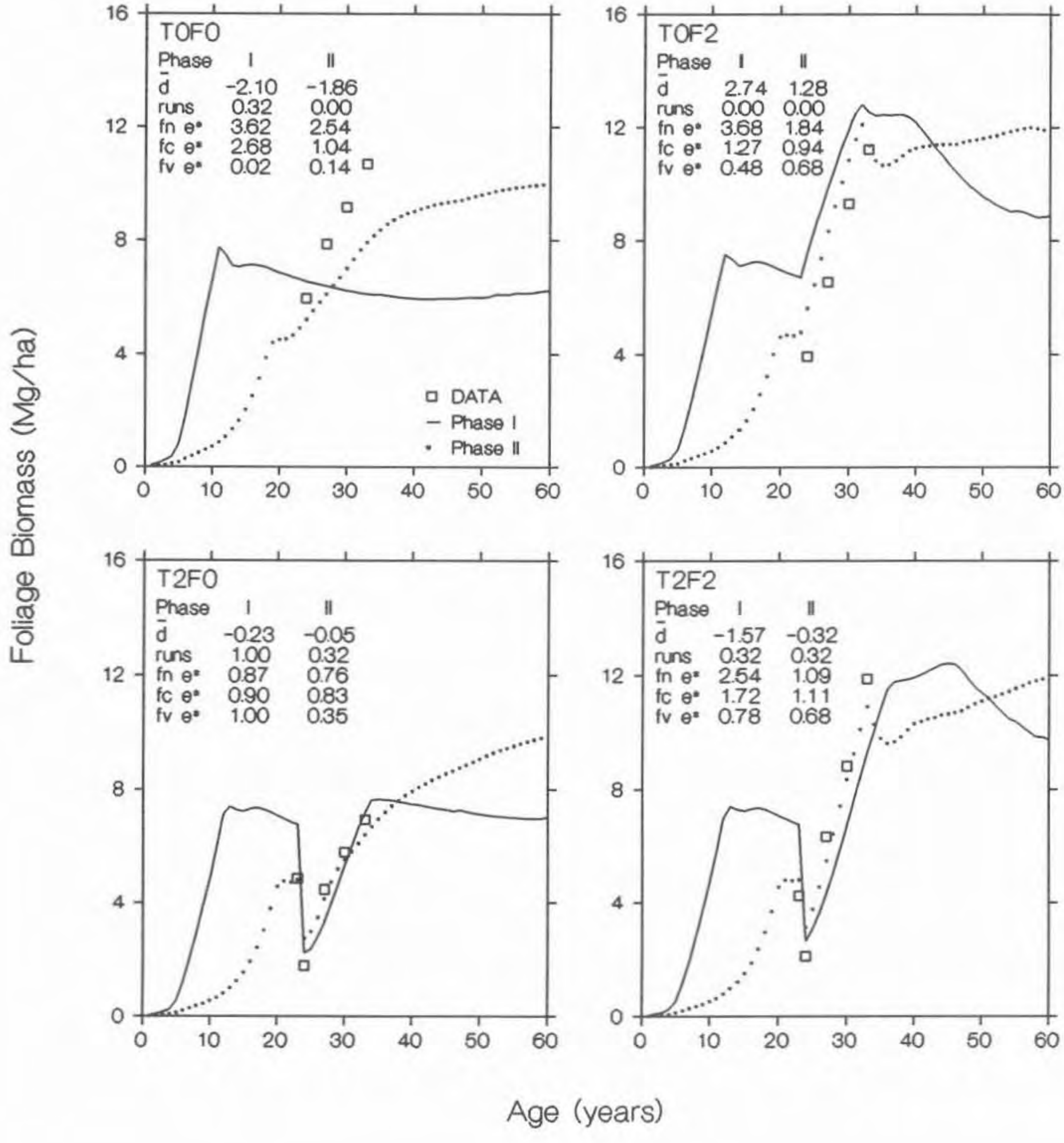


Figure 6. Predicted and measured foliage biomass under four thinning and fertilization treatments at Shawnigan Lake.

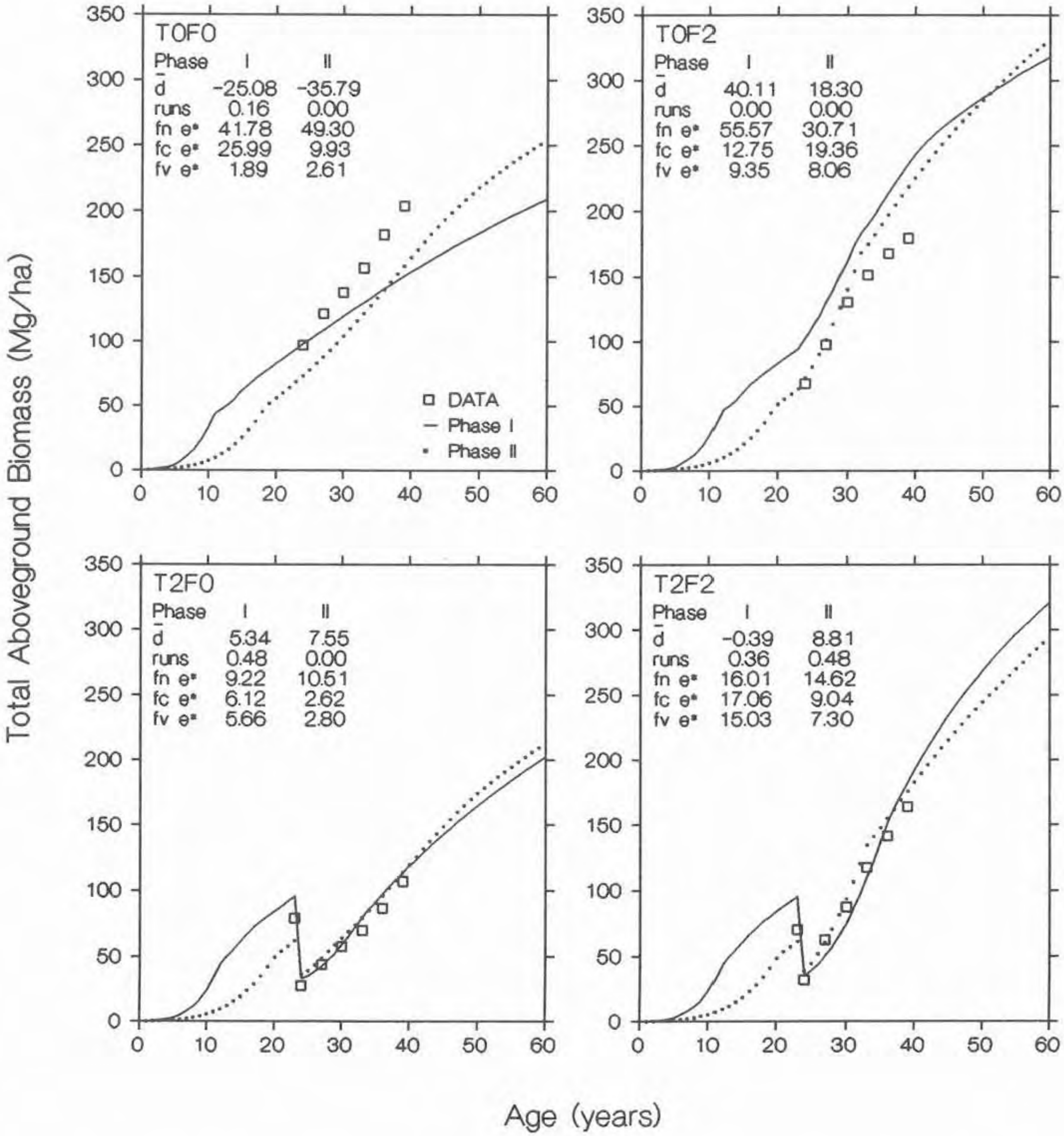


Figure 7. Predicted and measured total aboveground biomass under four thinning and fertilization treatments at Shawnigan Lake.

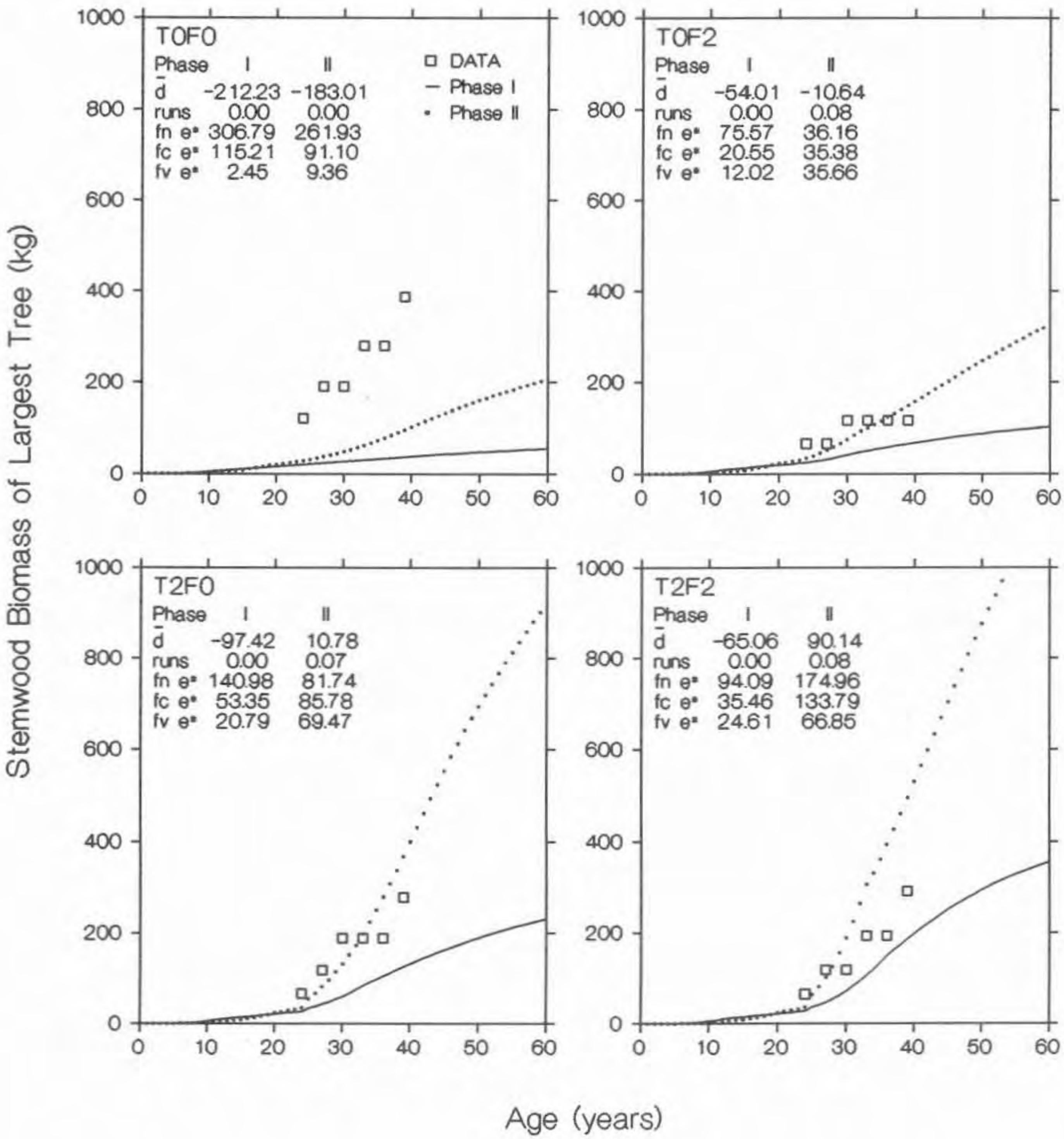


Figure 8. Predicted and measured largest tree stemwood biomass under four thinning and fertilization treatments at Shawnigan Lake.

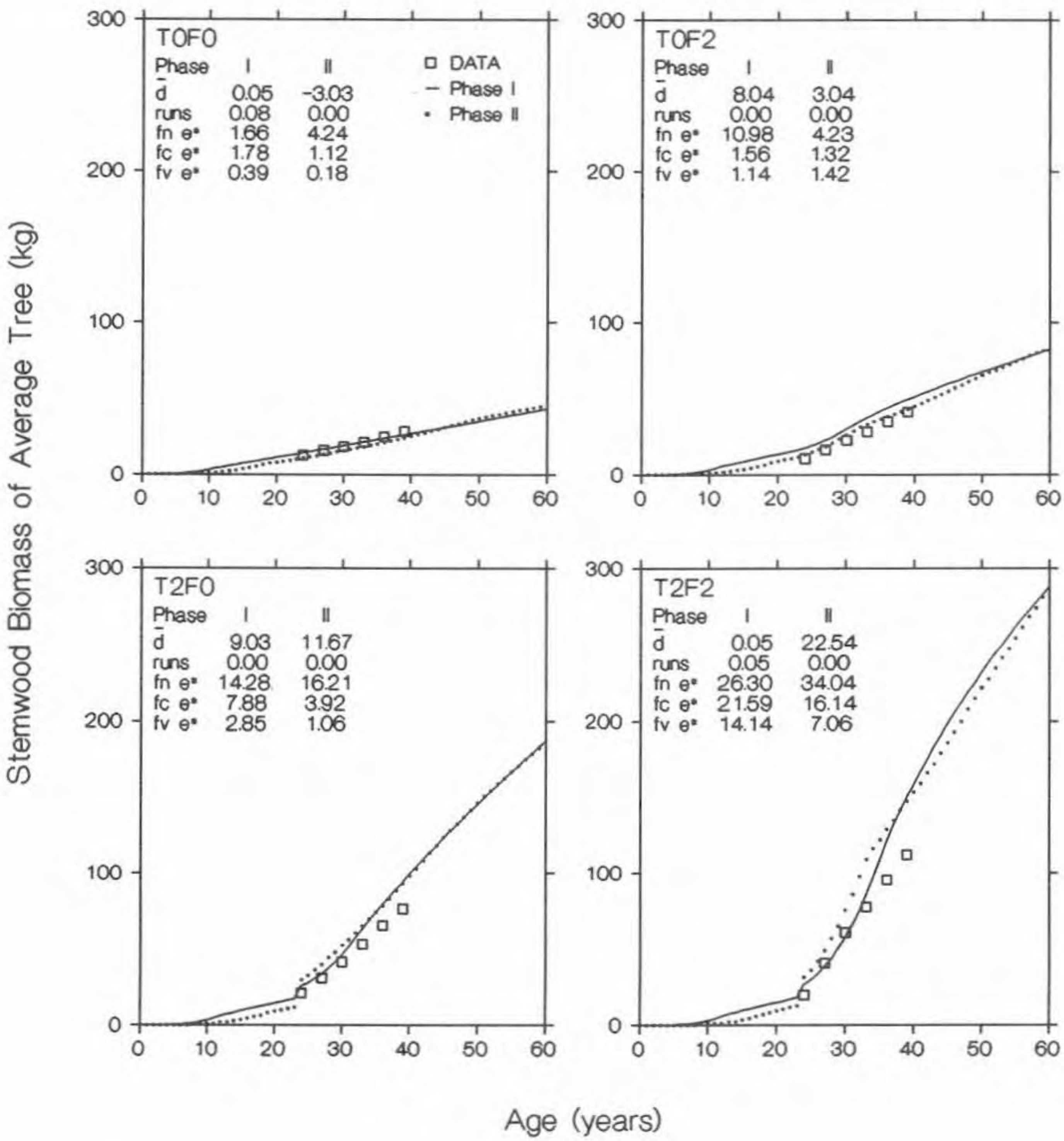


Figure 9. Predicted and measured average tree stemwood biomass under four thinning and fertilization treatments at Shawnigan Lake.

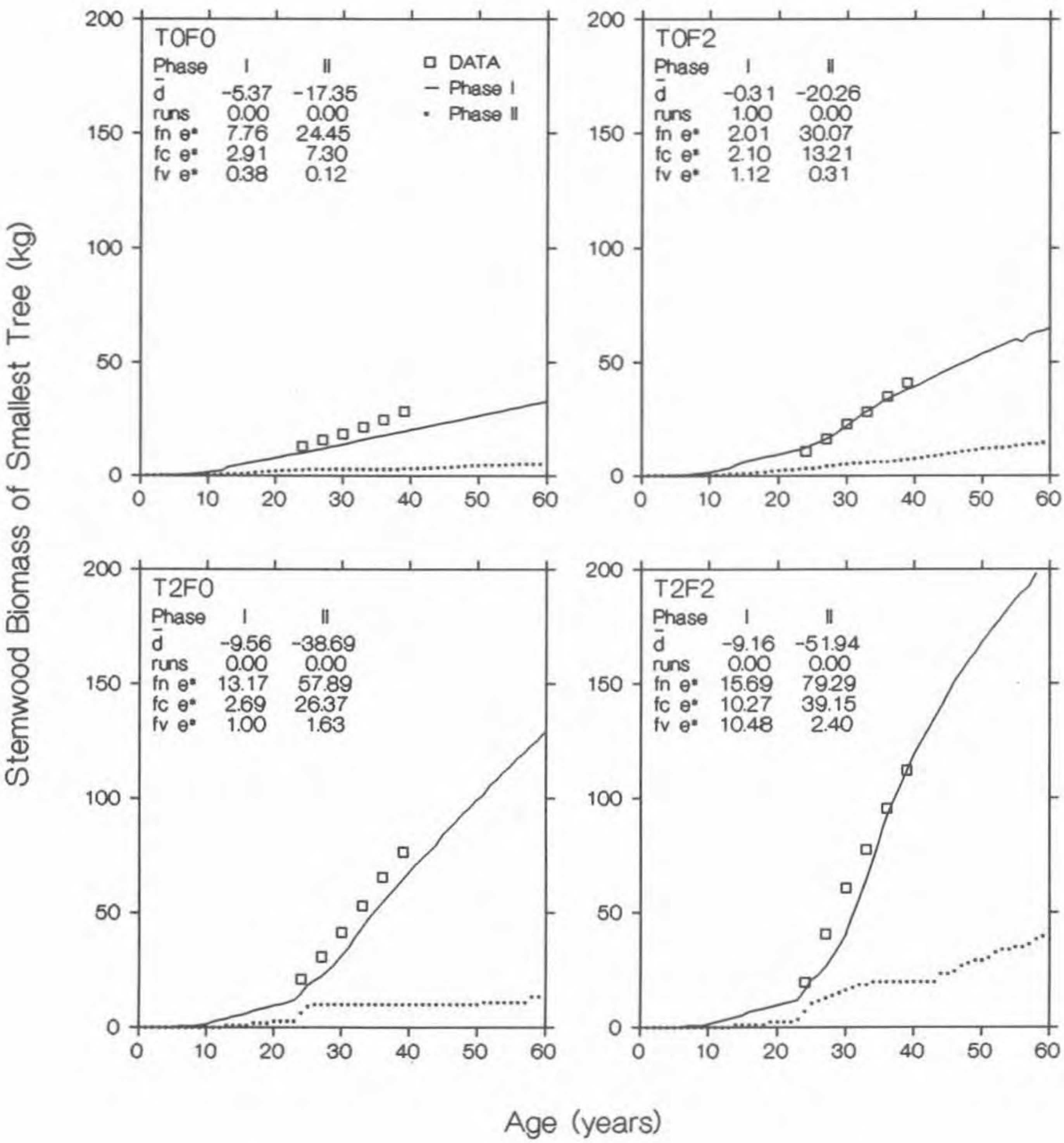


Figure 10. Predicted and measured smallest tree stemwood biomass under four thinning and fertilization treatments at Shawnigan Lake.

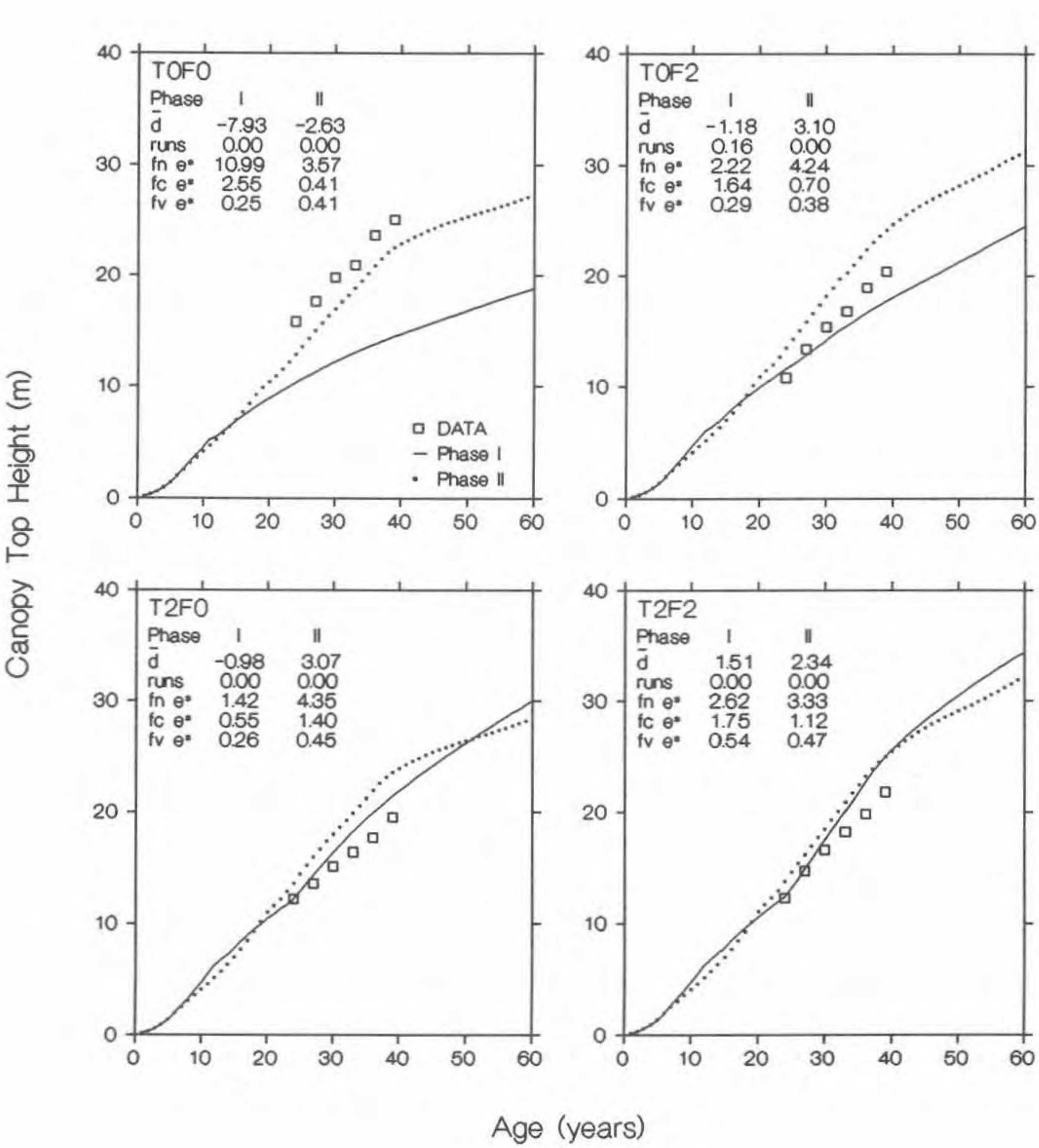


Figure 11. Predicted and measured canopy top height under four thinning and fertilization treatments at Shawnigan Lake.

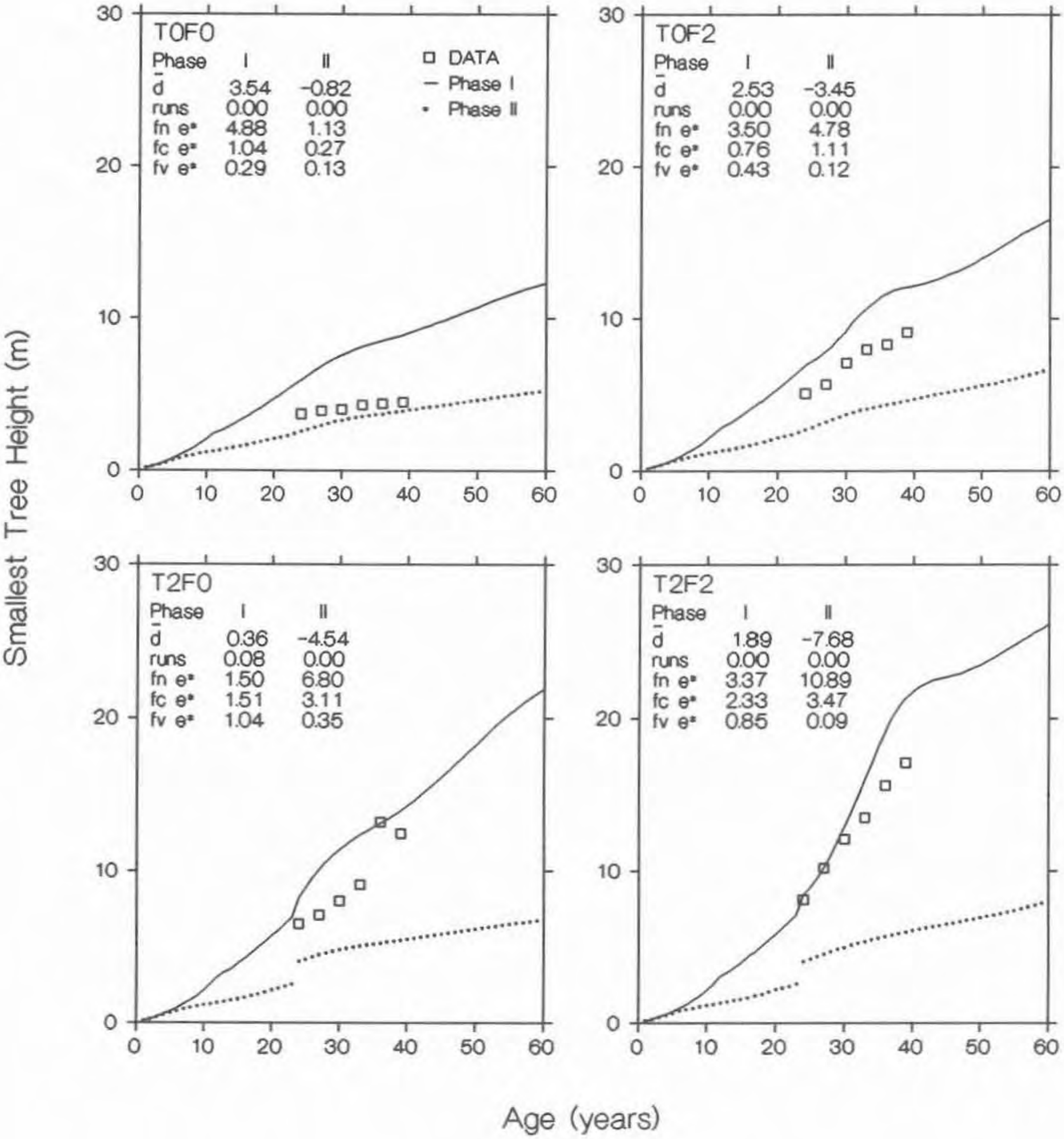


Figure 12. Predicted and measured smallest tree height under four thinning and fertilization treatments at Shawnigan Lake.

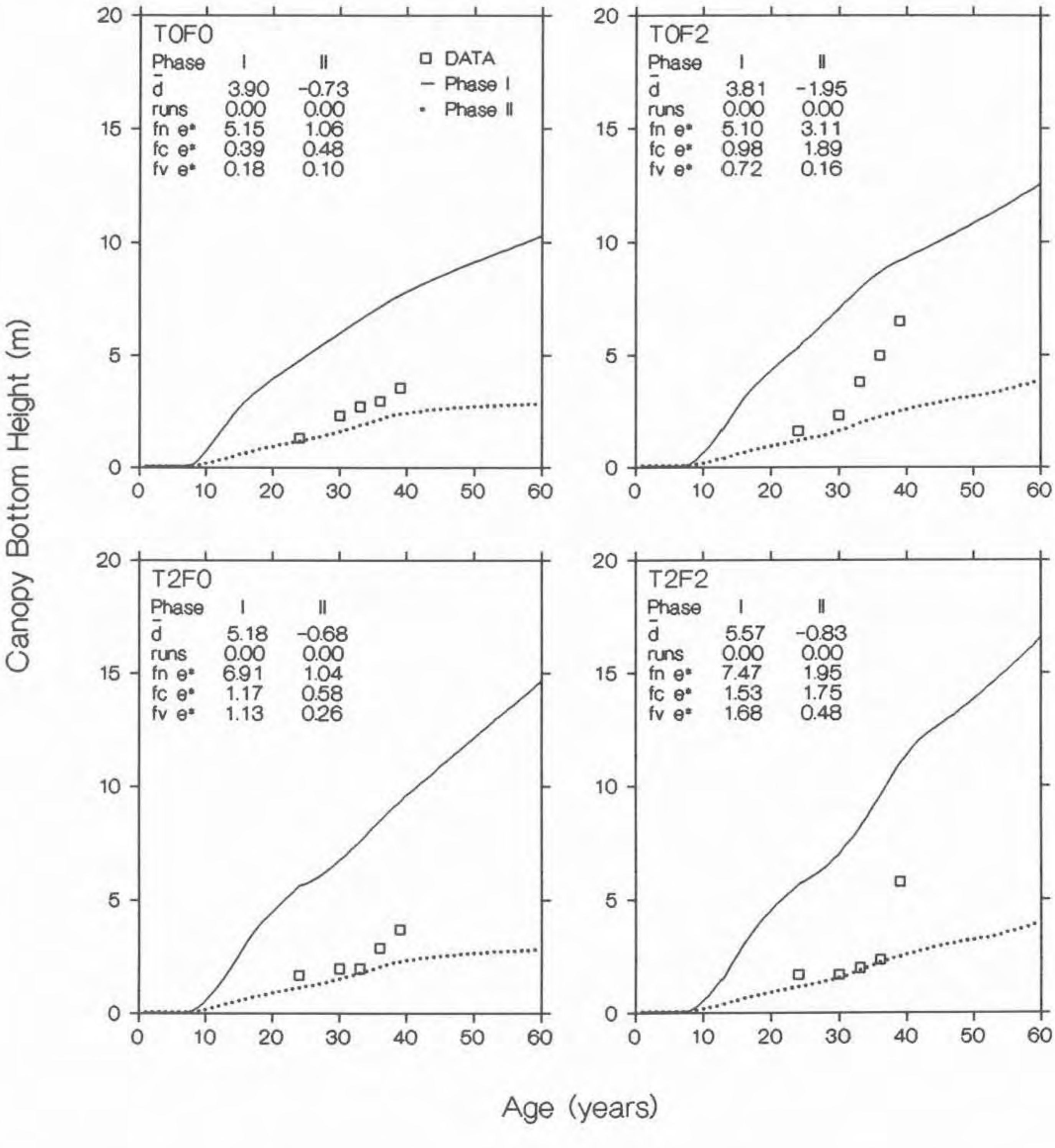


Figure 13. Predicted and measured canopy bottom height under four thinning and fertilization treatments at Shawnigan Lake.

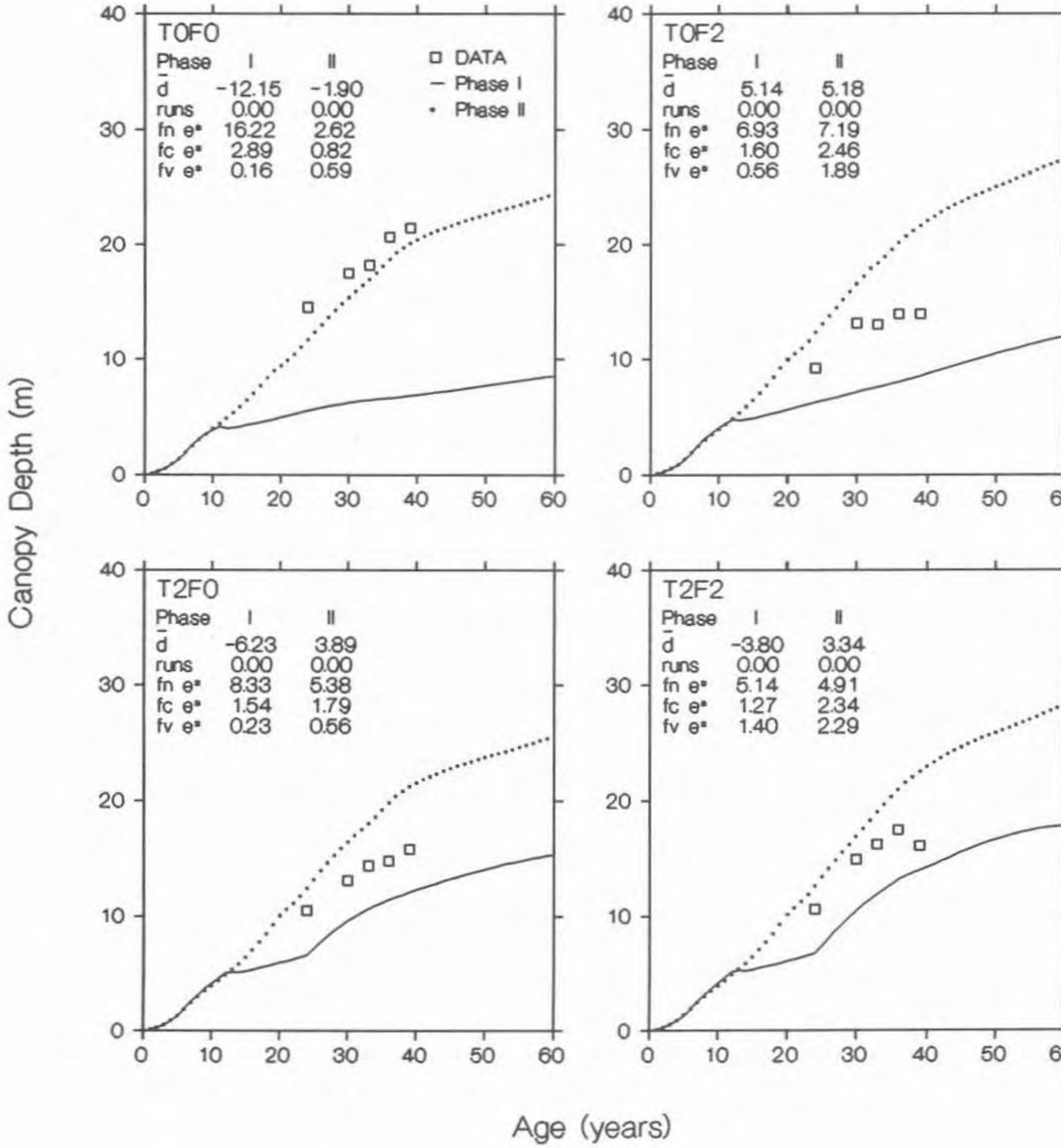


Figure 14. Predicted and measured canopy depth under four thinning and fertilization treatments at Shawnigan Lake.

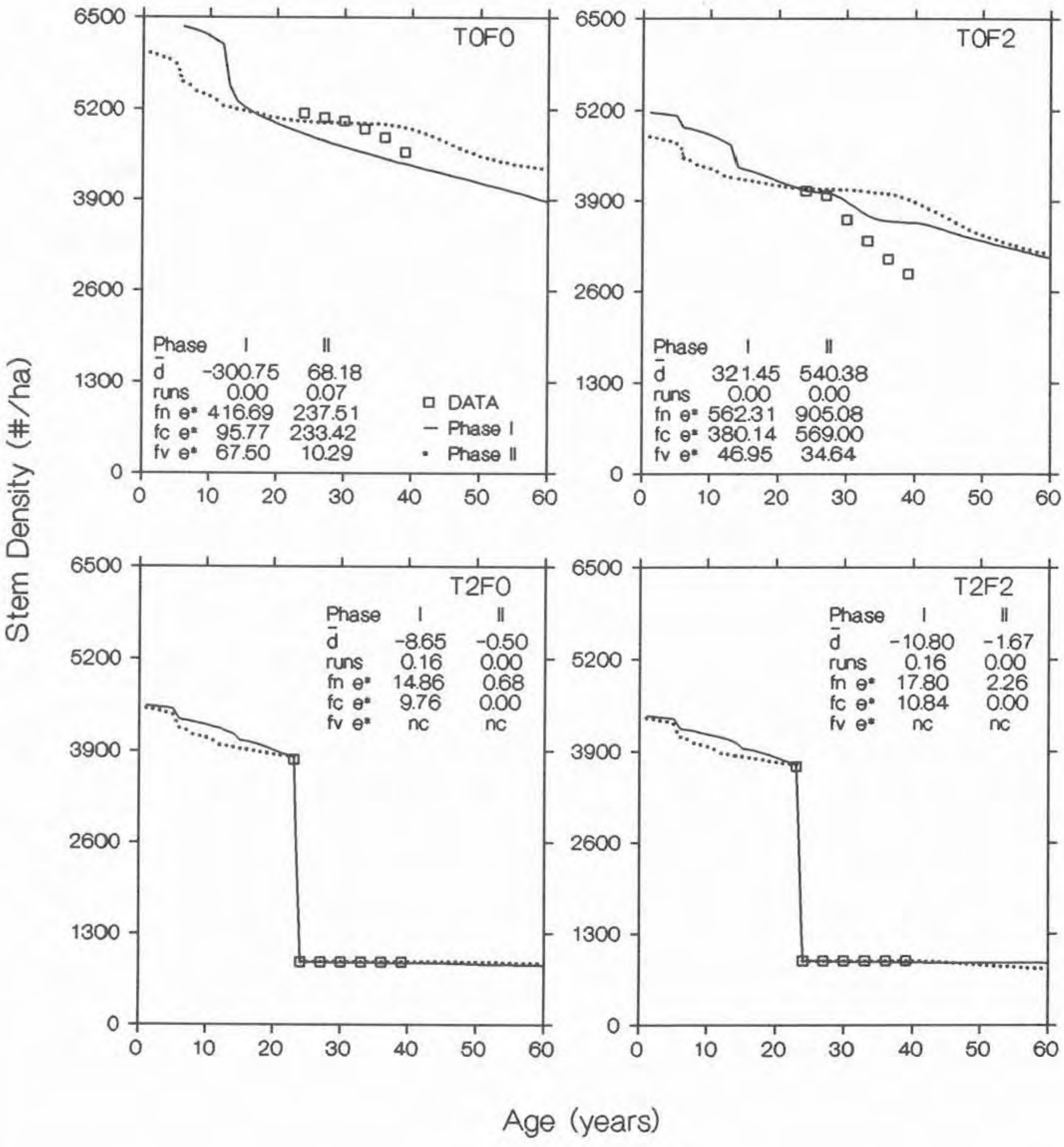


Figure 15. Predicted and measured number of trees per hectare under four thinning and fertilization treatments at Shawnigan Lake.

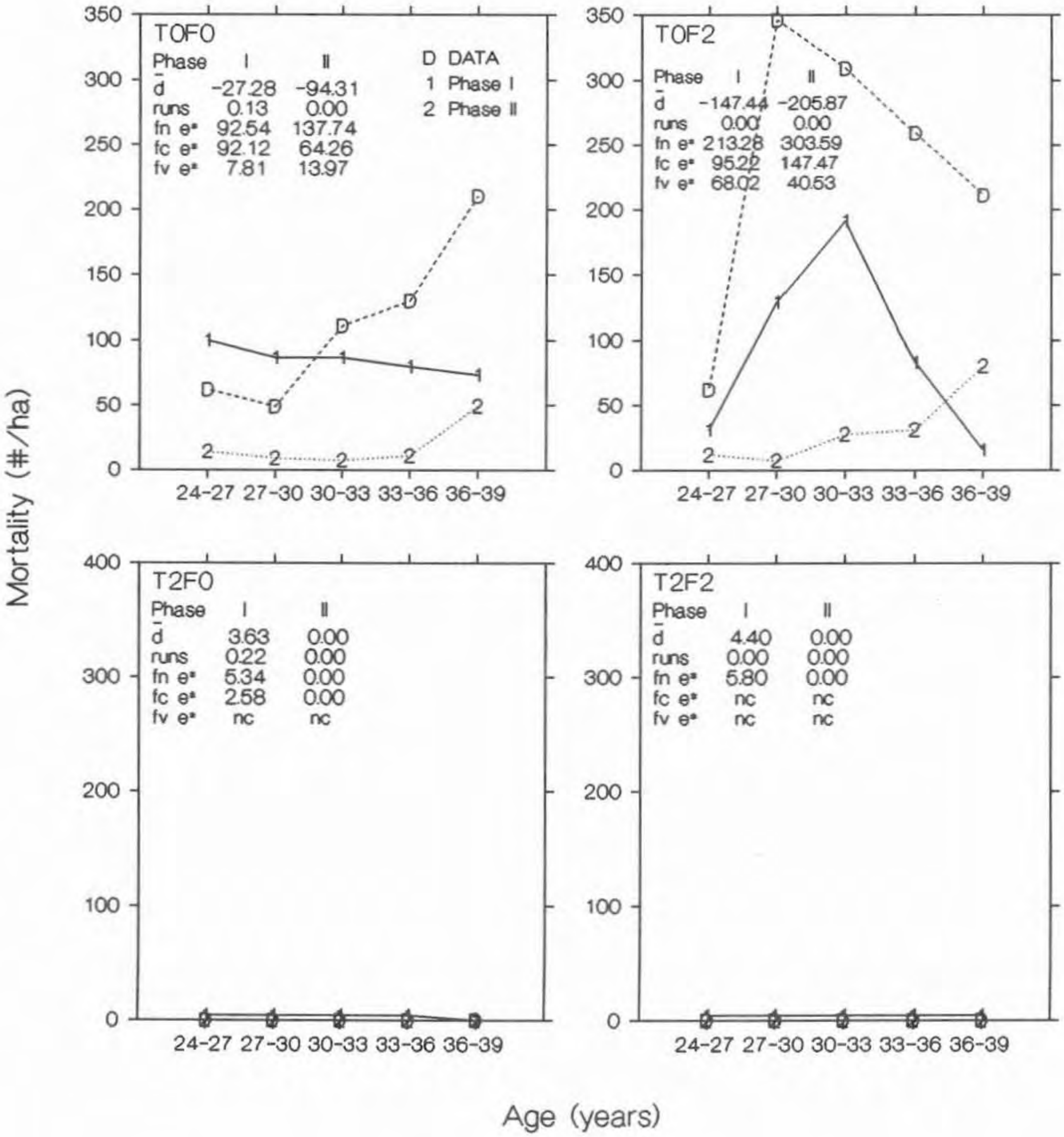


Figure 16. Predicted and measured mortality under four thinning and fertilization treatments at Shawnigan Lake.

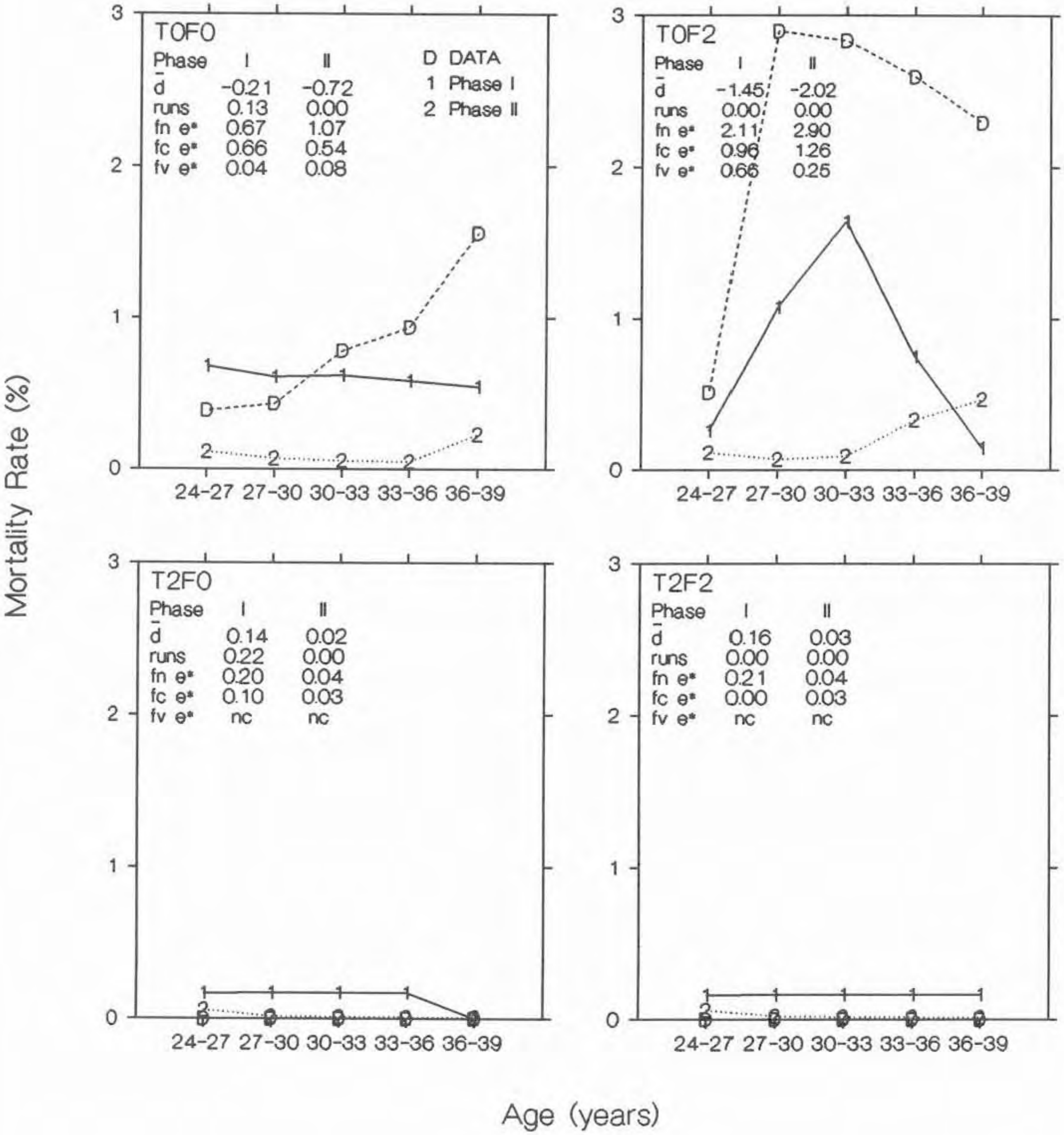


Figure 17. Predicted and measured mortality rate under four thinning and fertilization treatments at Shawnigan Lake.

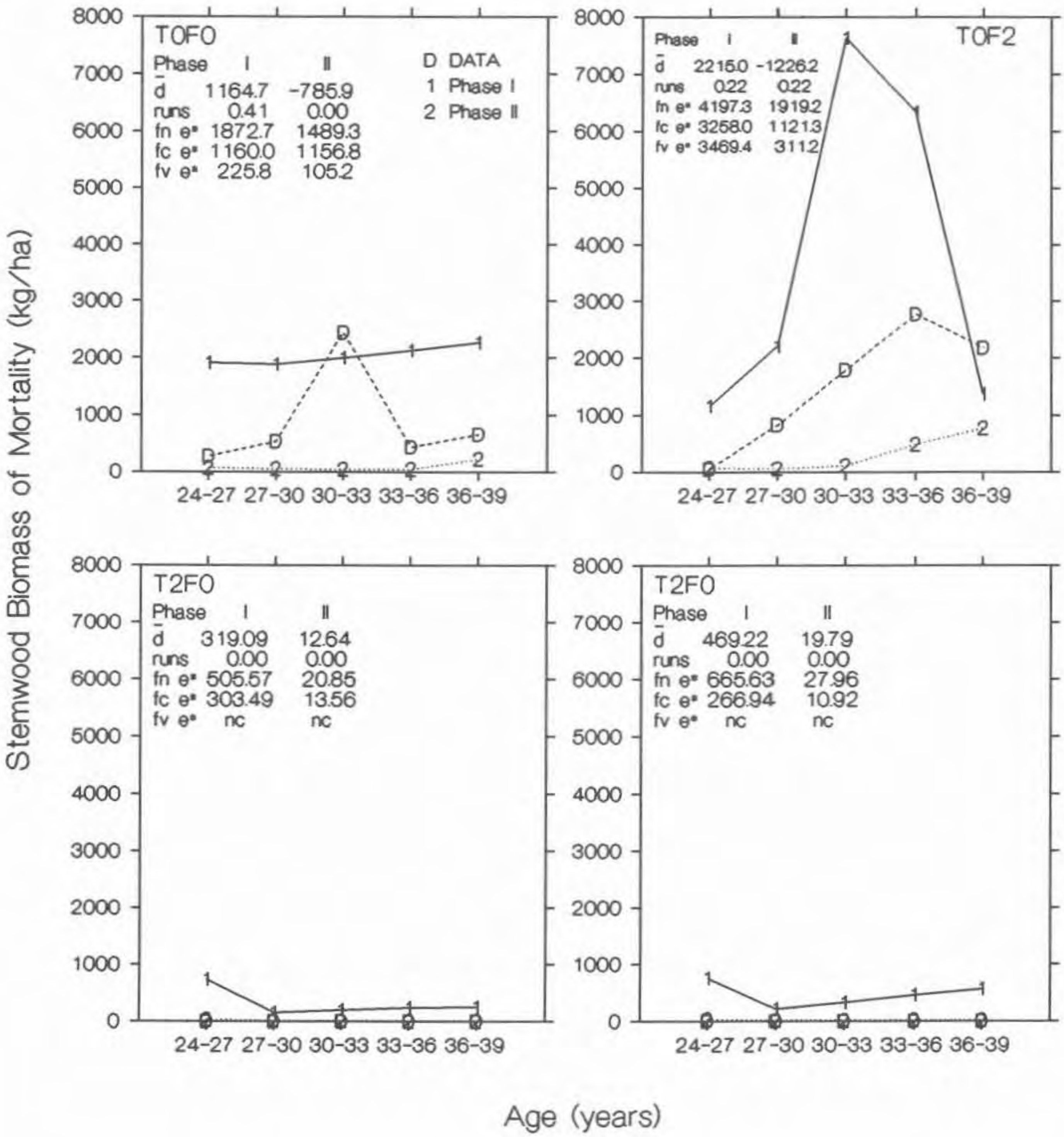


Figure 18. Predicted and measured stemwood biomass of dying trees under four thinning and fertilization treatments at Shawnigan Lake.

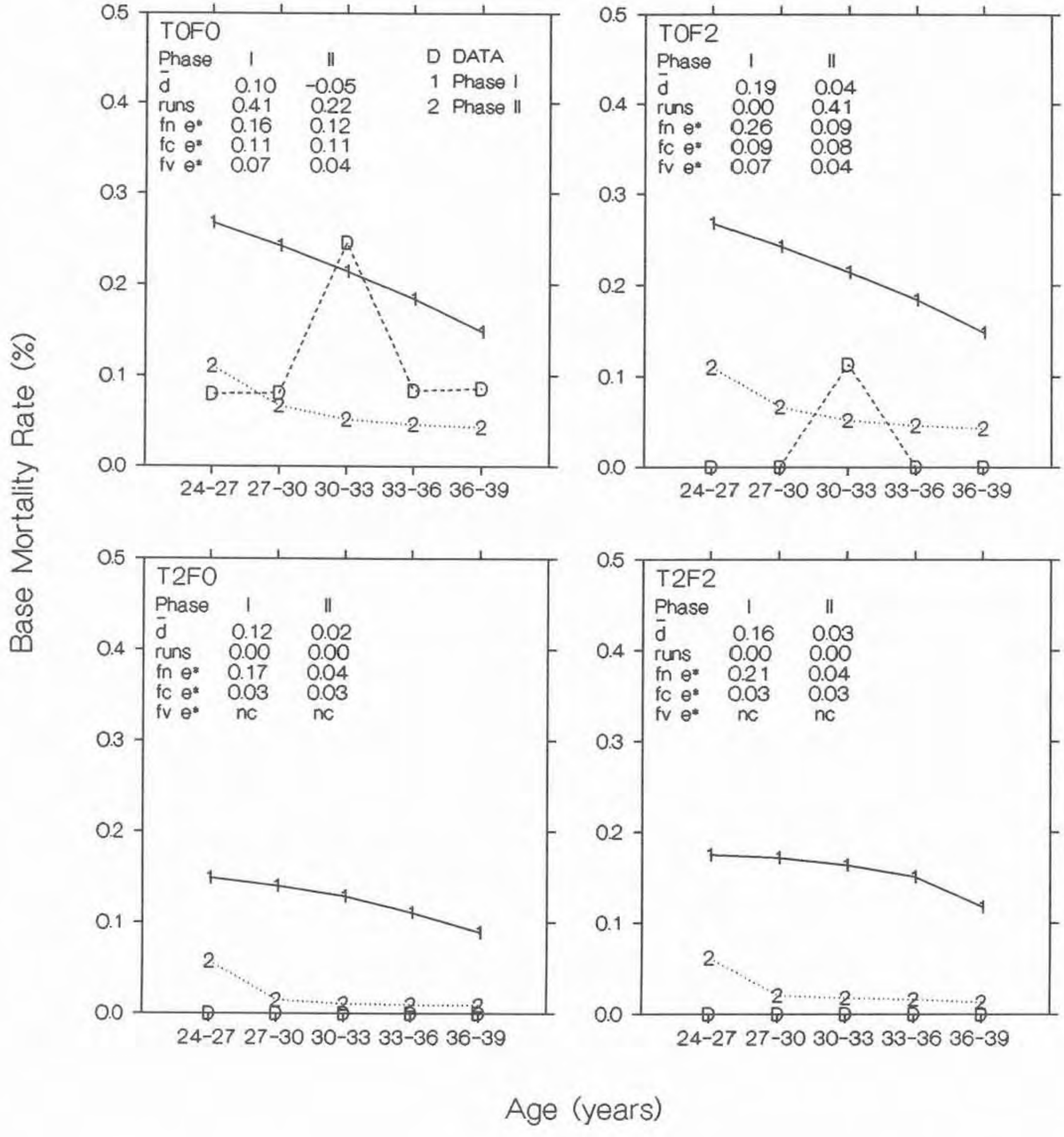


Figure 19. Predicted and measured base mortality (density-independent) rate under four thinning and fertilization treatments at Shawnigan Lake.

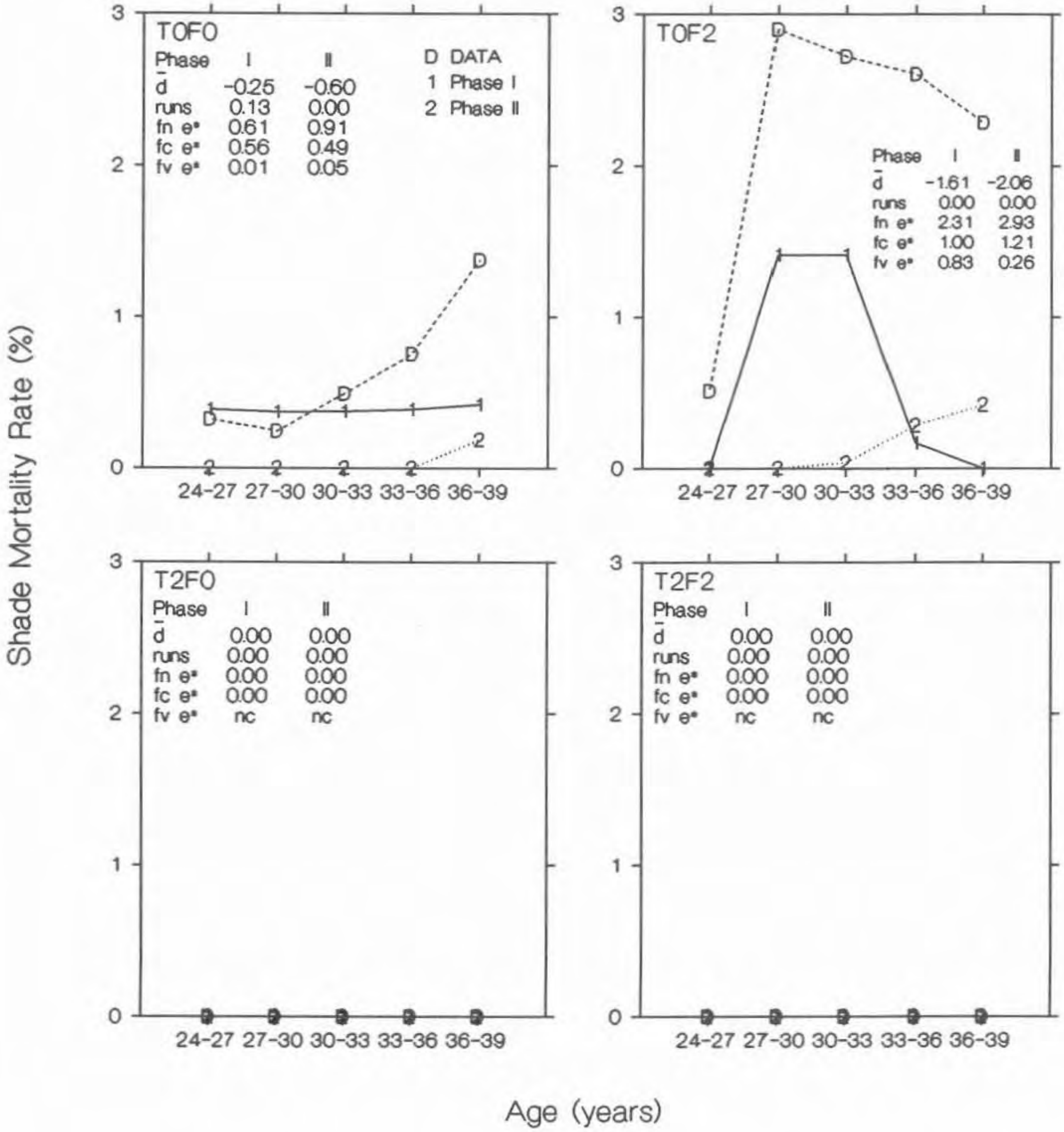


Figure 20. Predicted and measured shade mortality (density-dependent) rate under four thinning and fertilization treatments at Shawnigan Lake.

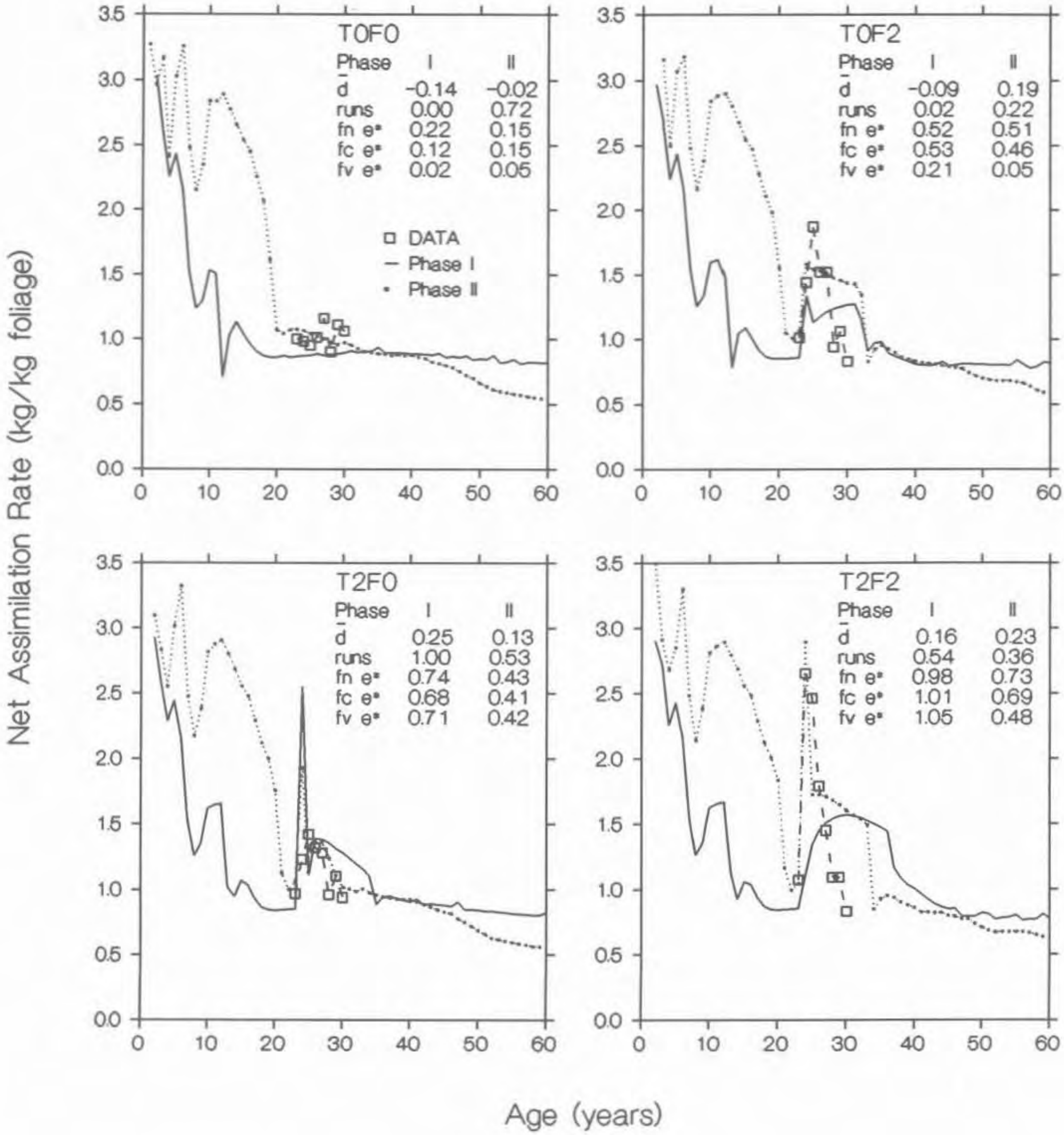


Figure 21. Predicted and measured net assimilation rate under four thinning and fertilization treatments at Shawnigan Lake.

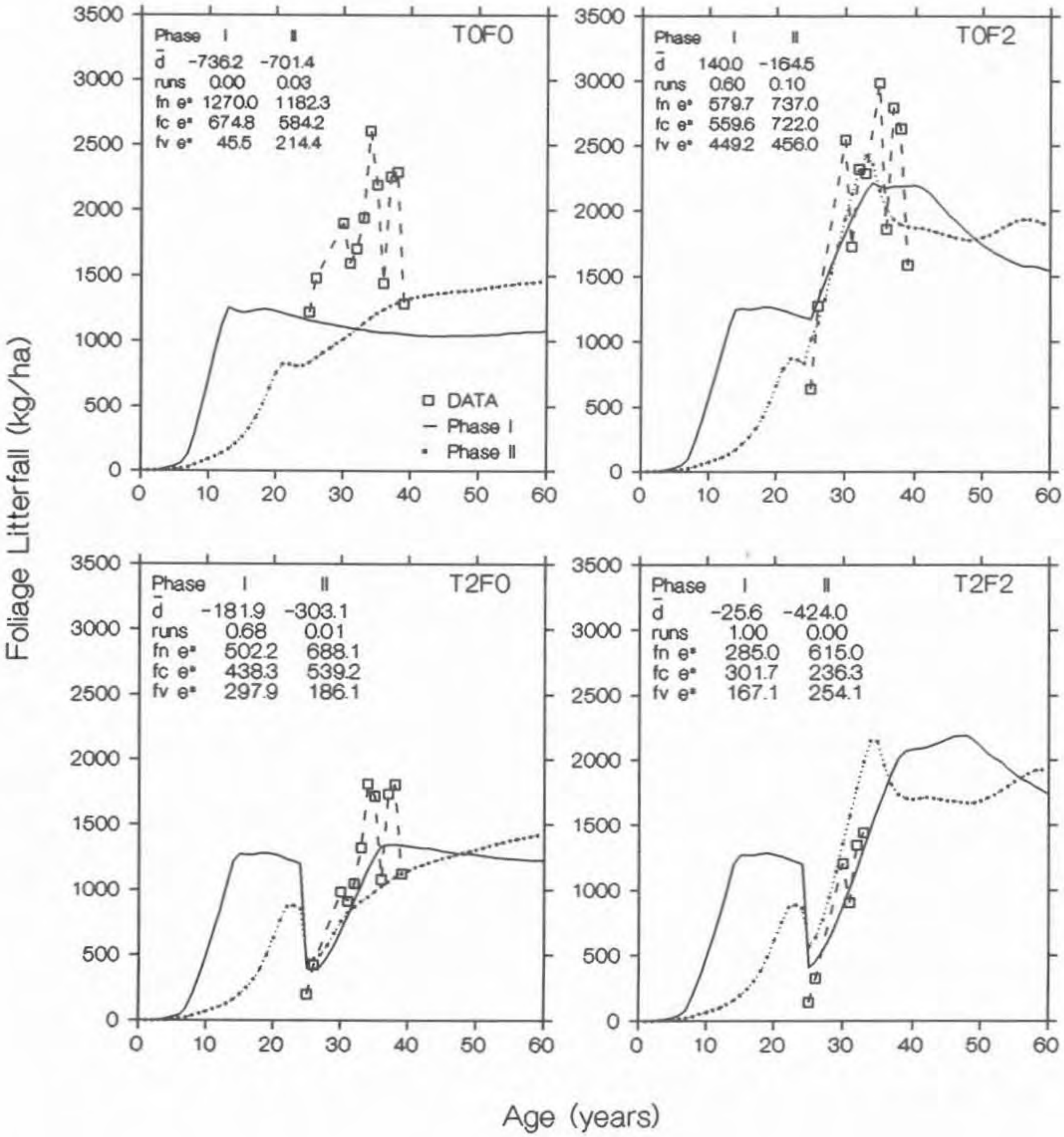


Figure 22. Predicted and measured foliar litterfall under four thinning and fertilization treatments at Shawnigan Lake.

Figure 23. Predicted and measured stand foliar N content under four thinning and fertilization treatments at Shawnigan Lake.

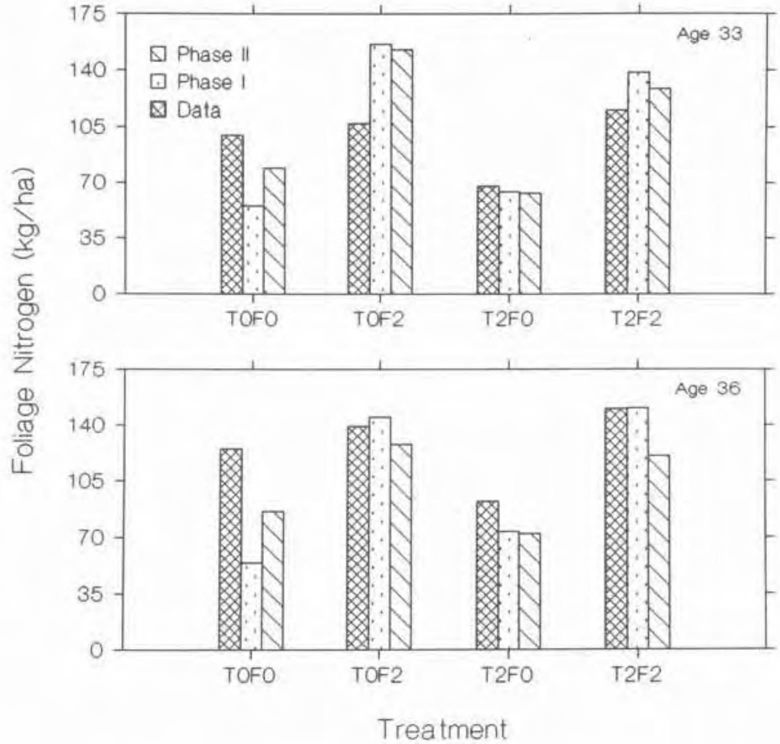
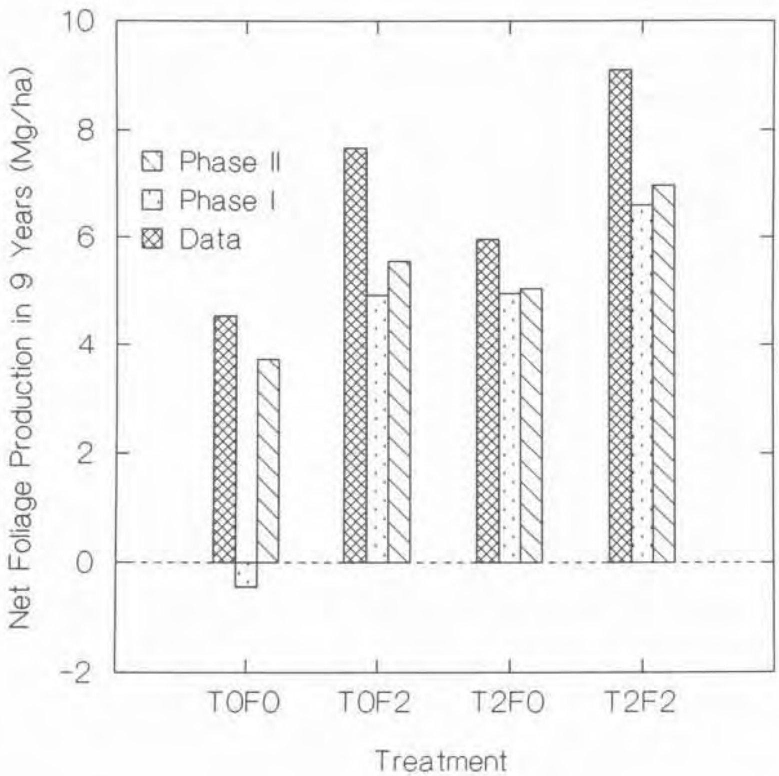


Figure 24. Predicted and measured net foliage production during the 9-year period following treatment under four thinning and fertilization treatments at Shawnigan Lake.



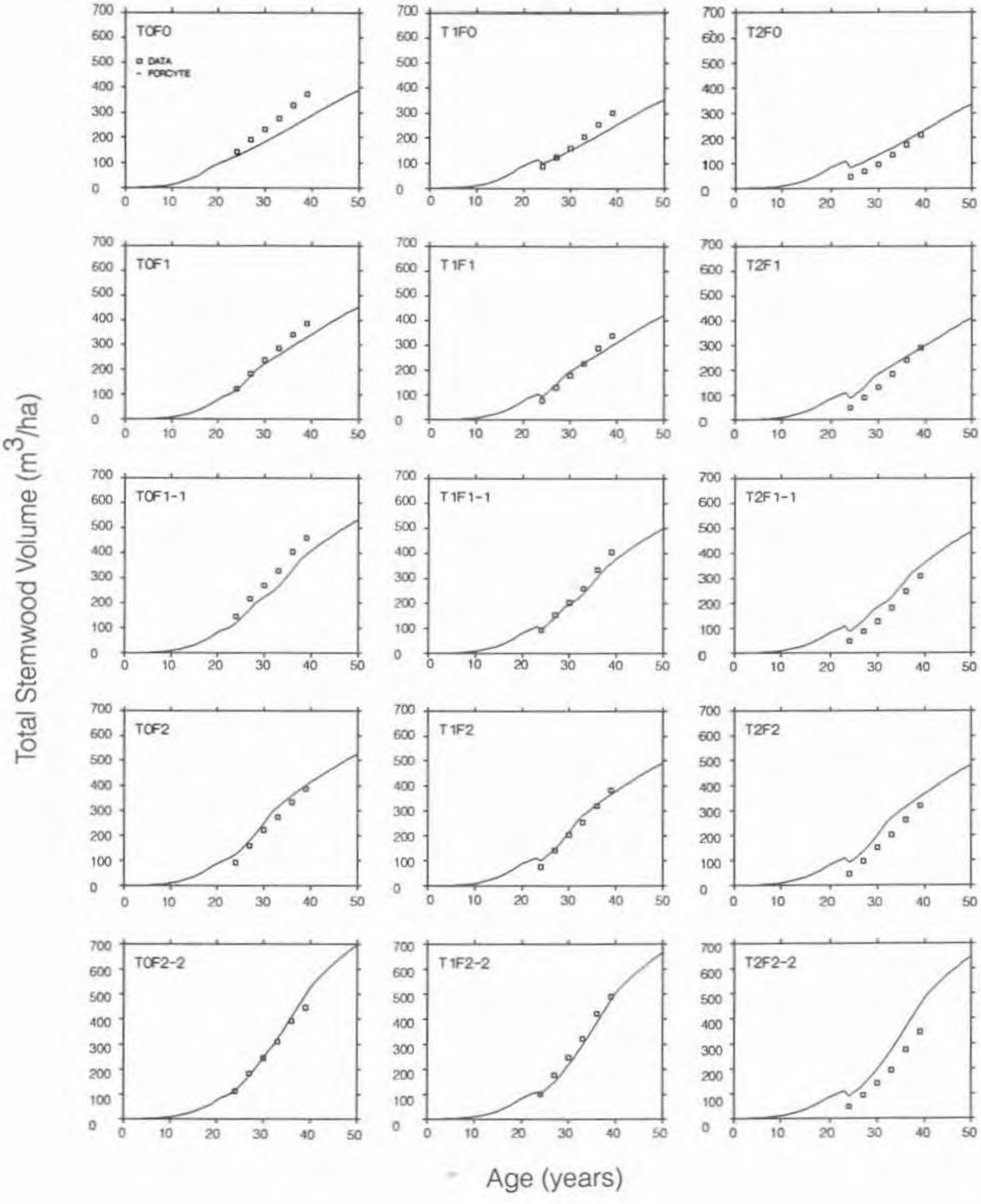


Figure 25. Predicted and measured total stemwood volume for 15 thinning and fertilization treatments at Shawnigan Lake after model calibration.

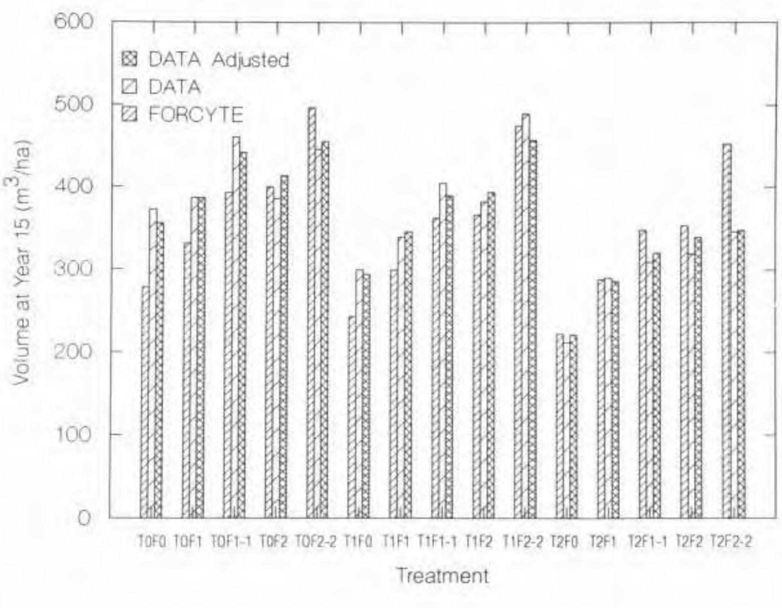


Figure 26. Comparison of predicted, measured and adjusted 15-year stemwood volume for 15 thinning and fertilization treatments at Shawnigan Lake after model calibration.

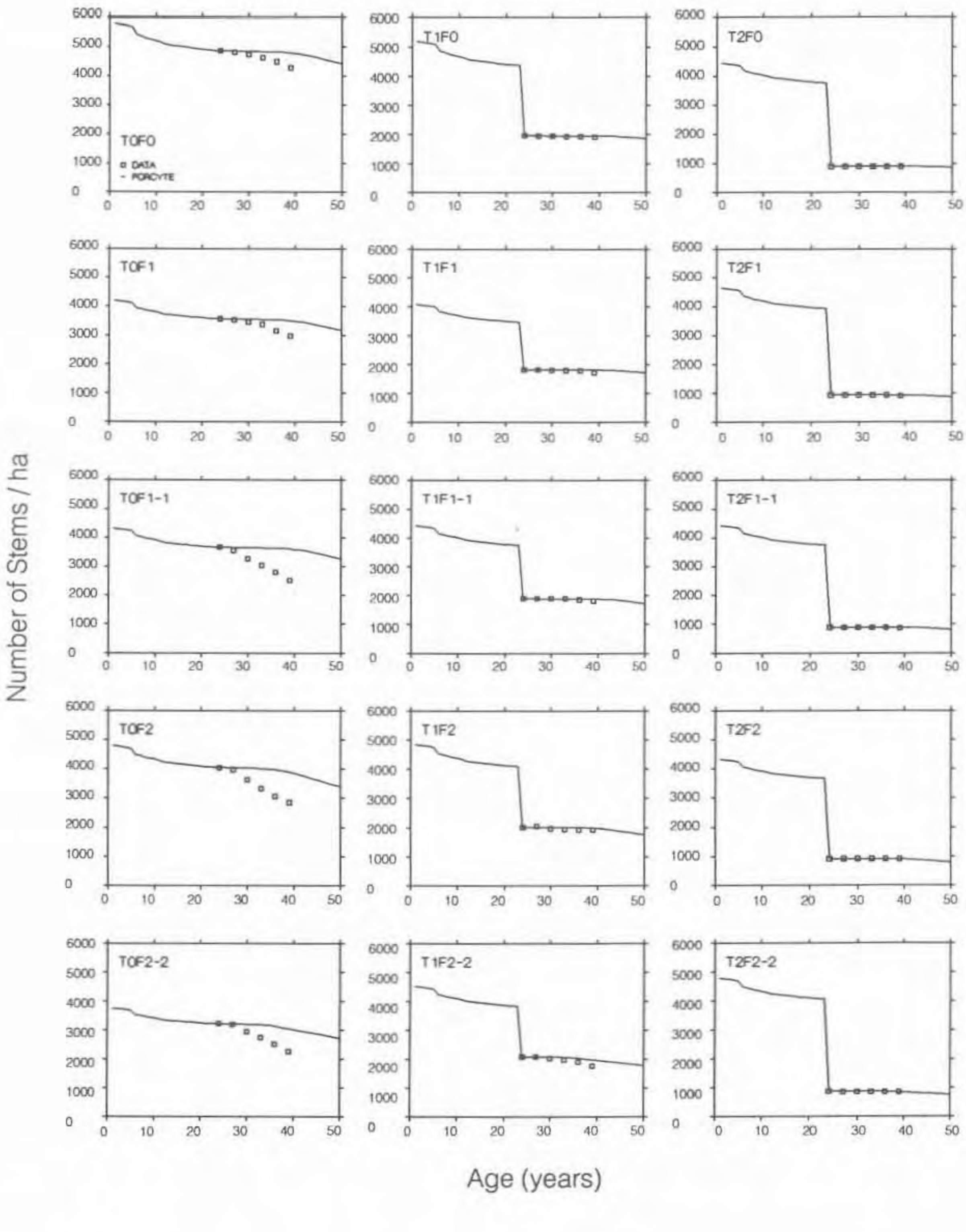


Figure 27. Predicted and measured stem density for 15 thinning and fertilization treatments at Shawnigan Lake after model calibration.

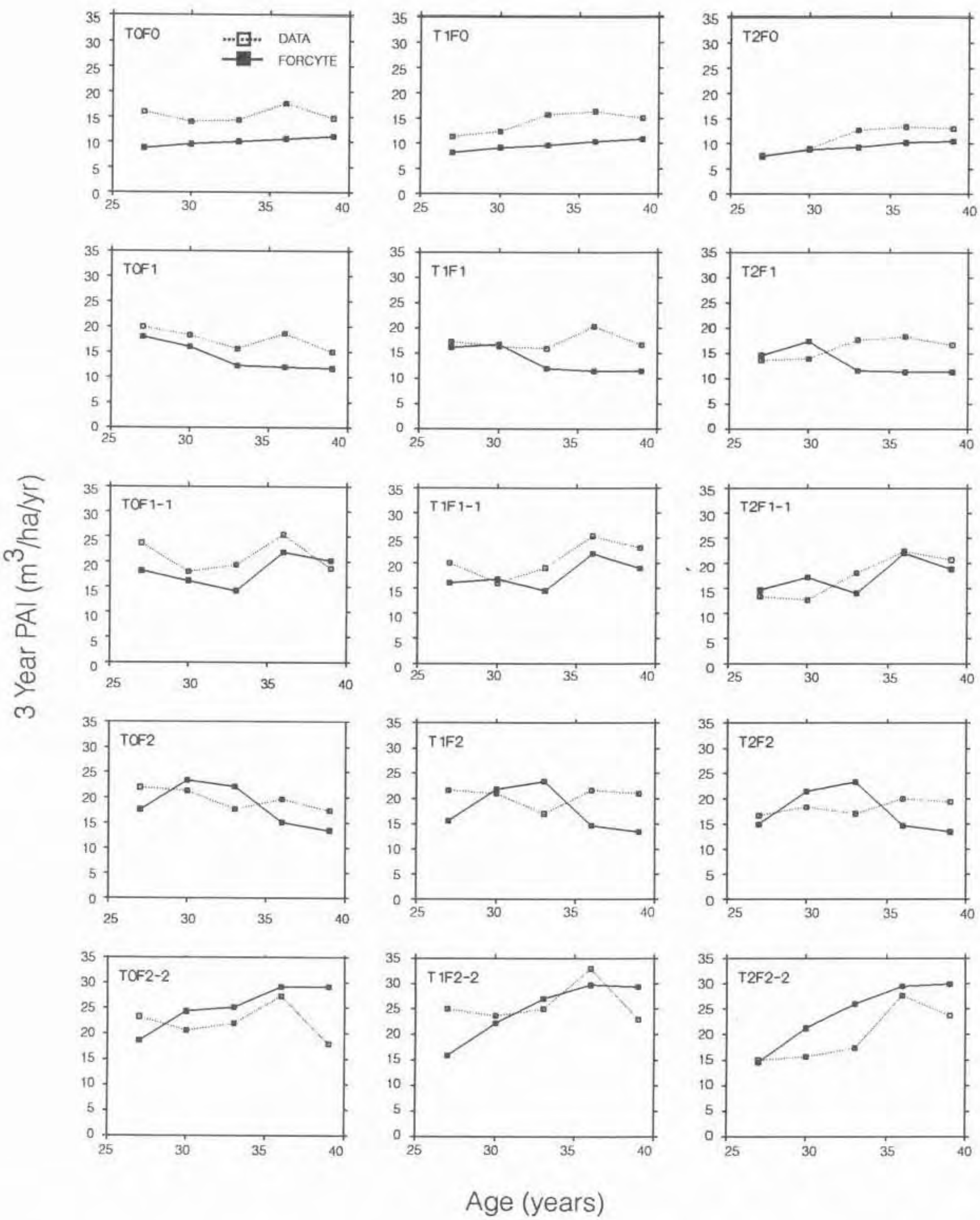


Figure 28. Predicted and measured 3-year periodic annual stemwood volume increment for 15 thinning and fertilization treatments at Shawnigan Lake after model calibration.

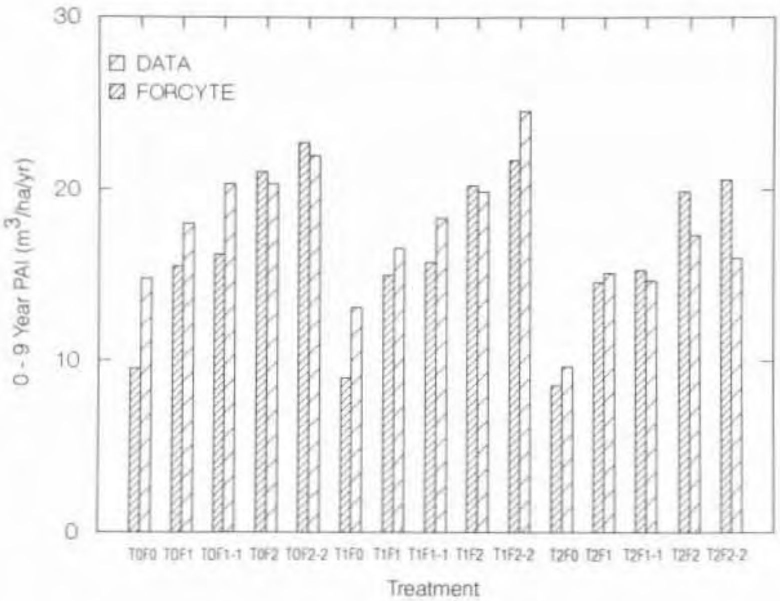


Figure 29. Comparison of predicted and measured 0-9 year periodic annual stemwood volume increment for 15 thinning and fertilization treatments at Shawnigan Lake after model calibration.

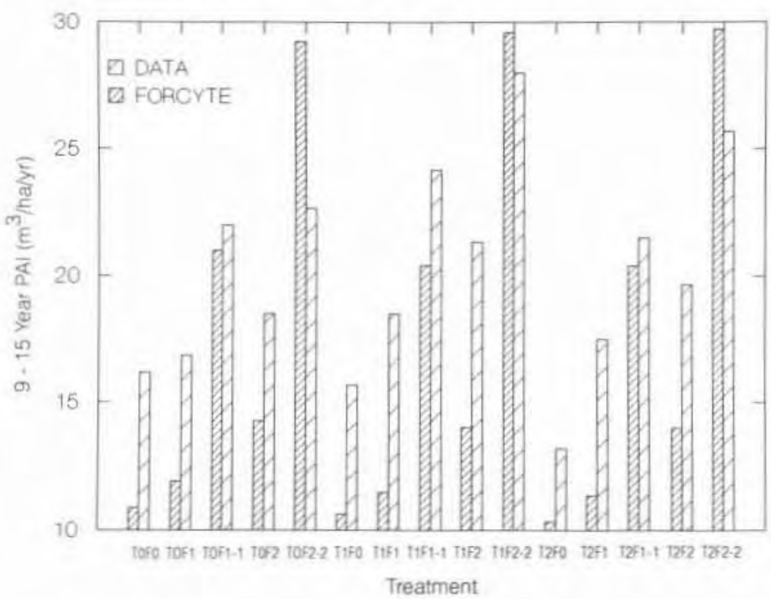


Figure 30. Comparison of predicted and measured 9-15 year periodic annual stemwood volume increment for 15 thinning and fertilization treatments at Shawnigan Lake after model calibration.

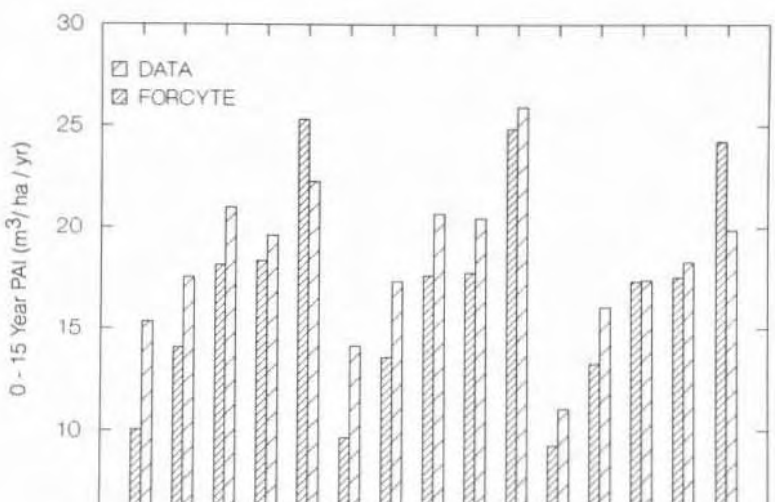


Figure 31. Comparison of predicted and measured 0-15 year periodic annual stemwood volume increment for 15 thinning and fertilization treatments at Shawnigan Lake after model calibration.

Appendix

The following is a partial listing of the SOILDATA, TREEDATA and PLNTDATA files used in running FORCYTE-11. Unshaded lines were data provided by the model's authors (Kimmins *et al.* 1990) and used in the uncalibrated simulations in Phase I. For Phase II, changed lines are shaded and are shown directly below the original group of lines. In order to save space, only sections of the data files which were changed are shown.

Appendix part a.

```
********************  SOILDATA:  INPUT DATA FILE FOR FORSOILS  ******  FORCYTE-11.40A ******************************
                                                                                                                 :
**********  SECTION 1                                                                                  00000     :
NOV 23 1988. UPDATED DECOMPOSITION DATA                          DATA FILE IDENTIFICATION              00        :
******  SECTION 1.1:  FILE LABEL AND CONTENT STATEMENTS  ************************************          00000     :
FORCYTE-11 DEMONSTRATION RUN                                      PROJECT NAME                            00     :
J. P. KIMMINS AND K. A. SCOULLAR                                  USER IDENTIFICATION                  00000     :
Mar  8 1990. UPDATED DECOMPOSITION DATA                           DATA FILE IDENTIFICATION             00        :
******  SECTION 1.1:  FILE LABEL AND CONTENT STATEMENTS  ************************************          00000     :
FORCYTE-11 Shawnigan Lake Project 15% to SOM                      PROJECT NAME                            00     :
D. Sachs                                                          USER IDENTIFICATION                  00000     :
SOUTHERN VANCOUVER ISLAND, BRITISH COLUMBIA                       LOCATION OF DATA SITES                         :
COASTAL WESTERN HEMLOCK ZONE, DRY SUBZONE                         ECOLOGICAL ZONE OF DATA SITES                  :
                                                                                                                 :
   2                                                              NUMBER OF TREE SPECIES                         :
DOUGLAS-FIR                                                          NAME OF TREE #1                             T1
RED ALDER                                                            NAME OF TREE #2                             T2
                                                                                                                 :
   2                                                              NUMBER OF PLANT SPECIES (SHRUBS, HERBS & SIMPLE TREES)  :
FIRE WEED                                                            NAME OF PLANT #1                            P1 F
SALMONBERRY                                                          NAME OF PLANT #2                            P2 F
Salal                                                                NAME OF PLANT #2                            P2 F
                                                                                                                 :

******  SECTION 1.4:  DEFINITION OF THE PATTERN OF CHANGE IN NUTRIENT CONCENTRATION FROM LITTER TO HUMUS  ***********
   9                                                     NUMBER OF DATA PAIRS                                 ALL TYPES
.10  .20  .30  .40  .50  .60  .70  .80  .90  .           PROPORTION OF TIME FOR FRESH LITTER TO BECOME HUMUS  ALL TYPES
**  PROPORTION OF THE CHANGE IN NUTRIENT CONCENTRATION BETWEEN LITTER AND HUMUS AT THE ABOVE TIME INTERVALS**      N1
.010 .020 .030 .050 .080 .100 .200 .400 .800 .           DECOMPOSITION TYPE 01                                 #01 N1
.035 .120 .210 .288 .440 .510 .650 .760 .850 .           DECOMPOSITION TYPE 01                                 #01 N1
.010 .020 .030 .050 .080 .100 .200 .400 .800 .           DECOMPOSITION TYPE 02                                 #02 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .           DECOMPOSITION TYPE 03                                 #03 N1
.100 .200 .300 .400 .500 .600 .700 .800 .900 .           DECOMPOSITION TYPE 04                                 #04 N1
.020 .040 .070 .100 .150 .250 .400 .750 .850 .           DECOMPOSITION TYPE 05                                 #05 N1
.035 .120 .210 .300 .420 .530 .650 .750 .850 .           DECOMPOSITION TYPE 05                                 #05 N1
.020 .040 .070 .100 .150 .250 .400 .750 .850 .           DECOMPOSITION TYPE 06                                 #06 N1
.020 .040 .070 .100 .150 .250 .400 .750 .850 .           DECOMPOSITION TYPE 07                                 #07 N1
.020 .040 .070 .100 .150 .250 .400 .750 .850 .           DECOMPOSITION TYPE 08                                 #08 N1

**********  SECTION 2                                                                                             DK1
DK1DK1DK1DK1DK1   DATA FOR SOILS SITE #1  DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1DK1   DATA SITE #1   DK1DK1DK1DK1
 25.00                                                   NUTRIENT STATUS OF THE SITE - EDAPHIC GRID NUTRIENT AXIS    DK1
******  SECTION 2.1:  RATES OF INPUT OF UP TO FIVE NUTRIENTS FROM THE GEOCHEMICAL CYCLE  **************************DK1
 5.00  0.02  1.00  0.00  0.00                            PRECIPITATION INPUT        (KG/HA/TIME STEP)                DK1
 0.00  0.01  1.00  0.00  0.00                            SEEPAGE INPUT              (KG/HA/TIME STEP)                DK1
 0.00  0.02  0.05  0.00  0.00                            WEATHERING INPUT           (KG/HA/TIME STEP)                DK1
 1.00  0.00  0.00  0.00  0.00                            NON-SYMBIOTIC FIXATION     (KG/HA/TIME STEP)                DK1
 0.50  0.00  0.00  0.00  0.00                            NON-SYMBIOTIC FIXATION     (KG/HA/TIME STEP)                DK1
******  SECTION 2.2:  SORPTION/DESORPTION OF UP TO FIVE NUTRIENTS BY MINERAL SOIL  *******************************DK1
1.000 0.500 0.300 0.000 0.000                            DESORPTION RATE (PROPORTION OF WAY TO EQUILIBRIUM/TIME STEP)   DK1
   1   0.0               NUTRIENT #1:    # DATA PAIRS DEFINING SORPTION     AMOUNT IRREVERSIBLY BOUND (KG/HA)   N1 DK1
  1.0   .     .     .     .     .     .     .     .      AMOUNT OF NUTRIENT ADDED (KG/HA)                      N1 DK1
  1.0   .     .     .     .     .     .     .     .      AMOUNT OF NUTRIENT IN SOLUTION (KG/HA)                N1 DK1
   6  10.0               NUTRIENT #2:    # DATA PAIRS DEFINING SORPTION     AMOUNT IRREVERSIBLY BOUND (KG/HA)   N2 DK1
  0.0  50.0 100.0 200.0 400.0 800.0       .     .        AMOUNT OF NUTRIENT ADDED (KG/HA)                      N2 DK1
 10.0  15.0  30.0 110.0 280.0 660.0       .     .        AMOUNT OF NUTRIENT IN SOLUTION (KG/HA)                N2 DK1
   6  10.0               NUTRIENT #3:    # DATA PAIRS DEFINING SORPTION     AMOUNT IRREVERSIBLY BOUND (KG/HA)   N3 DK1
  0.0  50.0 100.0 200.0 400.0 800.0       .     .        AMOUNT OF NUTRIENT ADDED (KG/HA)                      N3 DK1
 10.0  15.0  30.0 110.0 280.0 660.0       .     .        AMOUNT OF NUTRIENT IN SOLUTION (KG/HA)                N3 DK1
**  CALIBRATION OF EXPERIMENT TO TEST THE SORPTION/DESORPTION SIMULATION USING ABOVE DATA  (KG/HA)  **             DK1
  0.    0.    0.    0.  1.00     NUTRIENT #1:   INIT SOL CONTENT   FERT#1   FERT#2   FERT#3   RELEASE RATE   N1 DK1
 100.  100.  200.  400.  0.30    NUTRIENT #2:   INIT SOL CONTENT   FERT#1   FERT#2   FERT#3   RELEASE RATE   N2 DK1
 100.  100.  200.  400.  0.30    NUTRIENT #3:   INIT SOL CONTENT   FERT#1   FERT#2   FERT#3   RELEASE RATE   N3 DK1
******  SECTION 2.3:  IONIC FORMS OF NUTRIENTS, AND THE EFFECT OF ROOTS AND LITTER TYPE ON NUTRIENT #1 FORMS *****DK1
0.050 1.000 0.000 0.000 0.000              PROPORTION OF SOIL NUTRIENTS IN ANIONIC FORM FOR UP TO FIVE NUTRIENTS     DK1
0.040 1.000 0.000 0.000 0.000              PROPORTION OF SOIL NUTRIENTS IN ANIONIC FORM FOR UP TO FIVE NUTRIENTS     DK1
**  EFFECT OF THE PRESENCE OF FINE ROOTS ON THE PROPORTION OF NUTRIENT #1 IN ANIONIC FORM  **                      DK1 X
 1.00                                                        TREE#1 ROOT EFFECT  (.%)        1.00=NO CHANGE    T1 DK1 X
 1.00                                                        TREE#1 ROOT EFFECT  (.%)        2.00=DOUBLE       T2 DK1 X
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Appendix part b.

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 1.00                                                            PLANT#1 ROOT EFFECT (.%)          0.50=HALVE        P1 DK1 X
 1.00                                                            PLANT#1 ROOT EFFECT (.%)                            P2 DK1 X
 1.00                                                            BRYOPHYTE#1 EFFECT  (.%)                            B1 DK1 X
** EFFECT OF DECOMPOSITION TYPE ON THE PROPORTION OF NUTRIENT #1 IN ANIONIC FORM  **                                    DK1 X
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00      DECOMPOSITION TYPES 1 TO 10        1.00=NO CHANGE             DK1 X
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00      DECOMPOSITION TYPES 11 TO 20       2.00=DOUBLE                DK1 X
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00      DECOMPOSITION TYPES 21 TO 30       0.50=HALVE                 DK1 X
1.00 1.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00      DECOMPOSITION TYPES 31 TO 40                                  DK1 X
******  SECTION 2.4:  CATION AND ANION EXCHANGE CAPACITIES OF MINERAL SOIL AND SURFACE ORGANIC MATTER  ***********DK1
  20.0     20.0     20.0     0.0     0.0        MINERAL SOIL CATION EXCHANGE CAPACITY      (KG/HA)                 DK1
   5.0      5.0      5.0     0.0     0.0  FOREST FLOOR      5.0      5.0      5.0     0.0      0.0  HUMUS  CEC (KG/T)  DK1
   5.0      5.0      5.0     0.0     0.0        MINERAL SOIL ANION EXCHANGE CAPACITY       (KG/HA)                 DK1
   6.0      5.0      5.0     0.0     0.0        MINERAL SOIL ANION EXCHANGE CAPACITY       (KG/HA)                 DK1
   0.0      0.0      0.0     0.0     0.0  FOREST FLOOR      0.0      0.0      0.0     0.0      0.0  HUMUS  AEC (KG/T)  DK1
******  SECTION 2.5:  HUMUS CHEMISTRY AND DECOMPOSITION RATES  *****************************************************DK1
  .010   2.00    2.     HUMUS #1:    DECOMP RATE     EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)    HM1 DK1 F
  .01400  .00200  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE           HM1 DK1
  .005   1.50    7.     HUMUS #2:    DECOMP RATE     EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)    HM2 DK1
  .01000  .00100  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE           HM2 DK1
  .010   1.00    2.     HUMUS #1:    DECOMP RATE     EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)    HM1 DK1 F
  .01100  .00200  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE           HM1 DK1
  .003   1.00    7.     HUMUS #2:    DECOMP RATE     EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)    HM2 DK1
  .00900  .00100  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE           HM2 DK1
******  SECTION 2.6:  NUTRIENT CONCENTRATIONS AND WEIGHT LOSS FOR FAECES, ASH AND COMPOST  ***********************DK1
  .00500  .00200  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN ANIMAL FAECES  (.%)            DK1 F
  .500                                    KG FAECES PRODUCED PER  KG FOLIAGE CONSUMED   (KG/KG)                  DK1 F
  .00010  .00500  .02000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN ASHED MATERIAL  (.%)           DK1
  .015                                    KG ASH PRODUCED PER KG MATERIAL BURNED        (KG/KG)                  DK1
  .00500  .00200  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN COMPOST          (.%)          DK1 X
  .500                                    KG COMPOST PRODUCED PER KG MATERIAL COMPOSTED (KG/KG)                  DK1 X
******  SECTION 2.7:  CONCENTRATION OF UP TO FIVE NUTRIENTS IN LITTERFALL ENTERING EACH DECOMPOSITION TYPE  ******DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 01       USED FOR DIAGNOSTIC PURPOSES ONLY     #01 DK1
  .00060  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 01       USED FOR DIAGNOSTIC PURPOSES ONLY     #01 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 02                                             #02 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 03                                             #03 DK1
  .00250  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 03                                             #03 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 04                                             #04 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 05                                             #05 DK1
  .00150  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 05                                             #05 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 06                                             #06 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 07                                             #07 DK1
  .00050  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 07                                             #07 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 08                                             #08 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 09                                             #09 DK1
  .00210  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 09                                             #09 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 10                                             #10 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 11                                             #11 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 12                                             #12 DK1
  .00080  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 12                                             #12 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 13                                             #13 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 14                                             #14 DK1
  .00500  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 14                                             #14 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 15                                             #15 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 16                                             #16 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 17                                             #17 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 18                                             #18 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 19                                             #19 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 20                                             #20 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 21                                             #21 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 22                                             #22 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 23                                             #23 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 24                                             #24 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 25                                             #25 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 26                                             #26 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 27                                             #27 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 28                                             #28 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 29                                             #29 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 30                                             #30 DK1
  .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 31                                             #31 DK1
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 .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 32                                              #32 DK1
 .00200  .00100  .00000  .00000  .00000  DECOMPOSITION TYPE 33                                              #33 DK1
****** SECTION 2.8: TIME-DEPENDENT DECOMPOSITION RATES FOR EACH DECOMPOSITION TYPE (.% WT. LOSS/TIME STEP) *****DK1
  5                                   DECOMPOSITION TYPE 01     # DATA PAIRS                               #01 DK1
  1.  30.  45.  70. 100.  .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #01 DK1
 .002 .050 .080 .050 .010 .   .   .   .   .   .                  DECAY RATE                                 #01 DK1
 .020 .020 .020 .020 .020 .   .   .   .   .   .                  DECAY RATE                                 #01 DK1
  4                                   DECOMPOSITION TYPE 02     # DATA PAIRS                               #02 DK1
  1.  10.  20.  30.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #02 DK1
 .150 .200 .300 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #02 DK1
  4                                   DECOMPOSITION TYPE 03     # DATA PAIRS                               #03 DK1
  1.  10.  50. 100.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #03 DK1
 .010 .060 .100 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #03 DK1
 .020 .020 .020 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #03 DK1
  4                                   DECOMPOSITION TYPE 04     # DATA PAIRS                               #04 DK1
  1.  10.  20.  30.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #04 DK1
 .200 .400 .350 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #04 DK1
  5                                   DECOMPOSITION TYPE 05     # DATA PAIRS                               #05 DK1
  1.  10.  25.  40.  50.  .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #05 DK1
 .010 .080 .150 .100 .020 .   .   .   .   .   .                  DECAY RATE                                 #05 DK1
 .040 .040 .040 .040 .040 .   .   .   .   .   .                  DECAY RATE                                 #05 DK1
  4                                   DECOMPOSITION TYPE 06     # DATA PAIRS                               #06 DK1
  1.  10.  25.  30.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #06 DK1
 .100 .300 .400 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #06 DK1
  5                                   DECOMPOSITION TYPE 07     # DATA PAIRS                               #07 DK1
  1.   3.  10.  30.  50.  .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #07 DK1
 .040 .080 .150 .200 .020 .   .   .   .   .   .                  DECAY RATE                                 #07 DK1
 .040 .040 .040 .040 .040 .   .   .   .   .   .                  DECAY RATE                                 #07 DK1
  4                                   DECOMPOSITION TYPE 08     # DATA PAIRS                               #08 DK1
  1.   3.  10.  20.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #08 DK1
 .200 .300 .600 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #08 DK1
  4                                   DECOMPOSITION TYPE 09     # DATA PAIRS                               #09 DK1
  1.  10.  30.  50.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #09 DK1
 .050 .200 .150 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #09 DK1
 .040 .040 .040 .040 .   .   .   .   .   .   .                   DECAY RATE                                 #09 DK1
  4                                   DECOMPOSITION TYPE 10     # DATA PAIRS                               #10 DK1
  1.   5.  10.  15.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #10 DK1
 .300 .600 .500 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #10 DK1
  4                                   DECOMPOSITION TYPE 11     # DATA PAIRS                               #11 DK1
  1.   3.  10.  40.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #11 DK1
 .100 .300 .200 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #11 DK1
  4                                   DECOMPOSITION TYPE 12     # DATA PAIRS                               #12 DK1
  1.  10.  20.  50.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #12 DK1
 .080 .200 .300 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #12 DK1
 .040 .040 .040 .040 .   .   .   .   .   .   .                   DECAY RATE                                 #12 DK1
  4                                   DECOMPOSITION TYPE 13     # DATA PAIRS                               #13 DK1
  1.   5.  10.  15.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #13 DK1
 .300 .500 .600 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #13 DK1
  4                                   DECOMPOSITION TYPE 14     # DATA PAIRS                               #14 DK1
  1.   2.  10.  15.  20.  .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #14 DK1
 .200 .300 .400 .200 .020 .   .   .   .   .   .                  DECAY RATE                                 #14 DK1
 .090 .090 .090 .090 .090 .   .   .   .   .   .                  DECAY RATE                                 #14 DK1
  4                                   DECOMPOSITION TYPE 15     # DATA PAIRS                               #15 DK1
  1.   2.   4.   6.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #15 DK1
 .700 .700 .500 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #15 DK1
  4                                   DECOMPOSITION TYPE 16     # DATA PAIRS                               #16 DK1
  1.   2.   5.  10.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #16 DK1
 .200 .300 .600 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #16 DK1
  5                                   DECOMPOSITION TYPE 17     # DATA PAIRS                               #17 DK1
  1.   2.   3.   4.  10.  .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #17 DK1
 .200 .300 .600 .400 .020 .   .   .   .   .   .                  DECAY RATE                                 #17 DK1
 .090 .090 .090 .090 .090 .   .   .   .   .   .                  DECAY RATE                                 #17 DK1
  4                                   DECOMPOSITION TYPE 18     # DATA PAIRS                               #18 DK1
  1.   2.  10.  15.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #18 DK1
 .200 .250 .400 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #18 DK1
  4                                   DECOMPOSITION TYPE 19     # DATA PAIRS                               #19 DK1
  1.   2.   3.   5.   .   .   .   .   .   .   .                  AGE:  LAST AGE IS MAX AGE FOR TYPE         #19 DK1
 .950 .600 .500 .020 .   .   .   .   .   .   .                   DECAY RATE                                 #19 DK1
  4                                   DECOMPOSITION TYPE 20     # DATA PAIRS                               #20 DK1
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 1.   3.   6.  10.   .   .   .   .   .   .   .   .          AGE:  LAST AGE IS MAX AGE FOR TYPE          #20 DK1
.100 .250 .500 .020 .   .   .   .   .   .   .   .           DECAY RATE                                  #20 DK1
.180 .180 .180 .180 .   .   .   .   .   .   .   .           DECAY RATE                                  #20 DK1
 4                                 DECOMPOSITION TYPE 21    # DATA PAIRS                                #21 DK1
 1.   2.   3.   5.   .   .   .   .   .   .   .   .          AGE:  LAST AGE IS MAX AGE FOR TYPE          #21 DK1
.400 .600 .800 .020 .   .   .   .   .   .   .   .           DECAY RATE                                  #21 DK1
 4                                 DECOMPOSITION TYPE 22    # DATA PAIRS                                #22 DK1
 1.   3.   6.  10.   .   .   .   .   .   .   .   .          AGE:  LAST AGE IS MAX AGE FOR TYPE          #22 DK1
.300 .400 .600 .020 .   .   .   .   .   .   .   .           DECAY RATE                                  #22 DK1
 4                                 DECOMPOSITION TYPE 23    # DATA PAIRS                                #23 DK1
 1.   2.   3.   5.   .   .   .   .   .   .   .   .          AGE:  LAST AGE IS MAX AGE FOR TYPE          #23 DK1
.800 .600 .500 .020 .   .   .   .   .   .   .   .           DECAY RATE                                  #23 DK1
.090 .090 .090 .090 .   .   .   .   .   .   .   .           DECAY RATE                                  #23 DK1
 4                                 DECOMPOSITION TYPE 24    # DATA PAIRS                                #24 DK1
 1.   3.   6.  10.   .   .   .   .   .   .   .   .          AGE:  LAST AGE IS MAX AGE FOR TYPE          #24 DK1
.200 .300 .500 .020 .   .   .   .   .   .   .   .           DECAY RATE                                  #24 DK1
 5                                 DECOMPOSITION TYPE 25    # DATA PAIRS                                #25 DK1
 1.   2.   3.   4.   5.   .   .   .   .   .   .   .         AGE:  LAST AGE IS MAX AGE FOR TYPE          #25 DK1
.300 .600 .700 .400 .020 .   .   .   .   .   .   .          DECAY RATE                                  #25 DK1
.180 .180 .180 .180 .180 .   .   .   .   .   .   .          DECAY RATE                                  #25 DK1
 3                                 DECOMPOSITION TYPE 26    # DATA PAIRS                                #26 DK1
 1.   2.   3.   .   .   .   .   .   .   .   .   .           AGE:  LAST AGE IS MAX AGE FOR TYPE          #26 DK1
.950 .950 .020 .   .   .   .   .   .   .   .   .            DECAY RATE                                  #26 DK1
 3                                 DECOMPOSITION TYPE 27    # DATA PAIRS                                #27 DK1
 1.   2.   3.   .   .   .   .   .   .   .   .   .           AGE:  LAST AGE IS MAX AGE FOR TYPE          #27 DK1
.950 .950 .020 .   .   .   .   .   .   .   .   .            DECAY RATE                                  #27 DK1
 4                                 DECOMPOSITION TYPE 28    # DATA PAIRS                                #28 DK1
 1.   2.   3.   5.   .   .   .   .   .   .   .   .          AGE:  LAST AGE IS MAX AGE FOR TYPE          #28 DK1
.500 .700 .800 .020 .   .   .   .   .   .   .   .           DECAY RATE                                  #28 DK1
 4                                 DECOMPOSITION TYPE 29    # DATA PAIRS                                #29 DK1
 1.   2.   3.   4.   .   .   .   .   .   .   .   .          AGE:  LAST AGE IS MAX AGE FOR TYPE          #29 DK1
.600 .800 .900 .020 .   .   .   .   .   .   .   .           DECAY RATE                                  #29 DK1
.180 .180 .180 .180 .   .   .   .   .   .   .   .           DECAY RATE                                  #29 DK1
 3                                 DECOMPOSITION TYPE 30    # DATA PAIRS                                #30 DK1
 1.   2.   3.   .   .   .   .   .   .   .   .   .           AGE:  LAST AGE IS MAX AGE FOR TYPE          #30 DK1
.990 .990 .020 .   .   .   .   .   .   .   .   .            DECAY RATE                                  #30 DK1
 3                                 DECOMPOSITION TYPE 31    # DATA PAIRS                                #31 DK1
 1.   2.   3.   .   .   .   .   .   .   .   .   .           AGE:  LAST AGE IS MAX AGE FOR TYPE          #31 DK1
.990 .990 .020 .   .   .   .   .   .   .   .   .            DECAY RATE                                  #31 DK1
 3                                 DECOMPOSITION TYPE 32    # DATA PAIRS                                #32 DK1
 1.   2.   3.   .   .   .   .   .   .   .   .   .           AGE:  LAST AGE IS MAX AGE FOR TYPE          #32 DK1
.950 .900 .020 .   .   .   .   .   .   .   .   .            DECAY RATE                                  #32 DK1
 5                                 DECOMPOSITION TYPE 33    # DATA PAIRS                                #33 DK1
 1.   5.  10.  15.  30.   .   .   .   .   .   .   .         AGE:  LAST AGE IS MAX AGE FOR TYPE          #33 DK1
.200 .500 .300 .200 .020 .   .   .   .   .   .   .          DECAY RATE                                  #33 DK1
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Note: These decomposition rates are the same for sites 2 and 3 and are not shown below.

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**********  SECTION 2                                                                                                   DK2
DK2DK2DK2DK2DK2   DATA FOR SOILS SITE #2  DK2DK2DK2DK2DK2DK2DK2DK2DK2DK2DK2DK2DK2   DATA SITE #2   DK2DK2DK2DK2
 50.00                                          NUTRIENT STATUS OF THE SITE - EDAPHIC GRID NUTRIENT AXIS            DK2
******  SECTION 2.1:  RATES OF INPUT OF UP TO FIVE NUTRIENTS FROM THE GEOCHEMICAL CYCLE  ***************************DK2
 5.00  0.02  1.00  0.00  0.00                   PRECIPITATION INPUT       (KG/HA/TIME STEP)                         DK2
 1.00  0.01  1.00  0.00  0.00                   SEEPAGE INPUT             (KG/HA/TIME STEP)                         DK2
 0.00  0.01  1.00  0.00  0.00                   SEEPAGE INPUT             (KG/HA/TIME STEP)                         DK2
 0.00  0.02  0.05  0.00  0.00                   WEATHERING INPUT          (KG/HA/TIME STEP)                         DK2
 2.00  0.00  0.00  0.00  0.00                   NON-SYMBIOTIC FIXATION    (KG/HA/TIME STEP)                         DK2
 0.50  0.00  0.00  0.00  0.00                   NON-SYMBIOTIC FIXATION    (KG/HA/TIME STEP)                         DK2

******  SECTION 2.3:  IONIC FORMS OF NUTRIENTS, AND THE EFFECT OF ROOTS AND LITTER TYPE ON NUTRIENT #1 FORMS *****DK2
0.050 1.000 0.000 0.000 0.000            PROPORTION OF SOIL NUTRIENTS IN ANIONIC FORM FOR UP TO FIVE NUTRIENTS      DK2
0.040 1.000 0.000 0.000 0.000            PROPORTION OF SOIL NUTRIENTS IN ANIONIC FORM FOR UP TO FIVE NUTRIENTS      DK2

******  SECTION 2.5:  HUMUS CHEMISTRY AND DECOMPOSITION RATES  *****************************************************DK2
 .015    2.00      4.     HUMUS #1:    DECOMP RATE     EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)     HM1 DK2
 .01400   .00200   .01000   .00000   .00000   CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE          HM1 DK2
 .010    1.50      6.     HUMUS #2:    DECOMP RATE     EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)     HM2 DK2
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 .01000  .00100  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM2 DK2
 .010    1.00    4.     HUMUS #1:    DECOMP RATE      EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)   HM1 DK2
 .01250  .00200  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM1 DK2
 .003    1.00    6.     HUMUS #2:    DECOMP RATE      EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)   HM2 DK2
 .01050  .00100  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM2 DK2

*********** SECTION 2                                                                                       DK3
DK3DK3DK3DK3DK3   DATA FOR SOILS SITE #3  DK3DK3DK3DK3DK3DK3DK3DK3DK3DK3DK3DK3DK3   DATA SITE #3   DK3DK3DK3DK3
 75.00                                   NUTRIENT STATUS OF THE SITE - EDAPHIC GRID NUTRIENT AXIS           DK3
******  SECTION 2.1:  RATES OF INPUT OF UP TO FIVE NUTRIENTS FROM THE GEOCHEMICAL CYCLE  **************************DK3
 5.00  0.02  1.00  0.00  0.00                PRECIPITATION INPUT       (KG/HA/TIME STEP)                     DK3
 5.00  0.01  1.00  0.00  0.00                SEEPAGE INPUT             (KG/HA/TIME STEP)                     DK3
 0.00  0.01  1.00  0.00  0.00                SEEPAGE INPUT             (KG/HA/TIME STEP)                     DK3
 0.00  0.02  0.05  0.00  0.00                WEATHERING INPUT          (KG/HA/TIME STEP)                     DK3
 3.00  0.00  0.00  0.00  0.00                NON-SYMBIOTIC FIXATION    (KG/HA/TIME STEP)                     DK3
 0.50  0.00  0.00  0.00  0.00                NON-SYMBIOTIC FIXATION    (KG/HA/TIME STEP)                     DK3

******  SECTION 2.5:  HUMUS CHEMISTRY AND DECOMPOSITION RATES  ***************************************************DK3
 .020    2.00    3.     HUMUS #1:    DECOMP RATE      EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)   HM1 DK3
 .01400  .00200  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM1 DK3
 .015    1.50    4.     HUMUS #2:    DECOMP RATE      EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)   HM2 DK3
 .01000  .00100  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM2 DK3
 .010    1.00    3.     HUMUS #1:    DECOMP RATE      EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)   HM1 DK3
 .01350  .00200  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM1 DK3
 .003    1.00    4.     HUMUS #2:    DECOMP RATE      EXPOSURE FACTOR     DELAY IN ACHIEVING FACTOR (TIME)   HM2 DK3
 .01150  .00100  .01000  .00000  .00000  CONCENTRATION OF UP TO FIVE NUTRIENTS IN THIS HUMUS TYPE         HM2 DK3
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Appendix part f.

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******************** TREEDATA:   INPUT DATA FILE FOR THE TREEGROW-11.40A PROGRAM OF FORCYTE-11 ************************
                                                                                                                      :
*********** FILE LABEL AND CONTENT STATEMENT                                                            00000000      :
REVISED DATA FILE SEPTEMBER 14 1988                          DATA FILE IDENTIFICATION                      OO         :
FORCYTE-11  DEMONSTRATION PROJECT                            PROJECT NAME                                  OO         :
J.P. KIMMINS AND K.A. SCOULLAR                               USERS NAME(S)                                 OO         :
REVISED DATA FILE March      8 1990                          DATA FILE IDENTIFICATION                      OO         :
FORCYTE-11  Shawnigan Lake Project                           PROJECT NAME                                  OO         :
D. Sachs                                                     USERS NAME(S)                                 OO         :
SOUTHERN VANCOUVER ISLAND, BRITISH COLUMBIA                  LOCATION OF DATA SITE(S)                      OO         :
COASTAL WESTERN HEMLOCK ZONE, DRY SUBZONE                    ECOLOGICAL ZONE OF DATA SITE(S)                          :
                                                                                                                      :
   2                                                         NUMBER OF TREE SPECIES                                   :
DOUGLAS-FIR                                                  NAME OF TREE #1                                         T1
 140    0                                                    # OF TIME STEPS, AND SPROUTING ABILITY (0=NO 1=YES)     T1
RED ALDER                                                    NAME OF TREE #2                                         T2
  80    1                                                    # OF TIME STEPS, AND SPROUTING ABILITY (0=NO 1=YES)     T2
                                                                                                                      :
   3                                                         NUMBER OF NUTRIENTS                                      :
NITROGEN                                                     NAME OF NUTRIENT #1                                     N1
PHOSPHORUS                                                   NAME OF NUTRIENT #2                                     N2
POTASSIUM                                                    NAME OF NUTRIENT #3                                     N3
                                                                                                                      :
*********** SPREADSHEET PRODUCTION PARAMETERS **************************************************************************
   1 0000000.0000                        RUN NUMBER AND VALUE OF PARAMETER OR CASE #                                  :
  10                                     NUMBER OF AGES FOR SENSITIVITY ANALYSIS                                      :
   1    5   10   15   20   25   30   35   40   45    0    0    0    0    0    0    0    0    0    0                   :
   1    1    1      OUTPUT SELECTION:  SCREEN (1=YES 0=NO)   GRAPHS (2=VIEWS 1=GRAPHS 0=NO)   TRENDS (1=YES 0=NO)      :
                                                                                                                     T1
*********** SECTION T1:  DATA FOR TREE #1  T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1T1  TREE #1  T1T1T1T1T1T1T1T1T1T1T1
   3                                                         NUMBER OF DATA SITES                                    T1
   1     2     3     4     5     6     7     8     9    10 AGES FOR SAVING DATA                                        T1
  12    14    16    18    20    24    28    32    36    40                                                           T1
  46    52    58    64    70    80    90   100   120   140                                                           T1
                                                                                                                  Q1 T1
****** SUBSECTION T1 Q1:  DATA FOR TREE #1 ON SITE #1  Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1  DATA SITE #1  Q1Q1Q1Q1Q1Q1 T1
  25.00                                                      SITE QUALITY: EDAPHIC GRID NUTRIENT AXIS VALUE       Q1 T1
**** SUBDIVISION 1:  DATA DEFINING THE GROWTH OF TREES FROM SEEDLINGS                                             Q1 T1
** DATA PAIRS DEFINING BIOMASS ACCUMULATION                                                                       Q1 T1
   8                                                         STEMWOOD BIOMASS ACCUMULATION: # OF DATA PAIRS       Q1 T1
   3.    6.   11.   19.   48.   73.  100.  140.     .     .      STAND AGE                                        Q1 T1
0.100  0.40  6.0  28.0 155.0 225.0 285.0 325.0      .     .      BIOMASS (T/HA)                                   Q1 T1
   3.    6.   11.   19.   24.   39.   48.   73.  100.  140.      STAND AGE                                        Q1 T1
0.100  0.50  7.0  28.0  67.1 136.8 185.0 255.0 300.0 345.0       BIOMASS (T/HA)                                   Q1 T1
   8                                                         STEMBARK BIOMASS ACCUMULATION: # OF DATA PAIRS       Q1 T1
   3.    6.   11.   19.   48.   73.  100.  140.     .     .      STAND AGE                                        Q1 T1
0.020  0.05  0.75  3.5  18.6  27.0  34.2  37.0      .     .      BIOMASS (T/HA)                                   Q1 T1
   3.    6.   11.   19.   24.   39.   48.   73.  100.  140.      STAND AGE                                        Q1 T1
0.020  0.09  1.40  7.0  11.5  23.7  32.0  33.5  35.2  37.0       BIOMASS (T/HA)                                   Q1 T1
   8                                                         BRANCH BIOMASS ACCUMULATION: # OF DATA PAIRS         Q1 T1
   3.    6.   11.   19.   48.   73.  100.  140.     .     .      STAND AGE                                        Q1 T1
0.025  0.10  1.50  7.0  20.0  21.0  20.0  19.0      .     .      BIOMASS (T/HA)                                   Q1 T1
  10                                                         BRANCH BIOMASS ACCUMULATION: # OF DATA PAIRS         Q1 T1
   3.    6.   11.   19.   24.   39.   48.   73.  100.  140.      STAND AGE                                        Q1 T1
0.025  0.10  0.70  2.8   5.5  14.8  19.0  22.0  21.0  19.0       BIOMASS (T/HA)                                   Q1 T1
   8                                                         FOLIAGE BIOMASS ACCUMULATION: # OF DATA PAIRS        Q1 T1
   3.    6.   11.   19.   48.   73.  100.  140.     .     .      STAND AGE                                        Q1 T1
0.050  0.15  1.50  6.50  8.20  7.80  7.6   7.5      .     .      BIOMASS (T/HA)                                   Q1 T1
  15.00       150.00      300.   25.      FOLIAGE:  STAND MAX.(T/HA)  TREE MAX.(KG/TREE)  AGE MAX.  AGE CLOSURE   Q1 T1
  10                                                         FOLIAGE BIOMASS ACCUMULATION: # OF DATA PAIRS        Q1 T1
   3.    6.   11.   19.   24.   33.   48.   73.  100.  140.      STAND AGE                                        Q1 T1
0.050  0.15  0.90  3.00  5.95 10.50 10.4  10.3  10.3  10.2       BIOMASS (T/HA)                                   Q1 T1
  14.00       150.00      300.   25.      FOLIAGE:  STAND MAX.(T/HA)  TREE MAX.(KG/TREE)  AGE MAX.  AGE CLOSURE   Q1 T1
   8                                                         LARGE ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS    Q1 T1
   3.    6.   11.   19.   48.   73.  100.  140.     .     .      STAND AGE                                        Q1 T1
0.000  0.00  0.00  8.0  32.0  50.0  62.7  71.5      .     .      BIOMASS (T/HA)                                   Q1 T1
   8                                                         MEDIUM ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS   Q1 T1
   3.    6.   11.   19.   48.   73.  100.  140.     .     .      STAND AGE                                        Q1 T1
0.000  0.00  1.8   8.0  12.0  13.0  13.0  12.0      .     .      BIOMASS (T/HA)                                   Q1 T1
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   8                                                                   SMALL ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS    Q1 T1
   3.     6.    11.    19.    48.    73.   100.   140.      .     .        STAND AGE                                     Q1 T1
 0.030  0.10  1.20  4.00  5.00  4.50  4.00  4.00    .     .             BIOMASS (T/HA)                                Q1 T1
   8                                                                   FRUIT BIOMASS ACCUMULATION: # OF DATA PAIRS          Q1 T1
   3.     6.    11.    19.    48.    73.   100.   140.      .     .        STAND AGE                                     Q1 T1
 0.000  0.00  0.00  0.00  0.10  0.20  0.30  0.30    .     .             BIOMASS (T/HA)                                Q1 T1
** DATA DEFINING NATURAL MORTALITY AND HEIGHT GROWTH                                                                        Q1 T1
   8                                                                   STAND DENSITY: # OF DATA QUADRUPLETS                 Q1 T1
    3.      6.     11.     19.     48.     73.    100.    140.      .      .  STAND AGE                                   Q1 T1
 1800.   1780.   1750.   1725.   1500.   1250.   1100.   1000.      .      .  STEMS/HA                                    Q1 T1
 1.000   1.000   0.900   0.850   0.050   0.050   0.050   0.050      .      .  PROPORTION MORTALITY DENSITY INDEPENDENT    Q1 T1
 0.250   0.250   0.250   0.250   0.250   0.250   0.250   0.250      .      .  CANOPY REDUCTION TO STOP SHADE MORTALITY    Q1 T1
   10                                                                  STAND DENSITY: # OF DATA QUADRUPLETS                 Q1 T1
    3.      6.     11.     19.     24.     39.     48.     73.    100.    140.  STAND AGE                                   Q1 T1
 6000.   5800.   5600.   5400.   5142.   4585.   3700.   3500.   3200.   2800.  STEMS/HA                                    Q1 T1
 1.000   1.000   0.900   0.800   0.100   0.030   0.020   0.040   0.05    0.05   PROPORTION MORTALITY DENSITY INDEPENDENT    Q1 T1
 0.250   0.250   0.250   0.250   0.250   0.250   0.250   0.250   0.250   0.250  CANOPY REDUCTION TO STOP SHADE MORTALITY    Q1 T1
   10                                                                  TREE AND CANOPY HEIGHT DATA: # DATA QUADRUPLETS      Q1 T1
   5.    10.   20.    30.    40.    60.    80.   100.   140.  180.        STAND AGE                                     Q1 T1
 0.80  3.00  8.0  15.0  20.0  28.0  34.0  37.0  40.0  41.0          AVERAGE TOP HEIGHT OF DOMINANT TREES (M)      Q1 T1
 0.60  2.00  6.0  12.0  14.0  22.0  24.0  28.0  30.0  32.0          TOP HEIGHT OF SHORTEST LIVE CANOPY TREE (M)   Q1 T1
 0.00  0.00  0.0   5.0  10.0  15.0  20.0  22.0  23.0  24.0          AVERAGE HEIGHT OF CANOPY BOTTOM (M)           Q1 T1
   5.    10.   24.    33.    39.    60.    80.   100.   140.  180.        STAND AGE                                     Q1 T1
 0.80  3.00 15.8  18.8  25.0  28.0  34.0  37.0  40.0  41.0          AVERAGE TOP HEIGHT OF DOMINANT TREES (M)      Q1 T1
 0.60  1.00  3.7   4.3   4.6   6.0   7.0   8.0  10.0  12.0          TOP HEIGHT OF SHORTEST LIVE CANOPY TREE (M)   Q1 T1
 0.00  0.00  1.3   2.7   3.6   3.8   4.0   5.0   6.5   8.0          AVERAGE HEIGHT OF CANOPY BOTTOM (M)           Q1 T1
** DATA DEFINING PHOTOSYNTHESIS AND SOIL OCCUPATION BY ROOTS                                                                Q1 T1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00      PHOTO LIGHT SATURATION CURVE: .% FULL LIGHT *DNC*      Q1 T1
0.00 0.01 0.12 0.28 0.40 0.55 0.66 0.80 0.90 0.96 1.00             .% OF MAX. PHOTO: SUN FOLIAGE                     Q1 T1
0.00 0.20 0.32 0.40 0.43 0.45 0.47 0.49 0.45 0.25 0.00             .% OF MAX. PHOTO: SHADE FOLIAGE                   Q1 T1
f
  0.150                                                         SHADING BY OBSERVED MAXIMUM FOLIAGE (.% FULL LIGHT)  Q1 T1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00      SHAPE OF FOL.BIO.SHADING: .% OF MAX.FOLIAGE  *DNC*     Q1 T1
0.00 0.18 0.34 0.48 0.60 0.70 0.79 0.87 0.93 0.97 1.00                                 .% OF MAX.SHADING            Q1 T1
 0.20   .50                                         .% OF PHOTO. COMPETITION LEAFLESS    STUNTED HEIGHT CONTROL      Q1 T1
F
 1.00   .50                                         .% OF PHOTO. COMPETITION LEAFLESS    STUNTED HEIGHT CONTROL      Q1 T1
F
1.00                                                           .% OF SOIL VOLUME OCCUPIED AT MAX. SMALL ROOT BIO.   Q1 T1
1.00  1.00  1.00  0.00  0.00                                   .% EFFICIENCY OF NUTRIENT CAPTURE FOR EACH NUTRIENT  Q1 T1
** DATA DEFINING THE PROPORTION OF TREES IN UP TO TEN STEM BIOMASS CLASSES FOR UP TO 10 STAND AGES                          Q1 T1
   6                                                           # OF STAND AGES (UP TO 10) FOR WHICH DATA ARE GIVEN  Q1 T1
AGE   3.     0.01   0.02   0.03   0.04   0.05   0.06   0.07   0.08   0.09   0.10   0.11  STEM BIOMASS CLASSES         Q1 T1
              .01    .01    .15    .20    .40    .15    .05    .01    .01    .00        .% OF STEMS IN EACH CLASS    Q1 T1
AGE   6.     0.10   0.12   0.14   0.16   0.18   0.20   0.22   0.24   0.26   0.28   0.30  STEM BIOMASS CLASSES         Q1 T1
              .01   .025    .05   .075    .15    .50    .10   .025   .012    .01        .% OF STEMS IN EACH CLASS    Q1 T1
AGE  11.      1.0    1.5    2.0    2.5    3.0    3.5    4.0    4.5    5.0    5.5    6.0  STEM BIOMASS CLASSES         Q1 T1
              .05    .10    .15    .20    .30    .10    .05   .025   .012    .01        .% OF STEMS IN EACH CLASS    Q1 T1
AGE  19.      8.0   10.0   12.0   14.0   16.0   18.0   20.0   22.0   24.0   26.0   28.0  STEM BIOMASS CLASSES         Q1 T1
              .05    .10    .15    .20    .30    .10    .05   .025   .012    .01        .% OF STEMS IN EACH CLASS    Q1 T1
AGE  48.     60.0   70.0   80.0   90.0  100.0  110.0  120.0  130.0  140.0  150.   160.0  STEM BIOMASS CLASSES         Q1 T1
              .05    .10    .15    .20    .30    .10    .05    .05    .02    .01        .% OF STEMS IN EACH CLASS    Q1 T1
AGE  73.    100.0  110.0  120.   130.   140.   150.   160.   170.   180.   190.   200.   STEM BIOMASS CLASSES         Q1 T1
              .05    .05    .10    .10    .10    .20    .20    .15    .02    .01        .% OF STEMS IN EACH CLASS    Q1 T1
   3                                                           # OF STAND AGES (UP TO 10) FOR WHICH DATA ARE GIVEN  Q1 T1
AGE  23.      0.6    1.0   20.7   49.8   94.3  155.6      .      .      .      .      .  STEM BIOMASS CLASSES         Q1 T1
              .22    .57    .19    .01    .01      .      .      .      .      .        .% OF STEMS IN EACH CLASS    Q1 T1
AGE  33.      0.6    1.0   20.7   49.8   94.3  155.6  234.7      .      .      .      .  STEM BIOMASS CLASSES         Q1 T1
              .15    .45    .31    .08    .01    .01      .      .      .      .        .% OF STEMS IN EACH CLASS    Q1 T1
AGE  39.      0.6    1.0   20.7   49.8   94.3  155.6  234.7  332.7      .      .      .  STEM BIOMASS CLASSES         Q1 T1
              .09    .41    .31    .14    .03    .01    .01      .      .      .        .% OF STEMS IN EACH CLASS    Q1 T1
** DATA DEFINING THE CONCENTRATIONS OF UP TO 5 NUTRIENTS IN TREE BIOMASS COMPONENTS                                         Q1 T1
.001500  .000150  .000700  .000000  .000000     STEM SAPWOOD                      .% NUTRIENT CONCENTRATIONS            Q1 T1
.000500  .000050  .000250  .000000  .000000     STEM HEARTWOOD                                                          Q1 T1
.004000  .000700  .003000  .000000  .000000     LIVE BARK (PHLOEM)                                                      Q1 T1
.002900  .000570  .002000  .000000  .000000     DEAD BARK                                                               Q1 T1
.003000  .000300  .002500  .000000  .000000     LIVE BRANCHES                                                           Q1 T1
.003000  .000400  .002000  .000000  .000000     DEAD BRANCHES                                                           Q1 T1
.010000  .002800  .008500  .000000  .000000     YOUNG FOLIAGE (DEFINED BELOW)                                           Q1 T1
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.008000  .002400  .006000  .000000  .000000     OLD FOLIAGE (DEFINED BELOW)                                          Q1 T1
.006500  .001200  .003600  .000000  .000000     DEAD FOLIAGE (LITTERFALL)                                            Q1 T1
.001000  .000100  .000600  .000000  .000000     LARGE ROOT SAPWOOD                                                   Q1 T1
.000500  .000050  .000250  .000000  .000000     LARGE ROOT HEARTWOOD                                                 Q1 T1
.002500  .000220  .001000  .000000  .000000     MEDIUM ROOT SAPWOOD                                                  Q1 T1
.000800  .000080  .000400  .000000  .000000     MEDIUM ROOT HEARTWOOD                                                Q1 T1
.003000  .000300  .001500  .000000  .000000     LIVE SMALL AND FINE ROOTS (<5 CM)                                    Q1 T1
.002000  .000200  .001000  .000000  .000000     DEAD SMALL AND FINE ROOTS                                            Q1 T1
.015000  .003000  .008000  .000000  .000000     FRUIT                                                                Q1 T1
.001100  .000150  .000700  .000000  .000000     STEM SAPWOOD                    .% NUTRIENT CONCENTRATIONS           Q1 T1
.000600  .000050  .000250  .000000  .000000     STEM HEARTWOOD                                                       Q1 T1
.003800  .000700  .003000  .000000  .000000     LIVE BARK (PHLOEM)                                                   Q1 T1
.002500  .000570  .002000  .000000  .000000     DEAD BARK                                                            Q1 T1
.003730  .000300  .002500  .000000  .000000     LIVE BRANCHES                                                        Q1 T1
.002100  .000400  .002000  .000000  .000000     DEAD BRANCHES                                                        Q1 T1
.010700  .002800  .008500  .000000  .000000     YOUNG FOLIAGE (DEFINED BELOW)                                        Q1 T1
.008800  .002400  .006000  .000000  .000000     OLD FOLIAGE (DEFINED BELOW)                                          Q1 T1
.005000  .001200  .003600  .000000  .000000     DEAD FOLIAGE (LITTERFALL)                                            Q1 T1
.001000  .000100  .000600  .000000  .000000     LARGE ROOT SAPWOOD                                                   Q1 T1
.000500  .000050  .000250  .000000  .000000     LARGE ROOT HEARTWOOD                                                 Q1 T1
.002000  .000220  .001000  .000000  .000000     MEDIUM ROOT SAPWOOD                                                  Q1 T1
.000700  .000080  .000400  .000000  .000000     MEDIUM ROOT HEARTWOOD                                                Q1 T1
.003000  .000300  .001500  .000000  .000000     LIVE SMALL AND FINE ROOTS (<5 CM)                                    Q1 T1
.001800  .000200  .001000  .000000  .000000     DEAD SMALL AND FINE ROOTS                                            Q1 T1
.005000  .003000  .008000  .000000  .000000     FRUIT                                                                Q1 T1
**  DATA DEFINING ATMOSPHERIC INPUTS, FOLIAGE LEACHING AND SYMBIOTIC FIXATION OF UP TO 5 NUTRIENTS                   Q1 T1
 2.00  0.30  1.00  0.00  0.00             ATMOSPHERIC INPUTS: DUST AND PRECIPITATION (KG/HA)                         Q1 T1
 1.80  2.00 10.00  0.00  0.00             THROUGHFALL CONTENT (KG/HA)                                                Q1 T1
10.00 10.00 10.00  0.00  0.00             FOLIAGE BIOMASS ASSOCIATED WITH THROUGHFALL DATA (T/HA)                    Q1 T1
.0000 .0000 .0000 .0000 .0000             SYMBIOTIC FIXATION (KG NUTRIENT FIXED PER KG FOLIAGE)                      Q1 T1
**  DATA DEFINING TRANSFER OF BIOMASS FROM LIVE TO DEAD COMPONENTS, AND TO LITTERFALL                                Q1 T1
0.060 0.100 0.040 0.060 0.060            .% OF LIVE STEMWOOD, BARK, BRANCHES, LARGE AND MEDIUM ROOTS TO DIE          Q1 T1
0.030 0.001 0.020 2.000 1.000            .% OF DEAD BARK, LRG, MED & SML ROOTS AND FRUIT TO LITTERFALL               Q1 T1
  40    2.0   3.0                         RETENTION (# TIME STEPS) OF DEAD BRANCHES, YOUNG AND OLD FOLIAGE           Q1 T1
0.030 0.001 0.020 1.700 1.000            .% OF DEAD BARK, LRG, MED & SML ROOTS AND FRUIT TO LITTERFALL               Q1 T1
  40    2.0   4.0                         RETENTION (# TIME STEPS) OF DEAD BRANCHES, YOUNG AND OLD FOLIAGE           Q1 T1
 .050  .000   .000   .050   .000 -.150   .% WT CHANGE AT DEATH OF LIVE: STEM, BARK, BRANCHES, LRG, MED & SML ROOT Q1 T1
 .100 -.150                              .% WT CHANGE WITH FOLIAGE AGING AND DEATH                                   Q1 T1
CHECK OK                                                                                                             Q1 T1
                                                                                                                     Q2 T1
******  SUBSECTION T1 Q2:  DATA FOR TREE #1 ON SITE #2   Q2Q2Q2Q2Q2Q2Q2Q2Q2Q2Q2Q2Q2Q2  DATA SITE #2  Q2Q2Q2Q2Q2Q2 T1
  50.00                                                     SITE QUALITY: EDAPHIC GRID NUTRIENT AXIS VALUE       Q2 T1
****  SUBDIVISION 1:  DATA DEFINING THE GROWTH OF TREES FROM SEEDLINGS                                               Q2 T1
**  DATA PAIRS DEFINING BIOMASS ACCUMULATION                                                                         Q2 T1
   8                                                        STEMWOOD BIOMASS ACCUMULATION: # OF DATA PAIRS       Q2 T1
   3.     6.   11.   19.   48.   73.  100.  140.    .   .       STAND AGE                                            Q2 T1
0.500  2.00 12.0  80.0 263.6 360.6 460.0 510.0    .   .         BIOMASS (T/HA)                                       Q2 T1
   8                                                        STEMBARK BIOMASS ACCUMULATION: # OF DATA PAIRS       Q2 T1
   3.     6.   11.   19.   48.   73.  100.  140.    .   .       STAND AGE                                            Q2 T1
0.120  0.50  2.50   8.0  32.7  45.4  57.9  64.2    .   .        BIOMASS (T/HA)                                       Q2 T1
   8                                                        BRANCH BIOMASS ACCUMULATION: # OF DATA PAIRS         Q2 T1
   3.     6.   11.   19.   48.   73.  100.  140.    .   .       STAND AGE                                            Q2 T1
0.038  0.20  2.00 26.9  30.4  32.0  31.0  30.0    .   .         BIOMASS (T/HA)                                       Q2 T1
   3.     6.   13.   18.   48.   73.  100.  140.    .   .       STAND AGE                                            Q2 T1
0.038  0.20  2.00 10.0  26.4  30.0  31.0  30.0    .   .         BIOMASS (T/HA)                                       Q2 T1
   8                                                        FOLIAGE BIOMASS ACCUMULATION: # OF DATA PAIRS        Q2 T1
   3.     6.   11.   19.   48.   73.  100.  140.    .   .       STAND AGE                                            Q2 T1
0.074  0.50  5.50 14.94 14.10 11.45 10.0   9.5    .   .         BIOMASS (T/HA)                                       Q2 T1
  20.00       200.00     250.   18.      FOLIAGE:  STAND MAX.(T/HA)  TREE MAX.(KG/TREE)  AGE MAX.  AGE CLOSURE    Q2 T1
   3.     6.   13.   27.   48.   73.  100.  140.    .   .       STAND AGE                                            Q2 T1
0.074  0.50  3.00 13.50 13.20 12.70 12.4  12.2    .   .         BIOMASS (T/HA)                                       Q2 T1
  17.00       200.00     250.   20.      FOLIAGE:  STAND MAX.(T/HA)  TREE MAX.(KG/TREE)  AGE MAX.  AGE CLOSURE    Q2 T1
   8                                                        LARGE ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS    Q2 T1
   3.     6.   11.   19.   48.   73.  100.  140.    .   .       STAND AGE                                            Q2 T1
0.000  0.00  0.00 16.0  54.0  81.6  96.6 107.0    .   .         BIOMASS (T/HA)                                       Q2 T1
   8                                                        MEDIUM ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS   Q2 T1
   3.     6.   11.   19.   48.   73.  100.  140.    .   .       STAND AGE                                            Q2 T1
0.000  0.00  2.2  10.0  11.0  12.0  12.0  11.0    .   .         BIOMASS (T/HA)                                       Q2 T1
   8                                                        SMALL ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS    Q2 T1
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   3.     6.    11.    19.    48.    73.   100.   140.     .     .       STAND AGE                                        Q2 T1
0.046   0.20   3.58   4.50   4.30   4.20   4.00   4.00     .     .       BIOMASS (T/HA)                                   Q2 T1
   8                                                                  FRUIT BIOMASS ACCUMULATION: # OF DATA PAIRS        Q2 T1
   3.     6.    11.    19.    48.    73.   100.   140.     .     .       STAND AGE                                        Q2 T1
0.000   0.00   0.00   0.20   0.4    0.6    0.6    0.6      .     .       BIOMASS (T/HA)                                   Q2 T1
**  DATA DEFINING NATURAL MORTALITY AND HEIGHT GROWTH                                                                    Q2 T1
   8                                                                  STAND DENSITY: # OF DATA QUADRUPLETS               Q2 T1
    3.      6.     11.     19.     48.     73.    100.    140.     .     .  STAND AGE                                   Q2 T1
 1800.   1780.   1750.   1650.   1160.    920.    800.    700.     .     .  STEMS/HA                                    Q2 T1
 1.000   1.000   0.200   0.020   0.010   0.050   0.050   0.050     .     .  PROPORTION MORTALITY DENSITY INDEPENDENT    Q2 T1
 0.250   0.250   0.250   0.250   0.250   0.250   0.250   0.250     .     .  CANOPY REDUCTION TO STOP SHADE MORTALITY    Q2 T1
    3.      6.     11.     19.     48.     73.    100.    140.     .     .  STAND AGE                                   Q2 T1
 6000.   5400.   4800.   4400.   2800.   2300.   2000.   1700.     .     .  STEMS/HA                                    Q2 T1
 1.000   1.000   0.300   0.020   0.020   0.040   0.050   0.050     .     .  PROPORTION MORTALITY DENSITY INDEPENDENT    Q2 T1
 0.250   0.250   0.250   0.250   0.250   0.250   0.250   0.250     .     .  CANOPY REDUCTION TO STOP SHADE MORTALITY    Q2 T1
  10                                                                  TREE AND CANOPY HEIGHT DATA: # DATA QUADRUPLETS    Q2 T1
  5.    10.   20.   30.   40.   60.   80.  100.  140.  180.       STAND AGE                                            Q2 T1
 1.40  6.50 20.0  28.0  34.0  43.0  50.0  55.0  60.0  66.0        AVERAGE TOP HEIGHT OF DOMINANT TREES (M)             Q2 T1
 0.80  3.25 14.0  20.0  23.0  26.0  29.0  32.0  34.0  38.0        TOP HEIGHT OF SHORTEST LIVE CANOPY TREE (M)          Q2 T1
 0.00  0.00 12.0  18.0  21.0  23.0  25.0  27.0  28.0  30.0        AVERAGE HEIGHT OF CANOPY BOTTOM (M)                  Q2 T1
 0.80  2.30  6.0   8.5   9.5  12.0  18.0  18.0  23.0  25.0        TOP HEIGHT OF SHORTEST LIVE CANOPY TREE (M)          Q2 T1
 0.00  0.00  2.2   3.8   4.8   7.5  12.0  14.0  16.0  17.0        AVERAGE HEIGHT OF CANOPY BOTTOM (M)                  Q2 T1
**  DATA DEFINING PHOTOSYNTHESIS AND SOIL OCCUPATION BY ROOTS                                                             Q2 T1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00      PHOTO LIGHT SATURATION CURVE: .% FULL LIGHT *DNC*       Q2 T1
0.00 0.01 0.12 0.28 0.40 0.55 0.66 0.80 0.90 0.96 1.00           .% OF MAX. PHOTO: SUN FOLIAGE                       Q2 T1
0.00 0.20 0.32 0.40 0.43 0.45 0.47 0.49 0.45 0.25 0.00           .% OF MAX. PHOTO: SHADE FOLIAGE                     Q2 T1
 0.080                                                      SHADING BY OBSERVED MAXIMUM FOLIAGE (.% FULL LIGHT)     Q2 T1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00      SHAPE OF FOL.BIO.SHADING: .% OF MAX.FOLIAGE  *DNC*      Q2 T1
0.00 0.18 0.34 0.48 0.60 0.70 0.79 0.87 0.93 0.97 1.00                                .% OF MAX.SHADING             Q2 T1
 0.20   .50                                       .% OF PHOTO. COMPETITION LEAFLESS   STUNTED HEIGHT CONTROL        Q2 T1
 1.00   .50                                       .% OF PHOTO. COMPETITION LEAFLESS   STUNTED HEIGHT CONTROL        Q2 T1
1.00                                                        .% OF SOIL VOLUME OCCUPIED AT MAX. SMALL ROOT BIO.      Q2 T1
1.00  1.00  1.00  0.00  0.00                                .% EFFICIENCY OF NUTRIENT CAPTURE FOR EACH NUTRIENT     Q2 T1
**  DATA DEFINING THE PROPORTION OF TREES IN UP TO TEN STEM BIOMASS CLASSES FOR UP TO 10 STAND AGES                    Q2 T1
  6                                                         # OF STAND AGES (UP TO 10) FOR WHICH DATA ARE GIVEN     Q2 T1
AGE   3.     0.18    0.20    0.22    0.24    0.26    0.28    0.30    0.32    0.34    0.36    0.38  STEM BIOMASS CLASSES    Q2 T1
              .01     .01     .10     .15     .25     .25     .10     .05     .01     .01      .% OF STEMS IN EACH CLASS Q2 T1
AGE   6.     0.50    0.60    0.70    0.80    0.90    1.00    1.10    1.20    1.30    1.40    1.50  STEM BIOMASS CLASSES    Q2 T1
              .01     .01     .05     .05     .10     .20     .25     .20     .05     .01      .% OF STEMS IN EACH CLASS Q2 T1
AGE  11.      2.0     3.0     4.0     5.0     6.0     7.0     8.0     9.0    10.0    11.0    12.0  STEM BIOMASS CLASSES    Q2 T1
              .05     .10     .15     .20     .30     .15     .10     .05     .01     .01      .% OF STEMS IN EACH CLASS Q2 T1
AGE  19.     30.0    34.0    38.0    42.0    46.0    50.0    54.0    58.0    62.0    66.0    68.0  STEM BIOMASS CLASSES    Q2 T1
              .01     .05     .10     .20     .25     .20     .10     .05     .01     .01      .% OF STEMS IN EACH CLASS Q2 T1
AGE  48.    160.0   180.0   200.0   220.0   240.0   260.0   280.0   300.0   320.0   340.    360.0  STEM BIOMASS CLASSES    Q2 T1
              .01     .05     .10     .15     .20     .30     .15     .05     .01     .01      .% OF STEMS IN EACH CLASS Q2 T1
AGE  73.    350.0   380.0   410.    440.    470.    500.    530.    560.    590.    620.    650.   STEM BIOMASS CLASSES    Q2 T1
              .01     .05     .15     .20     .25     .20     .05     .05     .02     .01      .% OF STEMS IN EACH CLASS Q2 T1
   3                                                        # OF STAND AGES (UP TO 10) FOR WHICH DATA ARE GIVEN     Q2 T1
AGE  23.      4.0     8.0    30.7    69.8    84.3   200.6     .       .       .       .        .  STEM BIOMASS CLASSES    Q1 T1
              .22     .55     .19     .02     .02     .       .       .       .       .        .% OF STEMS IN EACH CLASS Q1 T1
AGE  33.      9.6    19.0    48.7    85.8   134.3   185.6   264.7     .       .       .        .  STEM BIOMASS CLASSES    Q1 T1
              .15     .45     .31     .08     .01     .01     .       .       .       .        .% OF STEMS IN EACH CLASS Q1 T1
AGE  39.      9.6    21.0    50.7    99.8   134.3   185.6   274.7   332.7     .       .        .  STEM BIOMASS CLASSES    Q1 T1
              .09     .40     .30     .13     .04     .02     .02     .       .       .        .% OF STEMS IN EACH CLASS Q1 T1
**  DATA DEFINING THE CONCENTRATIONS OF UP TO 5 NUTRIENTS IN TREE BIOMASS COMPONENTS                                     Q2 T1
.001700  .000170  .000900  .000000  .000000    STEM SAPWOOD                         .% NUTRIENT CONCENTRATIONS         Q2 T1
.000500  .000050  .000250  .000000  .000000    STEM HEARTWOOD                                                          Q2 T1
.004900  .000800  .003000  .000000  .000000    LIVE BARK (PHLOEM)                                                      Q2 T1
.002900  .000570  .002000  .000000  .000000    DEAD BARK                                                               Q2 T1
.003500  .000350  .002500  .000000  .000000    LIVE BRANCHES                                                           Q2 T1
.003000  .000400  .002000  .000000  .000000    DEAD BRANCHES                                                           Q2 T1
.011500  .003000  .010000  .000000  .000000    YOUNG FOLIAGE (DEFINED BELOW)                                           Q2 T1
.009000  .002800  .007000  .000000  .000000    OLD FOLIAGE (DEFINED BELOW)                                             Q2 T1
.007700  .001200  .003600  .000000  .000000    DEAD FOLIAGE (LITTERFALL)                                               Q2 T1
.001200  .000120  .000700  .000000  .000000    LARGE ROOT SAPWOOD                                                      Q2 T1
.000800  .000080  .000400  .000000  .000000    LARGE ROOT HEARTWOOD                                                    Q2 T1
.002500  .000250  .001500  .000000  .000000    MEDIUM ROOT SAPWOOD                                                     Q2 T1
.000500  .000050  .000400  .000000  .000000    MEDIUM ROOT HEARTWOOD                                                   Q2 T1
.003600  .000360  .002000  .000000  .000000    LIVE SMALL AND FINE ROOTS (<5 CM)                                       Q2 T1
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.002000  .000200  .001000  .000000  .000000     DEAD SMALL AND FINE ROOTS                                              Q2 T1
.015000  .003000  .008000  .000000  .000000     FRUIT                                                                  Q2 T1
.001500  .000170  .000900  .000000  .000000     STEM SAPWOOD                      .% NUTRIENT CONCENTRATIONS           Q2 T1
.000650  .000050  .000250  .000000  .000000     STEM HEARTWOOD                                                         Q2 T1
.004900  .000800  .003000  .000000  .000000     LIVE BARK (PHLOEM)                                                     Q2 T1
.002900  .000570  .002000  .000000  .000000     DEAD BARK                                                              Q2 T1
.003900  .000350  .002500  .000000  .000000     LIVE BRANCHES                                                          Q2 T1
.002500  .000400  .002000  .000000  .000000     DEAD BRANCHES                                                          Q2 T1
.011200  .003000  .010000  .000000  .000000     YOUNG FOLIAGE (DEFINED BELOW)                                          Q2 T1
.010200  .002800  .007000  .000000  .000000     OLD FOLIAGE (DEFINED BELOW)                                            Q2 T1
.006500  .001200  .003600  .000000  .000000     DEAD FOLIAGE (LITTERFALL)                                              Q2 T1
.001200  .000120  .000700  .000000  .000000     LARGE ROOT SAPWOOD                                                     Q2 T1
.000800  .000080  .000400  .000000  .000000     LARGE ROOT HEARTWOOD                                                   Q2 T1
.002100  .000250  .001500  .000000  .000000     MEDIUM ROOT SAPWOOD                                                    Q2 T1
.000500  .000050  .000400  .000000  .000000     MEDIUM ROOT HEARTWOOD                                                  Q2 T1
.003600  .000360  .002000  .000000  .000000     LIVE SMALL AND FINE ROOTS (<5 CM)                                      Q2 T1
.002000  .000200  .001000  .000000  .000000     DEAD SMALL AND FINE ROOTS                                              Q2 T1
.005000  .003000  .008000  .000000  .000000     FRUIT                                                                  Q2 T1
** DATA DEFINING ATMOSPHERIC INPUTS, FOLIAGE LEACHING AND SYMBIOTIC FIXATION OF UP TO 5 NUTRIENTS                      Q2 T1
 2.00  0.30  1.00  0.00  0.00            ATMOSPHERIC INPUTS: DUST AND PRECIPITATION (KG/HA)                            Q2 T1
 3.00  2.00 14.00  0.00  0.00            THROUGHFALL CONTENT (KG/HA)                                                   Q2 T1
12.00 12.00 12.00  0.00  0.00            FOLIAGE BIOMASS ASSOCIATED WITH THROUGHFALL DATA (T/HA)                       Q2 T1
.0000 .0000 .0000 .0000 .0000            SYMBIOTIC FIXATION (KG NUTRIENT FIXED PER KG FOLIAGE)                         Q2 T1
** DATA DEFINING TRANSFER OF BIOMASS FROM LIVE TO DEAD COMPONENTS, AND TO LITTERFALL                                   Q2 T1
0.080 0.100 0.070 0.080 0.080           .% OF LIVE STEMWOOD, BARK, BRANCHES, LARGE AND MEDIUM ROOTS TO DIE             Q2 T1
0.030 0.001 0.020 1.700 1.000           .% OF DEAD BARK, LRG, MED & SML ROOTS AND FRUIT TO LITTERFALL                  Q2 T1
  30   2.0   3.0                         RETENTION (# TIME STEPS) OF DEAD BRANCHES, YOUNG AND OLD FOLIAGE              Q2 T1
0.030 0.001 0.020 1.600 1.000           .% OF DEAD BARK, LRG, MED & SML ROOTS AND FRUIT TO LITTERFALL                  Q2 T1
  30   2.0   3.0                         RETENTION (# TIME STEPS) OF DEAD BRANCHES, YOUNG AND OLD FOLIAGE              Q2 T1
 .050  .000  .000  .050  .000 -.150     .% WT CHANGE AT DEATH OF LIVE: STEM, BARK, BRANCHES, LRG, MED & SML ROOT Q2 T1
 .100 -.150                             .% WT CHANGE WITH FOLIAGE AGING AND DEATH                                      Q2 T1
CHECK OK                                                                                                               Q2 T1
                                                                                                                       Q3 T1
****** SUBSECTION T1 Q3:  DATA FOR TREE #1 ON SITE #3   Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3Q3  DATA SITE #3  Q3Q3Q3Q3Q3Q3 T1
 75.00                                                    SITE QUALITY: EDAPHIC GRID NUTRIENT AXIS VALUE       Q3 T1
**** SUBDIVISION 1:  DATA DEFINING THE GROWTH OF TREES FROM SEEDLINGS                                                  Q3 T1
** DATA PAIRS DEFINING BIOMASS ACCUMULATION                                                                            Q3 T1
   8                                                      STEMWOOD BIOMASS ACCUMULATION: # OF DATA PAIRS       Q3 T1
   3.    6.   11.   19.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
1.000  9.00 45.0 145.0 500.0 595.0 640.0 660.0     .    .     BIOMASS (T/HA)                                     Q3 T1
   8                                                      STEMBARK BIOMASS ACCUMULATION: # OF DATA PAIRS       Q3 T1
   3.    6.   11.   19.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
0.500  2.50  9.00 16.0  63.0  74.9  80.6  83.1     .    .     BIOMASS (T/HA)                                     Q3 T1
   8                                                      BRANCH BIOMASS ACCUMULATION: # OF DATA PAIRS         Q3 T1
   3.    6.   11.   19.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
0.080  2.50 10.00 34.0  41.0  40.0  39.5  39.0     .    .     BIOMASS (T/HA)                                     Q3 T1
   8                                                      FOLIAGE BIOMASS ACCUMULATION: # OF DATA PAIRS        Q3 T1
   3.    6.   11.   19.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
0.150  1.50 14.00 19.50 17.50 16.50 16.0  16.0     .    .     BIOMASS (T/HA)                                     Q3 T1
  25.00       250.00     200.   13.      FOLIAGE:  STAND MAX.(T/HA)  TREE MAX.(KG/TREE)  AGE MAX.  AGE CLOSURE  Q3 T1
   3.    6.   16.   25.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
0.150  1.50 10.00 17.00 16.00 16.20 16.0  16.0     .    .     BIOMASS (T/HA)                                     Q3 T1
  20.00       250.00     200.   15.      FOLIAGE:  STAND MAX.(T/HA)  TREE MAX.(KG/TREE)  AGE MAX.  AGE CLOSURE  Q3 T1
   8                                                      LARGE ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS    Q3 T1
   3.    6.   11.   19.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
0.000  0.00  9.00 31.0 105.0 125.0 135.0 139.0     .    .     BIOMASS (T/HA)                                     Q3 T1
   8                                                      MEDIUM ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS   Q3 T1
   3.    6.   11.   19.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
0.000  0.10  8.0  14.0  15.0  14.0  14.0  13.0     .    .     BIOMASS (T/HA)                                     Q3 T1
   8                                                      SMALL ROOTS BIOMASS ACCUMULATION: # OF DATA PAIRS    Q3 T1
   3.    6.   11.   19.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
0.100  0.50  4.50  4.50  4.00  3.50  3.00  3.00    .    .     BIOMASS (T/HA)                                     Q3 T1
   8                                                      FRUIT BIOMASS ACCUMULATION: # OF DATA PAIRS          Q3 T1
   3.    6.   11.   19.   48.   73.  100.  140.    .    .     STAND AGE                                          Q3 T1
0.000  0.00  0.10  0.40  0.60  0.70  0.70  0.80    .    .     BIOMASS (T/HA)                                     Q3 T1
** DATA DEFINING NATURAL MORTALITY AND HEIGHT GROWTH                                                                   Q3 T1
   8                                                      STAND DENSITY: # OF DATA QUADRUPLETS                 Q3 T1
   3.      6.     11.     19.     48.     73.    100.    140.      .      .  STAND AGE                           Q3 T1
 1800.  1780.  1700.  1300.    800.    600.    500.    400.      .      .  STEMS/HA                            Q3 T1
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Appendix part k.

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 1.000  0.800  0.100  0.010  0.010  0.050  0.050  0.050   .      .       PROPORTION MORTALITY DENSITY INDEPENDENT  Q3 T1
 6000.  5000.  3900.  3000.  1800.  1500.  1300.  1000.   .      .       STEMS/HA                                  Q3 T1
 1.000  0.800  0.300  0.010  0.010  0.010  0.010  0.010   .      .       PROPORTION MORTALITY DENSITY INDEPENDENT  Q3 T1
 0.250  0.250  0.250  0.250  0.250  0.250  0.250  0.250   .      .       CANOPY REDUCTION TO STOP SHADE MORTALITY  Q3 T1
  10                                                           TREE AND CANOPY HEIGHT DATA: # DATA QUADRUPLETS     Q3 T1
  5.   10.   20.   30.   40.   60.   80.  100.  140.  180.        STAND AGE                                        Q3 T1
 2.50  8.00 18.0  28.0  38.0  52.0  60.0  65.0  68.0  70.0        AVERAGE TOP HEIGHT OF DOMINANT TREES (M)         Q3 T1
 1.50  5.00 12.0  25.0  36.0  45.0  54.0  56.0  59.0  62.0        TOP HEIGHT OF SHORTEST LIVE CANOPY TREE (M)      Q3 T1
 0.00  0.50  8.0  18.0  25.0  38.0  40.0  42.0  42.5  43.0        AVERAGE HEIGHT OF CANOPY BOTTOM (M)              Q3 T1
 1.50  2.90  6.0   9.0  10.5  13.0  17.0  21.0  25.0  29.0        TOP HEIGHT OF SHORTEST LIVE CANOPY TREE (M)      Q3 T1
 0.00  0.50  2.5   3.9   6.5   8.5  13.5  15.5  20.5  22.0        AVERAGE HEIGHT OF CANOPY BOTTOM (M)              Q3 T1
**  DATA DEFINING PHOTOSYNTHESIS AND SOIL OCCUPATION BY ROOTS                                                      Q3 T1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00      PHOTO LIGHT SATURATION CURVE: .% FULL LIGHT *DNC*    Q3 T1
0.00 0.01 0.12 0.28 0.40 0.55 0.66 0.80 0.90 0.96 1.00            .% OF MAX. PHOTO: SUN FOLIAGE                  Q3 T1
0.00 0.20 0.32 0.40 0.43 0.45 0.47 0.49 0.45 0.25 0.00            .% OF MAX. PHOTO: SHADE FOLIAGE                Q3 T1
 0.020                                                      SHADING BY OBSERVED MAXIMUM FOLIAGE (.% FULL LIGHT)  Q3 T1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00      SHAPE OF FOL.BIO.SHADING: .% OF MAX.FOLIAGE  *DNC*   Q3 T1
0.00 0.18 0.34 0.48 0.60 0.70 0.79 0.87 0.93 0.97 1.00                                .% OF MAX.SHADING          Q3 T1
 0.20   .50                                          .% OF PHOTO. COMPETITION LEAFLESS    STUNTED HEIGHT CONTROL Q3 T1
 1.00   .50                                          .% OF PHOTO. COMPETITION LEAFLESS    STUNTED HEIGHT CONTROL Q3 T1
1.00                                                        .% OF SOIL VOLUME OCCUPIED AT MAX. SMALL ROOT BIO.   Q3 T1
1.00  1.00  1.00  0.00  0.00                                .% EFFICIENCY OF NUTRIENT CAPTURE FOR EACH NUTRIENT  Q3 T1
**  DATA DEFINING THE PROPORTION OF TREES IN UP TO TEN STEM BIOMASS CLASSES FOR UP TO 10 STAND AGES               Q3 T1
   6                                                        # OF STAND AGES (UP TO 10) FOR WHICH DATA ARE GIVEN  Q3 T1
AGE  3.     0.30   0.35   0.40   0.45   0.50   0.55   0.60   0.65   0.70   0.75   0.80  STEM BIOMASS CLASSES      Q3 T1
             .01    .01    .05    .15    .20    .30    .20    .05    .01    .01      .% OF STEMS IN EACH CLASS Q3 T1
AGE  6.     2.50   3.00   3.50   4.00   4.50   5.00   5.50   6.00   6.50   7.00   7.50  STEM BIOMASS CLASSES      Q3 T1
             .02    .02    .05    .20    .20    .30    .10    .05    .02    .01      .% OF STEMS IN EACH CLASS Q3 T1
AGE  11.     6.0   10.0   14.0   18.0   22.0   26.0   30.0   34.0   38.0   42.0   44.0  STEM BIOMASS CLASSES      Q3 T1
             .02    .02    .05    .15    .20    .20    .20    .10    .05    .02      .% OF STEMS IN EACH CLASS Q3 T1
AGE  19.    60.0   70.0   80.0   90.0  100.0  110.0  120.0  130.0  140.0  150.0  160.0  STEM BIOMASS CLASSES      Q3 T1
             .02    .05    .15    .20    .20    .20    .10    .05    .02    .01      .% OF STEMS IN EACH CLASS Q3 T1
AGE  48.   500.0  525.0  550.0  575.0  600.0  625.0  650.0  675.0  700.0  725.0  750.0  STEM BIOMASS CLASSES      Q3 T1
             .02    .05    .10    .15    .25    .25    .10    .05    .02    .02      .% OF STEMS IN EACH CLASS Q3 T1
AGE  73.   550.0  600.0  700.   800.   900.  1000.  1100.  1200.  1300.  1400.  1500.  STEM BIOMASS CLASSES      Q3 T1
             .02    .02    .05    .25    .25    .10    .10    .10    .05    .01      .% OF STEMS IN EACH CLASS Q3 T1
   3                                                        # OF STAND AGES (UP TO 10) FOR WHICH DATA ARE GIVEN  Q3 T1
AGE  23.    15.0   38.0   70.7  149.8  134.3  240.6    .      .      .      .      .    STEM BIOMASS CLASSES      Q1 T1
             .22    .45    .25    .05    .03    .      .      .      .      .        .% OF STEMS IN EACH CLASS Q1 T1
AGE  33.    35.6   78.0  105.7  199.8  244.3  395.6  494.7    .      .      .      .    STEM BIOMASS CLASSES      Q1 T1
             .13    .40    .30    .12    .04    .02    .      .      .      .        .% OF STEMS IN EACH CLASS Q1 T1
AGE  39.    35.6   78.0  105.7  199.8  244.3  395.6  494.7  652.7    .      .      .    STEM BIOMASS CLASSES      Q1 T1
             .07    .36    .25    .15    .07    .05    .04    .      .      .        .% OF STEMS IN EACH CLASS Q1 T1
**  DATA DEFINING THE CONCENTRATIONS OF UP TO 5 NUTRIENTS IN TREE BIOMASS COMPONENTS                              Q3 T1
.002000  .000200  .001200  .000000  .000000     STEM SAPWOOD                  .% NUTRIENT CONCENTRATIONS          Q3 T1
.000800  .000080  .000300  .000000  .000000     STEM HEARTWOOD                                                    Q3 T1
.005500  .000850  .003000  .000000  .000000     LIVE BARK (PHLOEM)                                                Q3 T1
.003500  .000650  .003500  .000000  .000000     DEAD BARK                                                         Q3 T1
.005000  .000500  .003000  .000000  .000000     LIVE BRANCHES                                                     Q3 T1
.003500  .000350  .003000  .000000  .000000     DEAD BRANCHES                                                     Q3 T1
.015000  .003200  .011500  .000000  .000000     YOUNG FOLIAGE (DEFINED BELOW)                                     Q3 T1
.013000  .002500  .009000  .000000  .000000     OLD FOLIAGE (DEFINED BELOW)                                       Q3 T1
.011000  .001500  .007000  .000000  .000000     DEAD FOLIAGE (LITTERFALL)                                         Q3 T1
.002000  .000120  .000700  .000000  .000000     LARGE ROOT SAPWOOD                                                Q3 T1
.000800  .000080  .000500  .000000  .000000     LARGE ROOT HEARTWOOD                                              Q3 T1
.003000  .000300  .002000  .000000  .000000     MEDIUM ROOT SAPWOOD                                               Q3 T1
.000800  .000080  .000400  .000000  .000000     MEDIUM ROOT HEARTWOOD                                             Q3 T1
.005000  .000500  .002500  .000000  .000000     LIVE SMALL AND FINE ROOTS (<5 CM)                                 Q3 T1
.003000  .000300  .002000  .000000  .000000     DEAD SMALL AND FINE ROOTS                                         Q3 T1
.018000  .004000  .010000  .000000  .000000     FRUIT                                                             Q3 T1
.001700  .000200  .001200  .000000  .000000     STEM SAPWOOD                  .% NUTRIENT CONCENTRATIONS          Q3 T1
.000800  .000080  .000300  .000000  .000000     STEM HEARTWOOD                                                    Q3 T1
.005500  .000850  .003000  .000000  .000000     LIVE BARK (PHLOEM)                                                Q3 T1
.003500  .000650  .003500  .000000  .000000     DEAD BARK                                                         Q3 T1
.005000  .000500  .003000  .000000  .000000     LIVE BRANCHES                                                     Q3 T1
.002800  .000350  .003000  .000000  .000000     DEAD BRANCHES                                                     Q3 T1
.014000  .003200  .011500  .000000  .000000     YOUNG FOLIAGE (DEFINED BELOW)                                     Q3 T1
.012000  .002500  .009000  .000000  .000000     OLD FOLIAGE (DEFINED BELOW)                                       Q3 T1
.008000  .001500  .007000  .000000  .000000     DEAD FOLIAGE (LITTERFALL)                                         Q3 T1
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.002000  .000120  .000700  .000000  .000000     LARGE ROOT SAPWOOD                                                        Q3 T1
.000800  .000080  .000500  .000000  .000000     LARGE ROOT HEARTWOOD                                                      Q3 T1
.003000  .000300  .002000  .000000  .000000     MEDIUM ROOT SAPWOOD                                                       Q3 T1
.000800  .000080  .000400  .000000  .000000     MEDIUM ROOT HEARTWOOD                                                     Q3 T1
.005000  .000500  .002500  .000000  .000000     LIVE SMALL AND FINE ROOTS (<5 CM)                                         Q3 T1
.003000  .000300  .002000  .000000  .000000     DEAD SMALL AND FINE ROOTS                                                 Q3 T1
.007000  .004000  .010000  .000000  .000000     FRUIT                                                                     Q3 T1
**  DATA DEFINING ATMOSPHERIC INPUTS, FOLIAGE LEACHING AND SYMBIOTIC FIXATION OF UP TO 5 NUTRIENTS                        Q3 T1
 2.00  0.30  1.00  0.00  0.00           ATMOSPHERIC INPUTS: DUST AND PRECIPITATION (KG/HA)                                Q3 T1
 6.00  4.00 18.00  0.00  0.00           THROUGHFALL CONTENT (KG/HA)                                                       Q3 T1
14.00 14.00 14.00  0.00  0.00           FOLIAGE BIOMASS ASSOCIATED WITH THROUGHFALL DATA (T/HA)                           Q3 T1
.0000 .0000 .0000 .0000 .0000           SYMBIOTIC FIXATION (KG NUTRIENT FIXED PER KG FOLIAGE)                             Q3 T1
**  DATA DEFINING TRANSFER OF BIOMASS FROM LIVE TO DEAD COMPONENTS, AND TO LITTERFALL                                     Q3 T1
0.100 0.120 0.100 0.100 0.100          .% OF LIVE STEMWOOD, BARK, BRANCHES, LARGE AND MEDIUM ROOTS TO DIE                 Q3 T1
0.030 0.001 0.020 1.400 1.000          .% OF DEAD BARK, LRG, MED & SML ROOTS AND FRUIT TO LITTERFALL                      Q3 T1
   20   2.0   3.0                       RETENTION (# TIME STEPS) OF DEAD BRANCHES, YOUNG AND OLD FOLIAGE                  Q3 T1
   20   2.0   2.0                       RETENTION (# TIME STEPS) OF DEAD BRANCHES, YOUNG AND OLD FOLIAGE                  Q3 T1
 .050  .000  .000  .050  .000 -.150    .% WT CHANGE AT DEATH OF LIVE: STEM, BARK, BRANCHES, LRG, MED & SML ROOT Q3 T1
 .100 -.150                            .% WT CHANGE WITH FOLIAGE AGING AND DEATH                                          Q3 T1
CHECK OK                                                                                                                  Q3 T1
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Appendix part m.

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******************   PLNTDATA:   INPUT DATA FILE FOR THE PLNTGROW-11.40A PROGRAM OF FORCYTE-11 *******************
                                                                                                              :
*********** FILE LABEL AND CONTENT STATEMENT                                                         00000    :
PRELIMINARY DATA SET FOR PROGRAM TESTING                    DATA FILE IDENTIFICATION                 00 00    :
FORCYTE-11  DEMONSTRATION PROJECT                           PROJECT NAME                             00000    :
J.P. KIMMINS AND K.A. SCOULLAR                              USERS NAME(S)                            00       :
Shawnigan Lake March 8, 1990                                DATA FILE IDENTIFICATION                 00 00    :
FORCYTE-11  Shawnigan Lake PROJECT                          PROJECT NAME                             00000    :
D. Sachs                                                    USERS NAME(S)                            00       :
SOUTHERN VANCOUVER ISLAND, BRITISH COLUMBIA                 LOCATION OF DATA SITE(S)                 00       :
COASTAL WESTERN HEMLOCK ZONE, DRY SUBZONE                   ECOLOGICAL ZONE OF DATA SITE(S)                   :
                                                                                                              :
  2                                                         NUMBER OF PLANT SPECIES                           :
FIRE WEED                                                   NAME OF PLANT #1                                  P1
  5    1                                                    # OF TIME STEPS, GROWTH FORM (1=HERB OR SHRUB 2=BAMBOO) P1
SALMONBERRY                                                 NAME OF PLANT #1                                  P2
Salal                                                       NAME OF PLANT #1                                  P2
 10    1                                                    # OF TIME STEPS, GROWTH FORM (1=HERB OR SHRUB 2=BAMBOO) P2
                                                                                                              :
                                                                                                              P2
P2P2P2P2P2P2P2   DATA FOR PLANT #2   P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2P2  PLANT #2   P2P2P2P2P2P2P2P2P2
  1                                                         NUMBER OF DATA SITES                              P2
  1      2      3      4      5      6      7      8      9     10 AGES FOR SAVING DATA                       P2
 12     14     16     18     20     25     30     35     40     50                                            P2
                                                                                                           Q1 P2
Q1Q1Q1Q1Q1Q1Q1   DATA FOR PLANT #2 ON SITE #1  Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1Q1  DATA SITE #1  Q1Q1Q1Q1Q1Q1 P2
 50.00                                                      SITE QUALITY: EDAPHIC GRID NUTRIENT AXIS VALUE      Q1 P2
 25.00                                                      SITE QUALITY: EDAPHIC GRID NUTRIENT AXIS VALUE      Q1 P2
******  1.  DATA DEFINING THE GROWTH OF PLANTS FROM SEED (1) OR FROM SPROUTING (2)   1              ****** Q1 P2
****    1.1.  DATA PAIRS DEFINING BIOMASS ACCUMULATION                                                **** Q1 P2
 10                                                         STEM BIOMASS ACCUMULATION: # OF DATA PAIRS      Q1 P2
    1.        2.        3.        4.        5.        6.       7.       8.       9.       10.     PLANT AGE        Q1 P2
 1000.00   2200.00   4000.00   6500.00   8000.00   9000.    9500.    9800.    9900.   10000.00   BIOMASS (KG/HA)  Q1 P2
    1.        2.        3.        4.        5.        6.       8.      20.      25.       41.     PLANT AGE        Q1 P2
  200.00    462.00    633.00   1000.00   1200.00   1500.    1600.    1500.    1400.    1100.00   BIOMASS (KG/HA)  Q1 P2
 10                                                         FOLIAGE BIOMASS ACCUMULATION: # OF DATA PAIRS   Q1 P2
    1.        2.        3.        4.        5.        6.       7.       8.       9.       10.     PLANT AGE        Q1 P2
  100.00    500.00   1000.00   1200.00   1300.00   1400.    1500.    1500.    1500.    1500.     BIOMASS (KG/HA)  Q1 P2
    1.        2.        3.        4.        5.        6.       8.      20.      25.       41.     PLANT AGE        Q1 P2
  300.00    596.00    750.00   1200.00   1400.00   1500.    1500.    1300.    1000.     820.     BIOMASS (KG/HA)  Q1 P2
 1800.00                                                                FOLIAGE BIOMASS SITE MAX. (KG/HA)  Q1 P2
 10                                                         RHIZOME BIOMASS ACCUMULATION: # OF DATA PAIRS   Q1 P2
    1.        2.        3.        4.        5.        6.       7.       8.       9.       10.     PLANT AGE        Q1 P2
 1000.00   2200.00   4000.00   6500.00   8000.00   9000.    9500.    9800.    9900.   10000.     BIOMASS (KG/HA)  Q1 P2
    1.        2.        3.        4.        5.        6.       8.      20.      25.       41.     PLANT AGE        Q1 P2
  300.00    600.00   1300.00   1500.00   1500.00   2800.    2900.    2700.    2700.    2600.     BIOMASS (KG/HA)  Q1 P2
 10                                                         ROOT BIOMASS ACCUMULATION: # OF DATA PAIRS      Q1 P2
    1.        2.        3.        4.        5.        6.       7.       8.       9.       10.     PLANT AGE        Q1 P2
  100.00    500.00   1000.00   1200.00   1300.00   1400.    1500.    1500.    1500.    1500.     BIOMASS (KG/HA)  Q1 P2
    1.        2.        3.        4.        5.        6.       8.      20.      25.       41.     PLANT AGE        Q1 P2
  800.00   2200.00   2200.00   2800.00   2800.00   2900.    2900.    2200.    1800.    1600.     BIOMASS (KG/HA)  Q1 P2
 10                                                         FRUIT BIOMASS ACCUMULATION: # OF DATA PAIRS     Q1 P2
    1.        2.        3.        4.        5.        6.       7.       8.       9.       10.     PLANT AGE        Q1 P2
    0.00      0.00      1.00      2.50      5.00      8.00    11.00    15.00    18.00    20.00     BIOMASS (KG/HA)  Q1 P2
    1.        2.        3.        4.        5.        6.       8.      15.      25.       36.     PLANT AGE        Q1 P2
    0.00      0.00      1.00      2.50      5.00      8.00    15.00    15.00    15.00    10.00     BIOMASS (KG/HA)  Q1 P2
****    1.2.  DATA DEFINING HEIGHT GROWTH                                                             **** Q1 P2
  5                                                         PLANT CANOPY HEIGHT DATA: # DATA AGES           Q1 P2
  1.    2.    3.    4.    5.    6.    7.    8.    9.   10.      PLANT AGE                                   Q1 P2
 0.20  0.60  1.50  2.5   2.8   3.0   3.0   3.0   3.0   3.0      AVERAGE TOP HEIGHT OF PLANTS (M)            Q1 P2
 0.00  0.20  0.50  0.80  1.00  1.0   1.0   1.0   1.0   1.0      AVERAGE HEIGHT OF CANOPY BOTTOM (M)          Q1 P2
 10                                                         PLANT CANOPY HEIGHT DATA: # DATA AGES           Q1 P2
  1.    2.    3.    4.    5.    6.    7.   19.   40.   60.      PLANT AGE                                   Q1 P2
 0.10  0.15  0.20  0.30  0.35  0.55  0.8   1.2   1.5   1.5      AVERAGE TOP HEIGHT OF PLANTS (M)            Q1 P2
 0.00  0.10  0.10  0.20  0.25  0.3   0.3   0.4   0.4   0.4      AVERAGE HEIGHT OF CANOPY BOTTOM (M)          Q1 P2
****    1.3.  DATA DEFINING PHOTOSYNTHESIS AND SOIL OCCUPATION BY ROOTS                              **** Q1 P2
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00    PHOTO LIGHT SATURATION CURVE: .% FULL LIGHT *DNC*  Q1 P2
0.00 0.00 0.00 0.10 0.20 0.30 0.60 0.70 0.80 0.96 1.00        .% OF MAX. PHOTO: SUN FOLIAGE                  Q1 P2
0.00 0.20 0.32 0.20 0.30 0.45 0.70 0.90 0.95 0.80 0.50        .% OF MAX. PHOTO: SHADE FOLIAGE                Q1 P2
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 0.020                                                             SHADING BY OBSERVED MAXIMUM FOLIAGE (.% FULL LIGHT)  Q1 P2
0.00 0.20 0.25 0.30 0.40 0.60 0.85 0.60 0.50 0.40 0.20              .% OF MAX. PHOTO: SHADE FOLIAGE                     Q1 P2
 0.300                                                             SHADING BY OBSERVED MAXIMUM FOLIAGE (.% FULL LIGHT)  Q1 P2
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00            SHAPE OF FOL.BIO.SHADING: .% OF MAX.FOLIAGE  *DNC*   Q1 P2
0.00 0.18 0.34 0.48 0.60 0.70 0.79 0.87 0.93 0.97 1.00                                      .% OF MAX.SHADING           Q1 P2
 0.00   .50                                               .% OF PHOTO. COMPETITION LEAFLESS    STUNTED HEIGHT CONTROL   Q1 P2
 1.00   .60                                               .% OF PHOTO. COMPETITION LEAFLESS    STUNTED HEIGHT CONTROL   Q1 P2
1.00                                                               .% OF SOIL VOLUME OCCUPIED AT MAX. SMALL ROOT BIO.   Q1 P2
1.00  1.00  1.00  0.00  0.00                                       .% EFFICIENCY OF NUTRIENT CAPTURE FOR EACH NUTRIENT  Q1 P2
****    1.4.  DATA DEFINING THE CONCENTRATIONS OF UP TO 5 NUTRIENTS IN PLANT BIOMASS COMPONENTS                    **** Q1 P2
.017000  .001700  .017000  .000000  .000000     LIVE STEM                          .% NUTRIENT CONCENTRATIONS           Q1 P2
.005000  .000500  .005000  .000000  .000000     DEAD STEM                                                               Q1 P2
.035000  .004900  .030000  .000000  .000000     LIVE FOLIAGE                                                            Q1 P2
.029000  .002900  .029000  .000000  .000000     DEAD FOLIAGE                                                            Q1 P2
.015000  .005000  .015000  .000000  .000000     LIVE RHIZOME                                                            Q1 P2
.013000  .003000  .013000  .000000  .000000     DEAD RHIZOME                                                            Q1 P2
.001000  .003600  .010000  .000000  .000000     LIVE ROOTS                                                              Q1 P2
.000800  .002000  .008000  .000000  .000000     DEAD ROOTS                                                              Q1 P2
.050000  .010000  .050000  .000000  .000000     FRUIT                                                                   Q1 P2
.002000  .001700  .017000  .000000  .000000     LIVE STEM                          .% NUTRIENT CONCENTRATIONS           Q1 P2
.001200  .000500  .005000  .000000  .000000     DEAD STEM                                                               Q1 P2
.006000  .004800  .030000  .000000  .000000     LIVE FOLIAGE                                                            Q1 P2
.004000  .002800  .029000  .000000  .000000     DEAD FOLIAGE                                                            Q1 P2
.002000  .005000  .015000  .000000  .000000     LIVE RHIZOME                                                            Q1 P2
.001000  .003000  .013000  .000000  .000000     DEAD RHIZOME                                                            Q1 P2
.006000  .003600  .010000  .000000  .000000     LIVE ROOTS                                                              Q1 P2
.002000  .002000  .008000  .000000  .000000     DEAD ROOTS                                                              Q1 P2
.009000  .010000  .050000  .000000  .000000     FRUIT                                                                   Q1 P2
****    1.5.  DATA DEFINING ATMOSPHERIC INPUTS, FOLIAGE LEACHING AND SYMBIOTIC FIXATION                            **** Q1 P2
 2.00  2.00  2.00  0.00  0.00            ATMOSPHERIC INPUTS: DUST AND PRECIPITATION (KG/HA)                             Q1 P2
 4.00  3.00  3.00  0.00  0.00            THROUGHFALL CONTENT (KG/HA)                                                    Q1 P2
 2400.00                                 FOLIAGE BIOMASS ASSOCIATED WITH THROUGHFALL DATA (KG/HA)                       Q1 P2
 2.00  3.00  3.00  0.00  0.00            THROUGHFALL CONTENT (KG/HA)                                                    Q1 P2
 1800.00                                 FOLIAGE BIOMASS ASSOCIATED WITH THROUGHFALL DATA (KG/HA)                       Q1 P2
.0010 .0000 .0000 .0000 .0000            SYMBIOTIC FIXATION (KG NUTRIENT FIXED PER KG FOLIAGE)                          Q1 P2
.0000 .0000 .0000 .0000 .0000            SYMBIOTIC FIXATION (KG NUTRIENT FIXED PER KG FOLIAGE)                          Q1 P2
****    1.6.  DATA DEFINING TRANSFER OF BIOMASS FROM LIVE TO DEAD COMPONENTS, AND TO LITTERFALL                    **** Q1 P2
0.200 0.200 0.800 1.000                 .% OF LIVE STEM, RHIZOMES, ROOTS AND FRUIT TO LITTERFALL                        Q1 P2
 1.0                                    RETENTION (# TIME STEPS) OF FOLIAGE                                             Q1 P2
 .050  .050  .050  .050                 .% WT CHANGE AT DEATH OF LIVE: STEM, FOLIAGE, RHIZOME AND ROOT                  Q1 P2
******  2.  DATA DEFINING FIRST TIME STEP PROPAGATION                                                            ****** Q1 P2
****    2.1.  DATA DEFINING PROPAGATION FROM SEED                                                                  **** Q1 P2
**      2.1.1.  DATA DEFINING BIOMASS OF THE PLANTS AFTER FIRST TIME STEP GROWTH FROM SEED                           ** Q1 P2
 1000.00   100.00  1000.00   100.00     0.00     STEM   FOLIAGE   RHIZOME   ROOT   FRUIT   (KG/HA)                      Q1 P2
****    2.2.  DATA DEFINING PROPAGATION BY STUMP SPROUTING, ROOT SUCKERS, OR FROM RHIZOMES                         **** Q1 P2
**      2.2.1.  DATA DEFINING THE EXISTING MASS AFTER CUTTING BUT BEFORE MORTALITY OR SPROUTING                      ** Q1 P2
   20.00     0.00 10000.00  1500.00     0.00     STEM   FOLIAGE   RHIZOME   ROOT   FRUIT   (KG/HA)                      Q1 P2
**      2.2.2.  DATA DEFINING BIOMASS OF THE PLANTS AFTER FIRST TIME STEP GROWTH FROM SPROUTING                      ** Q1 P2
 2000.00   400.00  3000.00   500.00     2.00     STEM   FOLIAGE   RHIZOME   ROOT   FRUIT   (KG/HA)                      Q1 P2
  200.00   300.00  1000.00   200.00     2.00     STEM   FOLIAGE   RHIZOME   ROOT   FRUIT   (KG/HA)                      Q1 P2
0.050                                            LOSS OF VIGOUR AT EACH SUCCESIVE CUT  (.%)                             Q1 P2
**      2.2.3.  DATA DEFINING RHIZOME AND ROOT MORTALITY AFTER CUTTING                                               ** Q1 P2
 .100   .300                                     RHIZOME AND ROOT MORTALITY AFTER CUTTING  (.%)                         Q1 P2
CHECK OK                                                                                                                Q1 P2
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