EARLY HEIGHT GROWTH AND REGENERATION: APPLICABILITY OF PROGNOSIS COMPONENTS TO THE SOUTHERN INTERIOR OF BRITISH COLUMBIA

By

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Abstract

Predicting stand structure through time is a challenge in all aspects of forest management. Predictions in multi-cohort, mixed species, or spatially varied stands have mostly been based on field experience and have not been clearly quantified. The main hypothesis of this thesis is that the regeneration and small tree height growth components of the Northern Idaho variant of the growth and yield model Prognosis, can be calibrated for use in the stands of the southern interior of BC.

The original equation forms of Prognosis NI were applied to data collected in stands of the Columbia - Shuswap moist warm Interior Cedar - Hemlock variant of the Interior Cedar Hemlock moist warm subzone (ICHmw2 of the Biogeoclimatic Ecosystem Classification system of BC) in the vicinity of Nelson, BC. The same forms were then re-fitted with the Nelson data, and finally, other model forms were applied to Nelson data. In all cases, the original fitted equations in Prognosis NI were outperformed by either the refitted equations or equations with Nelson-based variables.

The equations presented in this thesis are a valid start to the calibration of regeneration and small tree height growth models Prognosis^{BC}. Some issues need to be addressed for model improvements. Prognosis NI was not developed in BC and it uses a different ecosystem classification. Although correspondences have been made between BC site series and Idaho habitat types, the two systems are different, and so are the sites. These differences contribute to errors in model predictions. The data set used for developing Prognosis NI was much larger than the data collected around Nelson. Some data categories used in the Prognosis model had more predictor variables than the number of observations in the corresponding data category in the Nelson data set. This lack of data resulted in non-robust models.

Despite these issues, the equations resulting from this calibration process improve the estimates of small tree height growth and regeneration in multi-cohort or mixed species stands in the southern interior of BC. Prior to the calibration efforts of Prognosis^{BC}, no quantitative tools were in place to aid silviculturists for predictions in these stands. Although these predictions are not completely accurate, they can serve as guidelines, to supplement field experience, for making predictions.

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Chapter 1: Introduction

Smith (1992) refers to predictions of stand responses in terms of structure and composition as an integral part of silviculture. He states that silviculture is based on a working understanding of how the forest got established and how it grows through its rotation; it is based on our ability to create constructive disturbances from which we can predict the outcome. Understanding stand dynamics is, therefore, necessary for effective manipulation of stand structure. Predicting the outcome of stand growth, with or without manipulation, is a challenge even in the most homogeneous forest stand. Tools have been developed for predicting management outcomes, but have mostly limited to even-aged monospecific stand types. Even the classic reversed J-shape curve (negative exponential) used to describe growth in uneven-aged stands can be viewed as the sum of a series of small, pure, single-canopied stands representing a series of evenly spaced age classes, each occupying an equal area. A perfect reversed J-shaped diameter distribution can also result from even-aged stratified mixed stands (Smith 1992).

The complexity of forest ecosystems and the need for bookkeeping may justify this narrowed approach to management; however, the dynamics of multi-cohort and/or mixed species stands needs to be quantified in order to generate effective growth and yield tools. The province of British Columbia (BC) has adopted the United States (U.S.) northern Idaho version of the growth and yield model Prognosis (Prognosis NI, Stage 1973) as a growth and yield tool for multi-cohort and/or mixed species stands in the southern interior of BC. Prognosis is a distance-independent growth and yield model; it grows stands based on the interaction among trees. The individual tree is the basic unit of projection and most combinations of species and age classes can be accommodated within the model architecture.

Efforts are presently underway to calibrate the Idaho version of Prognosis NI for the southern interior of BC ($Prognosis^{BC}$). The research described in this thesis is limited to the west Kootenays, around the city of Nelson. The Nelson region and the northern part of Idaho have similar species and stand structures. Stands of the Kootenays are among the most complex mix of species in BC (Braumandal and Curran 1992). In the West Kootenays, even-aged monospecific stands are practically nonexistent. Stands commonly have four to six commercial tree species, and may have up to 13 tree species in total. Growth and stand dynamics are further compounded by a variety of disturbance agents. Hence, in these highly productive ecosystems, our understanding of stand dynamics and our predictive abilities are very limited.

The main objective of this thesis was to calibrate the basic equations of the early height growth and regeneration component of Prognosis NI for managed stands in the Columbia-Shuswap moist warm Interior Cedar Hemlock variant of the Interior Cedar Hemlock, moist warm subzone (ICHmw2, Braumandal and Curran 1992), in the vicinity of Nelson, BC. These equations are for use in the Southern Interior version of Prognosis^{BC}. The hypothesis is that the early height growth and regeneration components of Prognosis NI can be calibrated for the southern interior of BC. Each component was tested in its original form for applicability to Nelson sites. The same form was then re-fit to the data collected on Nelson sites and finally, other model forms were applied. The specific objectives were the following:

1) to calibrate the basic equations of the regeneration component of Prognosis NI for ICHmw2 managed stands in the vicinity of Nelson;
2) to calibrate the basic equations for the early height growth component of PrognosisNI for ICHmw2 managed stands in the vicinity of Nelson; and
3) to improve the understanding of stand dynamics in early development stages for these stands.

Prognosis equations that will be dealt with in this project apply to early height growth and regeneration only. Chapter 2 gives background information on stand dynamics of targeted sites, their regeneration, and early height growth, and describes Prognosis NI. Methods for the 1998 data collection phase, and a compendium of analytical methods are provided in Chapter 3. Data summaries, and results for each individual equation are included in Chapter 4. Chapter 5 contains a discussion on the calibration of these equations and how they relate to management of these stands. Finally, conclusions are presented in Chapter 6.

Chapter 2: Background

2.1 ICHmw2 Stands Around Nelson

The Interior Cedar Hemlock (ICH) biogeoclimatic zone around Nelson is dominated by fire-origin stands. Fires were both of natural origin and of human origin resulting from mining activities at the turn of the century. Deposits leading to the present soils are fluvial at the valley bottoms, glacial-fluvial in low to mid-slope positions, and mainly colluvial on mid to high slope positions, with occasional morainal deposits. Mixing of the organic material through pedogenesis processes have created rich soils, especially on lower slopes and valley bottoms. The ICHmw2 occurs on these rich soils. Figure 2.1 illustrates the distribution of ICH in the West Kootenays. ICHmw2 sits at 1200m to 1450m elevation above the Interior Cedar Hemlock dry warm subzone (ICHdw) in the southern reaches of Kootenay Lake and Arrow Forest Districts where ICHdw occurs; it replaces ICHdw with increasing latitude, starting as low as 500 m where ICHdw does not occur (Braumandl and Curran 1992).

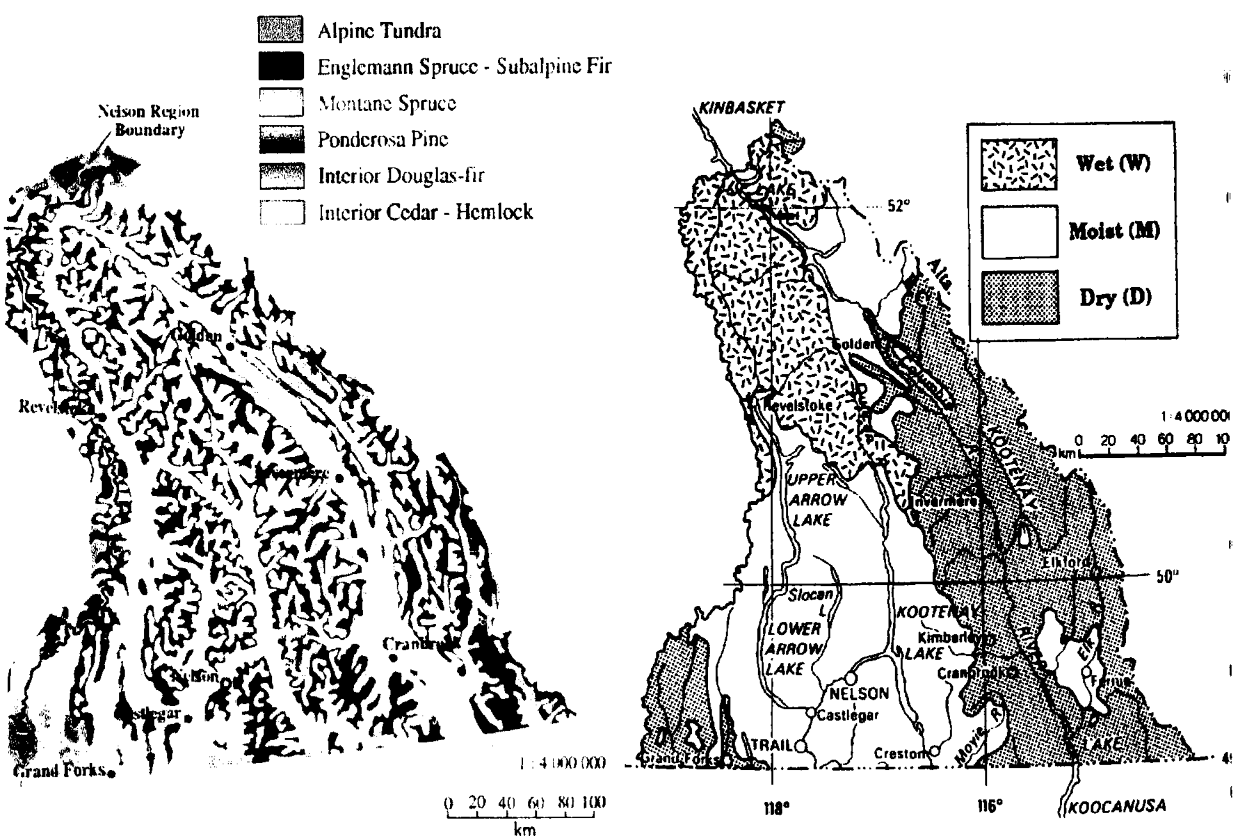


Figure 2.1 Biogeoclimatic zones of the Nelson Forest Region (Braumandl and Curran 1992).

The type of naturally occurring disturbance associated with these sites is believed to be wildfires of moderate size (20 to 1000 ha), with a mean return interval of 200 years (Ministry of Environment of BC 1995a). These fires follow topographic and fuel distributions, forming finger-like patterns usually running up ridges, leaving trees in wetter gullies standing or partly standing, and islands of standing timber behind sheltering terrain features, in high moisture zones, or randomly (Ministry of Environment of BC 1995a). Veteran fire-adapted tree species often survive fires, and are found singly or in groups throughout the landscape.

Tree species in the ICHmw2 include (Braumandl and Curran 1992):

- grand fir (Bg[1] - *Abies grandis* (Dougl.) Lindl.)
- subalpine fir (Bl - *Abies lasiocarpa* (Hook.) Nutt.)
- western redcedar (Cw - *Thuja plicata* Donn),
- Douglas-fir (Fd - *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco),
- western hemlock (Hw - *Tsuga heterophylla* (Raf.) Sarg.),
- western larch (Lw - *Larix occidentalis* Nutt.),
- lodgepole pine (Pl - *Pinus contorta* Dougl. var. *latifolia*)
- western white pine (Pw - *Pinus monticola* Dougl.),
- hybrid spruce (Sx - *Picea engelmannii* Parry x *glauca* (Moench) Voss),
- paper birch (Ep - *Betula papyrifera* Marsh.),
- trembling aspen (At - *Populus tremuloides* Michx.),
- black cottonwood (Act - *Populus balsamifera ssp. trichocarpa* Torr. & Gray)

This intricate mix of tree species is accompanied by an array of shrubs, herbaceous plants, mosses, lichens, and liverworts.

The number of species and the extent and intensity of fire alone provide many possible regeneration scenarios following fire; however, fire is not the only disturbance occurring in this subzone. Slides, avalanches, and windthrow are also common in the steep mountains of the Kootenays, as well as pest outbreaks. Pest outbreaks are increasingly apparent in the ICH. They are the most prominent disturbance in the BC and Canadian landscapes (Anonymous 1998, Voller and Harrison 1998). Pests occurring in the ICH target stands include:

[1] Tree species code follows the British Columbia Ministry of Forests, Inventory Branch standards.

- laminated root rot (*Phellinus weirii*)
- armillaria root rot (*Armillaria ostoyae*)
- tomentosus root rot (*Inonotus tomentosus*)
- white pine blister rust (*Cronartium ribicola*)
- mountain pine beetle (*Dendroctonus ponderosae*)
- spruce beetle (*Dendroctonus rufipennis*)
- dwarf mistletoe (*Aceuthobium americanum*)
- dwarf larch mistletoe (*Arceuthobium laricis*)
- spruce leader weevil (*Pissodes terminalis*)
- Cooley spruce gall adelgid (*Aldeges cooleyi*)
- hemlock sawfly (*Neodiprion tsugae*)
- Douglas-fir beetle (*Dendroctonus pseudotsugae*)
- Indian paint fungus (*Echinidintium tinctorium*)

Figure 2.2 is a visualization of tree species-disturbance interactions in the ICHmw2. This figure is based on an adaptation of Oliver and Larson's (1996) stand development stages and a working knowledge of these stands. Disturbances illustrated in Figure 2.2 can occur at any stand development stage and are not restricted to their position in this diagram. While identifying the disturbance agents is generally not difficult, disturbance regimes (intensity and frequency) vary according to regional climate and biophysical conditions (Bergeron and Harvey 1997); they are not distinct categories, and hence, are difficult to identify. Only extremes of the range of size and intensity of fires (small low intensity fire versus large intense fire) are traced in Figure 2.2 with their corresponding tree-species pathways. The array of possible tree-species regenerating and surviving post disturbances vary with the intensity and size of disturbance.

Stand development stages are continuous; they are not discrete categories and are often hard to determine (Oliver and Larson 1996). Throughout stand development, a disturbance can bring a stand back to the initiation stage (Oliver and Larson 1996). Stands go through changes at different temporal rates and can be maintained in specific states by disturbance or growth factors for varying time periods. Age does not necessarily define the development stage of a stand (Oliver and Larson 1996), as each species has its own growth rate, varying by the site and structure under which the individual tree has developed. Various stages of development can be observed in stands in the Kootenays. Post-fire compositional variation in regeneration is not only confounded by other disturbances, but also overlaid by fire suppression and human interventions.

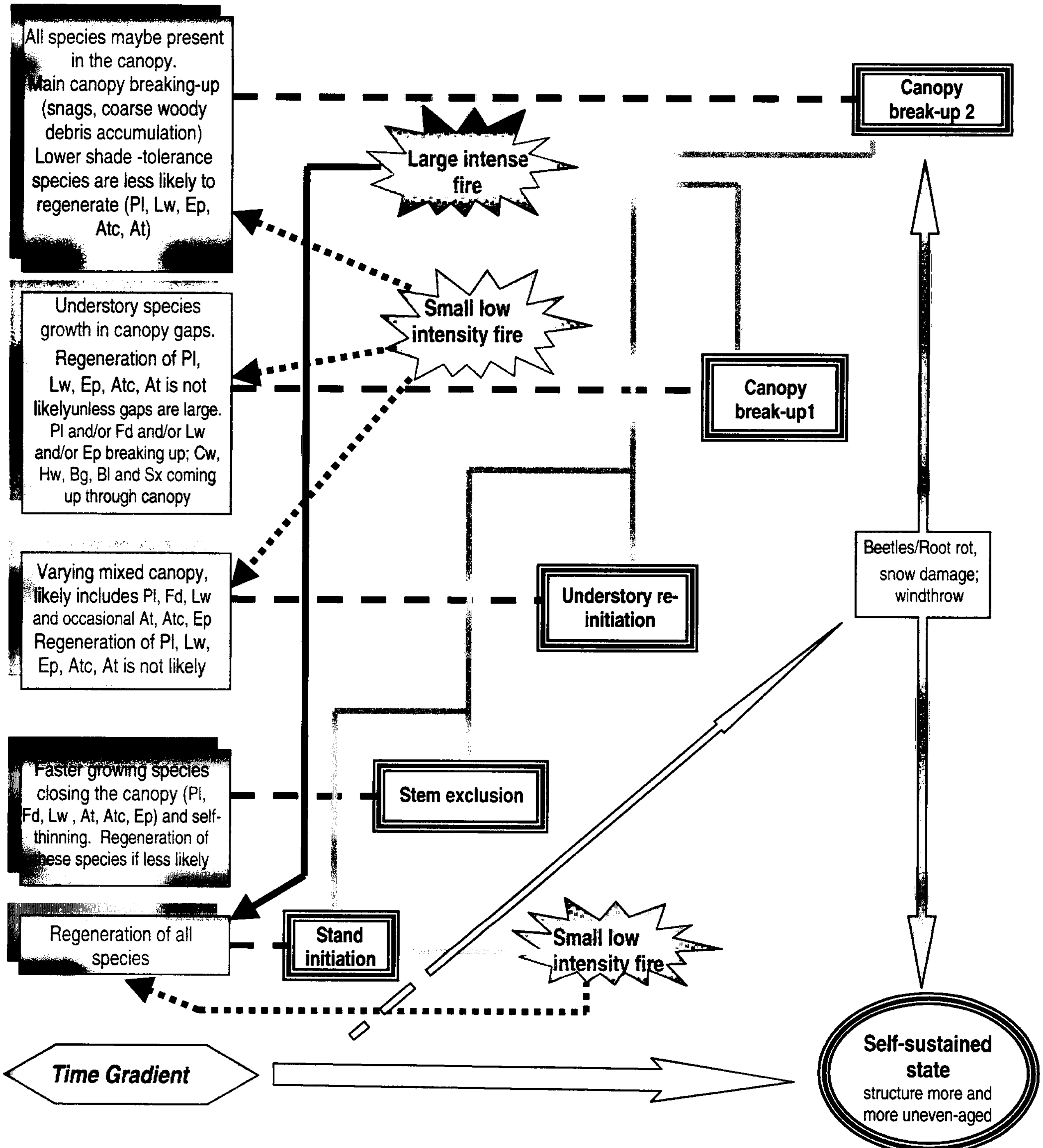


Figure 2.2 Species-disturbance interactions on ICHmw2 sites, adapted to Oliver and Larson's (1996) development stages.

2.2 Regeneration

Trees can regenerate by sexual and asexual methods. Establishment of tree species is a function of the presence and distance of seed source, microsite conditions and adequate seedbed, species shade tolerance, presence of competing tree or vegetation, and can also be a function of physiological adaptations to disturbance (e.g., logdepole pine fire adaptation).

Regeneration is not static. In monospecific, homogeneous stands, most regeneration is thought to occur concentrated in a post-disturbance period. However, in multi-cohort and/or mixed species stands, regeneration is apt to occur at any time through stand development. Results from a study in the forests of the American intermountain west showed stocking by natural regeneration to be a gradual accumulation process in spruce-fir forests (McCaughey *et al.* 1991). Ishikawa and Ito (1989) studied the regeneration process in a mixed forest in central Hokkaido, Japan, and found that almost all species regenerated intermittently. Regeneration is a function of simultaneous favorable site conditions and presence of a seed source of a species suited to those conditions.

Where disturbance events primarily affect individuals or small groups in the main canopy, advanced regeneration can play a crucial role in determining the structure of the next stand. Kneeshaw and Bergeron (1996) found time since disturbance and parent trees to be highly correlated to the amount and type of regeneration in the boreal mixedwoods of Québec. The species composition of the canopy was an important factor, not only because of the presence of parent trees, but also because of its effect on seedbed characteristics. The same factors might play an important role in the ICH. The number of species and regeneration dynamics in smaller, less severe, disturbances create a mix of vegetation presently not quantified or even well understood.

Looking at the influences of topographic position and evergreen-shrub understory on seedling establishment in the Appalachians, Clinton *et al.* (1994) found seedling density to be significantly correlated with percent slope and with age of the gap they were establishing in. The number of species decreased over time and increased with gap size. Species establishment was a function of gap area, gap age, topographic position, and cover of competing vegetation. In addition, they found species of varying tolerance levels to be capable of establishing in small to medium sized canopy openings, in the absence of an evergreen-shrub understory. These results indicate that composition of tree and competing vegetation species can have an effect on establishment of lower shade tolerance trees in smaller openings.

Knowledge of species shade tolerance and germination requirements is crucial to determining regeneration. Shade-tolerance levels vary among the species in the ICHmw2. Larch, aspen, black cottonwood, and birch are very shade intolerant tree species, lodgepole pine, Douglas-fir, and white pine are intolerant; spruce and grand fir are tolerant and western hemlock, subalpine fir, and western redcedar are the most shade tolerant species (Daniel *et al.* 1979). Douglas-fir can have bivalent coastal/interior autoecology and may be more shade tolerant on certain aspects, slopes or site conditions (Minore 1979). Larch, lodgepole pine, and black cottonwood require exposed mineral soil or burnt forest floor for germination, while aspen and birch are more polyvalent in terms of their seedbed requirements (Klinka *et al.* 1998). Aspen commonly regenerates by root suckering, which is encouraged by soil disturbance. Like lodgepole pine and larch, spruce germination requires an exposed mineral seedbed or a burnt forest floor to regenerate; western redcedar and hemlock can regenerate on open forest floor (Klinka *et al.* 1998). Subalpine fir and grand fir regenerate on all substrates, while Douglas-fir and white pine regenerate better after wildfires (Klinka *et al.* 1998). Clearly, management manipulations, like site preparation, size of opening, and species left on site have a great influence on the amount and variety of species regenerating.

The main challenge to modelling regeneration is accounting for all influential factors. Most regeneration models predict the occurrence of new trees only in response to disturbance such as harvesting and site preparation (Monserud 1987). At a regional or forest level, such models may provide acceptable predictions and are valuable tools. Management of mixed species stands in the Kootenays and elsewhere has traditionally implied planting sites after clearcutting. However, these planted sites still do not conform to the general regeneration models; plantations are invaded by a considerable amount of natural regeneration, sometimes outcompeting planted stock. Therefore, regeneration scenarios from these models do not apply. The increasing use of silvicultural systems with partial cutting adds advanced regeneration and regeneration of tolerant species to the already uncertain predictions. A model that assumes regeneration occurring only as a result of a stand management treatment will produce biased predictions of future multi-cohort and/or mixed species stands (Monserud 1987).

In a study of the distribution of regeneration, Fröhlich and Quednan (1995) found no pronounced deviation from a random distribution when studying regeneration distribution in mixed mountain forest stands in Germany. They detected only small amounts of aggregation.

Favrichon's (1998) modelling efforts in tropical forests were based on a matrix model approach. He estimated density-dependence of ingrowth using non-linear regression. Models using a successional approach to modelling regeneration have also been developed. The successional approach uses ecological site factors and/or processes to predict regeneration (e.g., JABOWA (Botkin *et al.* 1972)). Kimmins (1993) uses a combination of both in his model FORCYTE-11 (FORest nutrient Cycling and Yield Trend Evaluator). FORCYTE-11, or the newer version FORECAST, is a deterministic model based on species characteristics, present vegetation, and site characteristics. These models were not driven by the need to provide accurate timber yields, and thus are not particularly useful in doing so.

Many growth models simply start with trees at 1.3 metres in height, or with 20-year-old stands, avoiding the issue of regeneration or small tree growth (e.g., STEMS (Belcher *et al.* 1982). Ek (1974) improved on this by using an empirical approach, where ingrowth was predicted in the smallest diameter classes as function of residual density and site index in northern hardwood stands.

Modelling establishment and subsequent growth and structures of these stands can be seen as a probability problem: the probability of the right species being present, under the right site conditions, the site being unoccupied, with the appropriate climatic and environmental conditions. Prognosis NI uses a probability approach to modelling regeneration. The details of the analytical approach to modelling regeneration used in Prognosis NI are presented later in this chapter.

2.3 Early Height Growth

Different species have characteristically different height growth patterns (Carmean 1970b). Oliver and Larson (1996) identified four types of height-growth patterns for individual trees: asymptotic, sigmoid, linear fast, and linear slow. However, tree growth patterns alone do not determine height growth. The time required for a species to reach a given height varies with site and species. The stand structure and accumulated volume of individual trees seem to be more closely correlated with tree height than with age (Oliver and Larson 1996). Therefore, the rate of growth is dependent on the competition and site quality context. Differences among species height growth rates influence crown expansion and strongly influence the ability of a species to compete under different situations (Oliver and Larson

1996). Height growth patterns, together with information from shade tolerance tables (Baker 1950), can be used to place species into groupings with similar developmental characteristics (Ashton 1992). Palik and Pregitzer (1991 in Cobb *et al.* 1993) attributed the importance of establishment time and attribute stratification of northern hardwoods more to establishment patterns than to differences between- or within-species height growth rates in a single-cohort stand. Establishment time then becomes an important factor for competitive advantage; first-established species, with faster growth characteristics, monopolize resources and have an advantage over later established species

However, the species first established will not necessarily be dominant later in the stand development. Stand structure varies over time, changing with each growing tree and simultaneously, changing the conditions in which trees are growing. Interspecific differences in height growth and shade tolerance promote stratification of the species into layers (Cameron 1996). Species with height growth at the time when growing conditions are favorable within the growing season have competitive advantages over other species. Lodgepole pine and western larch, for example, initiate rapid height growth early in the growing season, while non-determinant species like western hemlock and western redcedar grow in height at various time throughout the year, when conditions are favorable (Schmidt *et al.* 1980). Schuler and Smith (1988) suggested that different rooting habits and response to drought is responsible for the higher size/density relations and the greater stand leaf area in their study of a pinyon (*Pinus edulis* Engelm.) and juniper (*Juniperus monosperma* (Engelm.) and *J. osteosperma* Torr.) Little) stand.

Most of the variation in growth in harsh environments has been found to be due to species differentiation, although site and aspect are also contributing factors (Peterson and Peterson 1994). Certain species can compete more effectively within certain species combinations (Cobb 1993) and some have shown variable growth rates due to the effects of surrounding species (LePage 1997). Contrary to Palik and Pegitzer's (1991 in Cobb *et al.* 1993) scenario that first established species becoming the dominant canopy species later in stand development, some species have been found to positively influence each other's growth (Kneeshaw and Bergeron 1996). Height distributions of major regenerating species were skewed away from small (<15cm) height classes when competing vegetation was high (>50% cover of competing vegetation) in a study in the southern Appalachians (Clinton *et al.* 1994), implying the importance of competing vegetation. Oliver and Larson (1996) identified crown position as an important factor in the growth rate potential realized by each tree. All these observations reinforce the difficulty in attributing species height differences to site quality, competition, genetics, age, or other factors.

In certain species, understory or advanced regeneration can vary growth patterns drastically. Understory trees often exhibit periodically lower and higher rates of height growth as they are released and later suppressed again by temporary overstory gaps. During times of unsuppressed growth, small trees, which were formerly suppressed by high shade, can grow at a rate which parallels height growth of dominant trees which were never suppressed on the same site (Oliver and Larson 1996).

In the ICHmw2, height growth patterns can be associated with shade tolerance levels. In general, pioneer species (Pl, Lw, Ep, At, Atc) tend to have more asymptotic height growth, forging their way to the main canopy for light (Oliver and Larson 1996). Other species are less differentiated in their growth patterns. Tolerant species (Cw, Hw, Sx, Bg, Bl) display mostly slow linear growth patterns, while the semi-tolerant species (Fd, Pw) tend to have sigmoidal height growth patterns (Oliver and Larson 1996). However, early height growth represents only a portion of the overall height growth patterns. Site conditions and species physiological traits still drive height growth, and most early height growth seems to follow a fast or slow linear model. Cameron (pers. com. in Nigh 1995) identifies three different ways that a mixture of species in the upper strata of canopy can occur in even-aged stands: uniform stratification (together from beginning to end), consistent stratification (one species is consistently above the other), and inconsistent stratification (species dominance varies through the development of the stand). This stratification could be applied to ICHmw2 stands in early stages of development or applied to layers under the main canopy.

Efforts to model early height growth in the United States have been fueled by the need to model young stands not dealt with in plantation growth and yield models such as OREGANON (Hann *et al.* 1993) and CACTOS (Wensel *et al.* 1986). SYSTUM-1 (Ritchie and Powers 1993) models small tree height for input into OREGANON or CASTOS using linear regression. It requires heights, species, expansion factor, and breast-height diameters, and if available, crown ratio. Competitive vegetation information is also required. Zhang *et al.* (1996) predicted height and diameter for juvenile loblolly pine (*Pinus taeda* L.) plantations based on a transformation of von Bertalanffy's differential equation for growth and non-linear regression methods. In Europe, Golser and Hasenauer (1997) predicted the height increment for a given tree by adjusting a given site potential by the tree's crown ratio, which represents the growing conditions in the past, and a competition index, which accounts for the current competition the tree experiences. Height increment potentials were determined by the change in dominant tree height over time using regional index functions. Such functions were developed based on large and extensive databases developed over time, which are not commonly available outside Europe. A sigmoidal decay function was used to predict small tree height increments. Favrichon (1998) chose to separate trees into groups based on growth behavior, with reference to shade tolerance and maximum potential size, to model early height growth in mixed tropical forests.

2.4 Prognosis

Prognosis was developed in the United States in the early 1970s (Stage 1973). It is an analytical tool built to aid natural resource managers in projecting the development of forest stands under varying management options. It has evolved into a suite of computer programs, continually being improved, dealing with stand level changes, pests in forest stands, habitat modelling, vegetation competition modelling, and landscape level management (Teck *et al.* 1997).

Prognosis uses a compendium of mathematical models to represent tree and stand development. It was designed to use inventory data and adapt to all types of stands and stand conditions. It is not a static model; information can be incorporated, as it becomes available. Links to other biotic and hydrologic components of the ecosystem and economic analysis procedures for selecting the most appropriate management regimes are also included in Prognosis. Figure 2.3 present a low-resolution diagram showing the logical organization of the Prognosis model (Stage 1973). The base model starts by describing initial stand conditions based on available data. Silvicultural actions scheduled for the cycle are then applied to the compiled information. Periodic diameter and height increments, mortality rates, and crown ratios are then projected for each tree record. Volumes for each tree are calculated based on updated tree attributes and stand conditions are compiled (Stage 1973). All values produced by Prognosis are given at the stand level on a per acre basis.

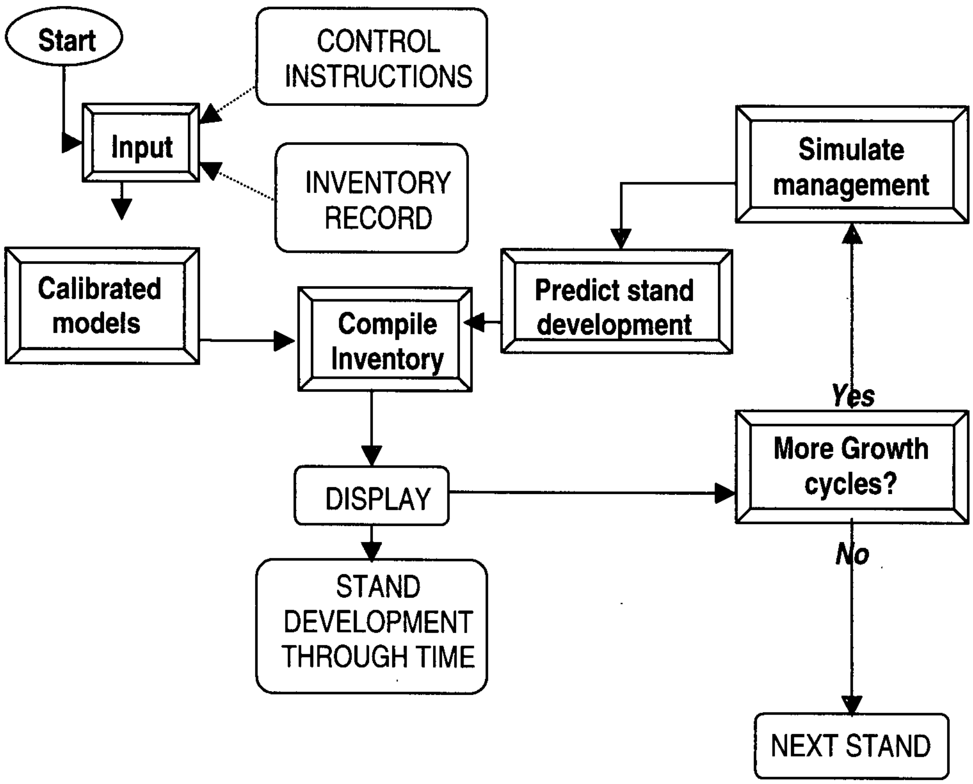


Figure 2.3 Logical organization of the Prognosis model.

The growth equations within Prognosis NI, contrary to many growth and yield models, used in North America, do not use site index as a predictor variable. Most equations in Prognosis NI are based on site variables and the habitat types developed for Idaho and Montana (Cooper *et al.* 1991, Pfister *et al.* 1977, Steele *et al.* 1981).

The regeneration model of Prognosis NI is separate from the base model. Information on regeneration is also produced by acre at a stand level. The information produced and used by the regeneration model is compiled with the "compiled inventory" information (see Figure 2.3). The technique used for developing the regeneration equations in Prognosis NI follows Hamilton and Brickell's (1983) two-state system: each sampled plot is either stocked or not stocked. Each plot in the sample is in one of two states: stocked with at least one established seedling or non-stocked. All plots are used to develop equations predicting the probability of a plot being stocked. Only stocked plots are used to estimate the number of trees on a plot, number of species, species composition, and seedling heights (Ferguson and Carlson 1993).

The probability of stocking t years after disturbance is estimated by a logistic equation within the interval [0,1]. After the attributes of a stocked plot are estimated, the probability of stocking is used to scale stocked plot attribute to a per-acre basis. Four attributes are estimated for each plot: probability of regeneration, number of stems per hectare, species composition, and seedling height. Figure 2.4 illustrates the approach to regeneration modelling used in Prognosis NI.

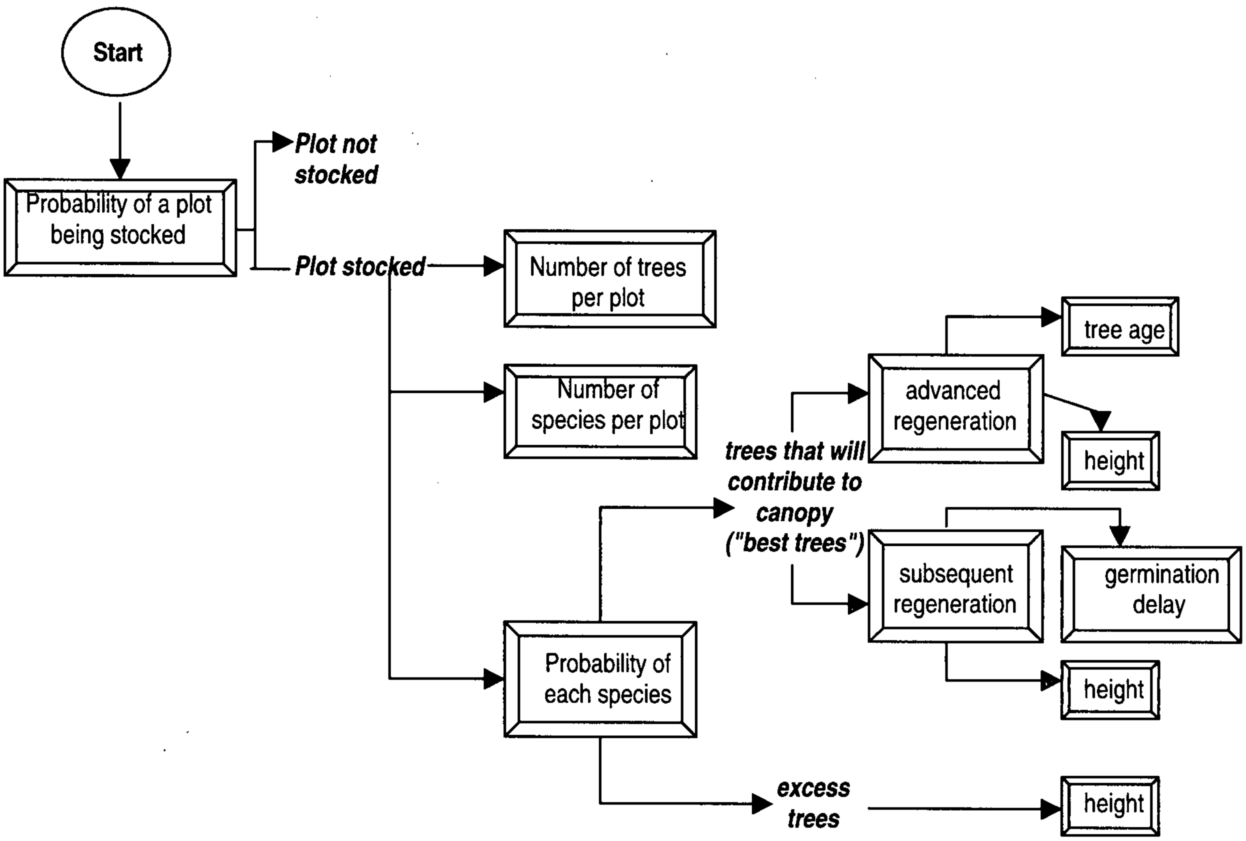


Figure 2.4 Illustration of the modelling approach used in the regeneration component of Prognosis NI (Note: boxes represent equations).

When modelling regeneration, it is sometimes more important to reproduce the distribution as opposed to the mean. Prediction of mean values with linear regression would not properly simulate the natural occurrence of regeneration, because categories with high probabilities of occurrence may not be predicted. Weibull cumulative density distributions are used in Prognosis NI to reproduce cumulative distributions for the number of trees in stocked plots, for the number of years to germination for subsequent regeneration and the age of advanced regeneration trees, both necessary in the seedling height model.

In Prognosis NI, seedlings are divided into excess or best trees. Best trees play a key role in Prognosis NI model. The idea of best trees follows from the fact that many more trees reproduce than will exist in the mature forest (Wellner 1940). By selecting a few trees on each stocked plot, attention is focused on the growing stock that will contribute to yield. Best trees of each plot are then divided into advanced or subsequent regeneration. Advanced regeneration is defined as the "best" trees that germinated more than three years prior to harvest. Subsequent regeneration is defined as the best trees up to three years old at the time of harvest and excess regeneration is all the regeneration not chosen as best trees. Each has an attached probability, predicted with logistic equations. Equations for advanced, subsequent, and excess regeneration types were developed by species.

Separate equations for predicting the height of regeneration were developed for each type of regeneration, in Prognosis NI. Height of advanced and subsequent regeneration is predicted with a linearized exponential function of site variables and site variable transformations. These equations use tree age as one of the predictor variables. This necessitates determining tree age at the end of the Prognosis cycle. Weibull functions were developed that represent the distribution of the number of years from harvest to germination, which in turn enables the determination of tree-age at the end of the Prognosis cycle. In Prognosis NI, Weibull functions for age of advanced regeneration were developed for six different categories: three categories of the number of budworm years in the 5 years prior to disturbance (BWB4) and two categories of basal area (BAA, 0-5.97 m^2/ha (0-25 ft^2/acre) and 5.97+ m^2/ha (26+ ft^2/acre)). Separate functions were developed to estimate germination delay of subsequent regeneration for six data categories: three categories of years since disturbance (TIME) and two categories of the number of years since the last budworm disturbance (BWAF). The data set used in building Prognosis NI did not include age of excess regeneration. The cumulative height of excess regeneration was estimated with Weibull distributions for which the shape and form parameters were based on the Weibull cumulative distribution of the heights of the best trees of the same species.

Tree height predictions in Prognosis NI are done with linear or linearized functions. Two models predict height growth of trees: a small tree model and a large tree model. To prevent discontinuity in predictions between these models, a function is employed for the transition from one model to the other. This function applies to trees between small and large trees (2 – 10 inches/ 5.08 – 25.4 cm diameter outside bark at breast height (dbh)). The large tree predictions for each tree is given a weight of HWT, and the small tree prediction is given a weight of (1-HWT), avoiding discontinuity in the response surface.

Chapter 3: Methods

3.1 Field Methods

During the summer of 1998, data were collected for purposes of calibrating the regeneration and small tree height growth components of Prognosis NI, for incorporation into Prognosis^{BC}. The targeted population was the ICHmw2 stands around Nelson, BC, that had been disturbed in the last two to 20 years. Physically locating all the recently disturbed sites in the ICHmw2 for random selection of a sample was practically impossible. Tracking systems and databases are scattered between licensees and government agencies, and existing records do not necessarily correspond with the actual field status of sites. Resources necessary for locating all possible sites were not available for this project. Furthermore, providing access to field crews in operating areas may be a liability for the operating licensee in the steep terrain of the Kootenays.

A sample population was identified by contacting seven local licensees who agreed to provide access and information on recently disturbed sites on their respective license (Slocan Group - Slocan Division, Kalesnikoff Lumber, Small Business Forest Enterprise Programs in Arrow and Kootenay Lake Districts, Atco Lumber, Meadow Creek Cedar, and Selkirk College on their Woodlot license). A sample of these sites was randomly selected from a list of the sample population.

The sampling phase served two purposes: to provide a representative sample of the sampled population and to allow the Prognosis NI small tree height growth and regeneration components to be calibrated for use in Prognosis^{BC}. The sampled population is not the same as the targeted population. However, the assumption is made that most of the bias between the sampled population and the targeted population is removed by the BEC system and site variables used in the equations. The regeneration components of Prognosis NI (Ferguson and Crookston 1991) and the Prognosis NI tree growth model (Wykoff *et al.* 1982) stratify sites into habitat types (parallel to the BEC classification), site preparation method, regeneration method, level of overstory retention, aspect, and elevation. The same stratification was used for sampling sites. Sites in the sampled population are expected to cover the same range of explanatory variables as those in the targeted population.

Model calibration is better served using purposive sampling, usually spaced throughout the population, including the extremes, in order to make the model applicable to the population as a whole. It is more important to encompass the range of conditions present than it is to sample the area proportionally to the representation of the conditions when calibrating models (Demaerschalk and Kozak 1974, Demaerschalk and Kozak 1975). To capture the range of sites in these strata, there was an effort to stratify remaining sites at the mid-point in the data collection phase. Sites were then randomly selected from strata not yet covered by the data collection. For proper calibration, all these strata should be sampled. However, the calibration of Prognosis^{BC} is only one objective of this project and a stratified random sample was necessary to allow linking the results to the population.

Once sites were selected, plots were randomly located on each selected site. The number of plots per site was dependent on the variability of the site in terms of the stratification criteria and its size; the larger and the more variable the site in terms of the stratification characteristics, the more plots were established. A minimum of two plots were established per site. At each plot location, stands were divided into sub-populations: large trees, small trees, and regeneration. All three sub-populations were sampled at each plot, without any overlap, describing the stand as a whole when combined. Large trees were defined as trees with a dbh above 7.5 cm, small trees were defined as trees with a dbh between 7.5 cm and 2 cm, and the regeneration layer was defined as trees below 2 cm in dbh down to two-year-old seedlings.

Large trees were sampled with a fixed area plot of 11.28 m in diameter (0.04 ha). Information collected for large trees was only used in this project for identifying residual basal area per hectare (ba/ha), crown competition factor, and overstory species.

Small trees were sampled using a fixed area plot of 3.99 m (0.005 ha) with the same centre as the large-tree plot. In the small-tree plot, dbh and height of all small trees were recorded, and trees were selected for sub-sampling age and height increment. To avoid bias in the field, selection rules were pre-established for selecting sub-sampled trees:

- if two or less trees were present per species, both trees were measured for height and age.
- if more than two trees per species were present, then two were randomly selected on site using the tree numbers.

Each tree selected in the sub-sample was felled for measurement of total age, and the last 5-year height growth increment (measured up to the 1997 growth) was recorded. For non-determinant species, like western redcedar and western hemlock, trees were sectioned until the 5-year height increment period could be established and measured.

The regeneration sub-population was also sampled with a fixed area plot, with the same plot centre as the large-tree and small-tree plots. The Prognosis NI model used 1/300 acre plots (0.00135 ha). For ease of calibration, the same size of plot was used in this study. The Prognosis NI regeneration model also requires information on stocking probability. This information was acquired using four satellite plots located in the cardinal directions from the centre plot on the 11.28 m circumference line (large-plot boundary). In the regeneration-centre-plot, count per species was recorded with a sub-sample of height and ground age for the best[2] trees. Best trees were selected in each regeneration centre-plot. In satellite plots, only count per species was recorded. Plot layout is illustrated in Figure 3.1.

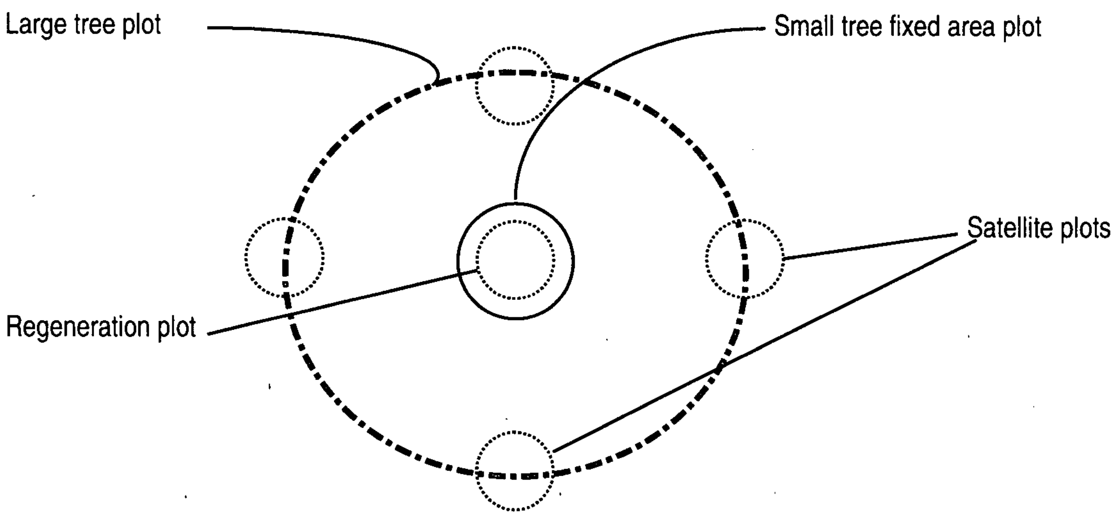


Figure 3.1 Plot layout for sampling large tree, small tree and regeneration sub-populations.

Site information was collected on each plot. This included BEC site series, slope (%), aspect (degrees), elevation (m), retention level defined as the basal area (ba/ha) and species left on site post-harvest, stand condition observations in terms of forest health, and any other relevant or peculiar attribute about the site.

[2] Refer to section 2.4 p.14 for definition of best tree.

3.2 Analytical Methods

The Prognosis NI does not include any broadleaved species. Based on the timber production orientation for which Prognosis[BC] is being developed (Annual Allowable Cut (AAC) calculation) and following consultation with local forest licensees, the calibration in this thesis excludes hardwoods also. Tree species included in this project are:

- grand fir
- subalpine fir
- western redcedar
- Douglas-fir
- western hemlock
- western larch
- lodgepole pine
- western white pine
- hybrid spruce

Ponderosa pine (*Pinus ponderosa*) is part of Prognosis NI, but was not present in the Nelson small tree and regeneration data, and was therefore not included in any of the analyses.

The habitat types used in Prognosis NI (Idaho and Montana habitat types) have been equated to the site series (ss) of the BEC system of BC (Robinson 1997); the systems are interchanged throughout this thesis. Correspondence between habitat types and ss in the ICHmw2 for the Nelson Forest Region are outlined in Table 3.1.

Table 3.1 Idaho and Montana habitat type correspondence to BC BEC site series (from Robinson 1997).

ICHmw2 ss	Corresponding habitat type
03	PSME/VACA – *Pseudostuga menziesii/Vaccinium caespitosum*
04	TSHE/CLUN – *Tsuga heterophylla/Clintonia uniflora*
01	TSHE/CLUN – *Tsuga heterophylla/Clintonia uniflora*
05	THPL/OPHO – *Thuja plicata/Opoplanax horridus*
06	THPL/OPHO – *Thuja plicata/Opoplanax horridus*

Prognosis NI regeneration and small tree height growth equations require many variables and variable transformations that may differ slightly from the data in the Nelson database. Variables are defined in Table 3.2 for both the regeneration sub-models and the small tree height growth model.

Table 3.2 Definition of variables used in the Prognosis NI and Nelson-based Prognosis^{BC} regeneration establishment and small tree height growth equations.

Variable	Definition
ASP/ Asp_r	Plot aspect converted to radians.
SLO/ Slope	Plot slope tangent (slope percent/100).
TIME/ Yrsince	Number of years since last disturbance.
REGT	Number of years since last disturbance without budworm; no budworm information was collected[a], value of 0 for the Nelson data.
BWAF	Number of years since last disturbance with budworm; value of 0 for the Nelson data.
BWB4	Number of budworm years in the 5 years before last disturbance.
SQREGT/ $Time^{1/2}$	Sum of square roots for each year without budworm. Represented as square root of time in the Nelson data.
SQBWAF	Sum of square roots for each year with budworm; in the Nelson data, the number of years with budworm=0, therefore variable is always equal to 0.
ELEV	Stand elevation expressed in feet or in metres
BAA/ ba_ha	Plot residual basal area (ft^2/acre or in m2/ha).
NONE/ Dsitep1-2	Class variable if no site preparation; dummy variables (0,0).
MECH/ Dsitep1-2	Class variable for mechanical disturbance; dummy variables (0,1)
BURN/ Dsitep1-2	Class variable for burn disturbance in plot; dummy variables (1,0).
ROAD	Class variable that occurs on road cuts, road fills, or unmaintained roadbeds; no data was collected on or near road in Nelson data collection effort.
TPSP/ Ntrees	Number of regeneration-size trees on the plot, conditional to the plot having at least one established seedling.
OVER	Class variable for the presence of the same species in the large tree plot.
BOTTOM/ Dpos1-3	Class variable for the bottom topographic positions; dummy variable for topographic position (1,0,0).
LOWER	Class variable for the lower topographic position; dummy variable for topographic position (1,0,0).
MIDSLOPE	Class variable for the midslope topographic positions; dummy variable for topographic position (0,1,0).
UPPER	Class variable for the upper topographic position; dummy variable for topographic position (0,1,0).
RIDGE	Class variable for the ridge topographic positions; dummy variable for topographic position (0,0,1).
AGE	Tree age at ground line.
Hab/ Dhab	Class variable for habitat types; dummy variable for habitat types and corresponding site series, Dhab=0 when ss=3 otherwise Dhad=1.

[a]Budworm defoliation was not collected. Such defoliations are not as prominent in the west Kootenays as in Idaho and Montana and occurrence in the Nelson sites was negligible.

[b] The calibration of the regeneration equations only used natural regeneration data from the Nelson data set. No calibration was performed for planted stock.

Each equation in Prognosis NI regeneration and small tree height components were applied to the data collected on Nelson sites. Throughout the analyses Prognosis NI equations with their original coefficients are referred to as Model 1 for all equations. The coefficients of the same equations were then re-fitted to the Nelson data and are referred to as Model 2. Finally, other variable subsets or Model forms were applied to the Nelson data to see if predictions could be improved. These are referred to as Model 3 and Model 3-1, 3-2, etc., when more than one alternative was tested.

Concordant to the approach used in Prognosis NI presented in Figure 2.3, the regeneration sub-model analyses of the number of trees per plot, the number of species per plot, and the species composition were only performed on stocked plots. In the case of stocking levels, number of species and species composition, binary response variables were predicted using a logistic equation. The general equation form is:

$$P = (1 + e^{-(\Sigma \beta_i x_i)})^{-1} + \epsilon_i \qquad [1]$$

where: P is the probability of success; *e* is the base of natural logarithms; β_i is a vector of regression coefficients; x_i is a vector of independent variables; and ϵ_i is the error term.

For all binary response variables, the response surface is sigmoid-shaped and will have non-normal error terms, with non-constant error variances (Neter *et al.* 1996). The binary responses are constrained to a [0,1] interval. Consequently, using non-linear least squares (NLLS) to estimate coefficients would yield biased variance estimates for these coefficients. Maximum likelihood methods were used to estimate of the vector of regression coefficients in all these equations. Variable subsets with best maximum likelihood estimates were selected from backward and forward variable selection methods to develop Model 3. Models using maximum likelihood estimates were evaluated with: the coefficient of determination (R^2), the log likelihood expressed as -2*log L (smaller values are better), the probability value (p) of the Score statistic which tests the significance of the explanatory variables in the model (if $p<0.05$ variables in model are significant), and two statistics (Akaike Information Criterion – AIC and Schwartz Criterion – SC) primarily used for comparing models (lower values are better). These statistics were calculated with the Statistical Analysis System (SAS - version 6.12 - 1996). Estimated probabilities were compared to calculated stocking levels, number of species, and proportions of advanced, subsequent, and excess regeneration in plots.

Probability of stocking was determined in Prognosis NI with separate logistic equations for each of the four habitat type groupings. Each of these equations was applied to the Nelson data using the Prognosis NI coefficients (Model 1). Site series were grouped accordingly to their corresponding habitat types. Only two habitat type groupings encompassed all site series in the Nelson data – THPL and TSHE were calibrated together in Prognosis NI. For each habitat type, the coefficients of the Prognosis NI equation were re-fitted to Nelson data (Model 2). Probabilities were also estimated using linear models and ordinary least squares (OLS) estimated coefficients, the resulting model is referred to as Model 3-1. Logistic equations with different subsets of variables were also evaluated for best predictor variables when using non-linear maximum likelihood coefficients estimates for both habitat types. The best resulting equation is referred to as Model 3-2.

The Prognosis NI regeneration model uses a logistic equation to predict the probability of having a particular number of species present in a stocked plot. In the data used to build Prognosis NI, the number of species present had a reversed J-shaped distribution, with one species having the highest probability and six or more having the least. Separate equations were developed for the probability of 1, 2, 3, 4, 5, and 6+ species occurring on a plot. These six probabilities were estimated with the Prognosis NI equation (model 1), re-fitted coefficients of the Prognosis NI equation (model 2), and a new subset of variables (model 3). To compare predictions from Model 1, Model 2 and Model 3, a uniform pseudo-random number was used to make discrete but unbiased, choices of the number of species on a plot. To do so, the probabilities of each number of species (1 through 6) within each model group (1, 2, and 3) were calculated and totaled within each model group. For each model, the total was then divided back into the probabilities so that the sum of the adjusted probabilities was accumulated within the interval [0,1]. A uniformly distributed pseudo-random number was compared to the accumulated probabilities; the number of species on a plot was determined as the number at which the accumulated probabilities (probability of 1 to probability of 6+) first exceeded the pseudo-random number. The process was executed 1000 times for each of the three models. The frequency of each number of species was averaged and compared per model group to the actual frequency of the number of species per plot in the original data.

Seedlings in the Nelson data were divided into advanced, subsequent, and excess regeneration in the same way as in Prognosis NI. Best trees were selected and aged only in the centre regeneration subplot; therefore, only the centre plots were used in the seedling height calibration process. As in the Prognosis NI approach, probabilities for each regeneration type were modelled by species. Probabilities were first calculated using Prognosis NI equations (Model 1); a second set of probabilities were calculated with the Prognosis NI equation with re-fitted coefficients (Model 2); and a third set of probabilities were calculated with the best variable subset from a variable-selection process (Model 3). As in the Prognosis NI approach illustrated in Figure 2.3, probabilities of excess regeneration and occurrence of best trees were cumulated within a [0, 1] interval, and probabilities of advanced and subsequent regeneration (which together represent the best trees) were also cumulated within a [0, 1] interval for each of the three models. A pseudo-random number was used to determine which type of regeneration by species occurred in the plot. This process was repeated 100 times and the results averaged for each model. Results from all three models were graphically compared to the actual proportions of advanced, subsequent, and excess regeneration.

A Weibull cumulative density distribution was used to reproduce the distribution of the number of trees in stocked plots and of the number of years to germination. The Weibull equation is of the form:

$$F(x) = 1\text{-}EXP[-(y/B)^C] + \epsilon_i \qquad [2]$$

where: F(x) is the Cumulative Density Function (CDF); y is the number of trees per stocked plot or the number of years to germination; *B* is the Weibull scale parameter; and *C* is the Weibull shape parameter. The area bounded by the Weibull equation is within the interval [0,1]. Equation [2] is sometimes used in the form (Bailey and Dell 1973):

$$y = B[-\ln(1-F(x))]^{1/C} + \epsilon_i \qquad [3]$$

Parameters of this function were estimated using NLLS.

The number of trees per stocked plot was determined with a two-step analysis as in Prognosis NI. In Prognosis NI, the data were categorized by habitat series, four aspects, three time periods, and two budworm defoliation histories. Correspondences in the Nelson data included two habitat series, four aspects, and three time periods, resulting in 24 possible data categories. The *B* and *C* Weibull parameters were estimated using NLLS for each of the data groupings with above 20 observations. Site variables for each category were averaged and all categories were pooled to create a data set of 16 observations of *B* and *C* (16 out of 24 categories had above 20 observations). These parameters were then linearly predicted using different approaches. The first approach used the Prognosis NI linear equation and coefficients to predict Weibull parameters *B* and *C*. The predicted parameters were then applied to the Weibull to estimate a CDF for each data-category (Model 1). The second approach used re-fitted OLS estimated coefficients in the Prognosis NI linear equations for *B* and *C* predictions. Those estimates of *B* and *C* produced a second CDF for each data-category (Model 2). A third CDF was produced using linear estimates of *B* and *C* with the best subset of variables from a backwards-stepwise variable selection procedure (Model 3). Of these three CDF, the closest to the actual cumulative density was selected for coefficient estimation using two other methods: a joint-generalized least-square approach (referred to as Seemingly Unrelated Regressions – SUR (Model 3-1)) (Kmenta 1986) and a NLLS estimation of linear model coefficients directly substituted in the Weibull function (Model 3-2). The model producing a cumulative density distribution closest to the actual cumulative density of the number of trees per stocked plot was then further tested on the remaining data categories with less than 20 observations.

Predictions of delay to germination also used a Weibull cumulative density function. As in Prognosis NI, cumulative germination delays were predicted for advanced or subsequent regeneration of each species. Only three out of nine species in the advanced regeneration had more than 20 observations, and eight out of nine subsequent regeneration categories had more than 20 observations. For each of these categories, Weibull density functions were estimated using NLLS for determination of cumulative germination delays. Model 1 refers to the Prognosis NI equation and Model 2 refers to the same equation, re-fitted. No other model forms were tested as no site variables are used in modelling germination delay in Prognosis NI.

Height of excess regeneration was not available in the database used to develop Prognosis NI; however, it was collected on Nelson sites. Prognosis NI predicts the cumulative height of excess regeneration with a Weibull function. For comparative purposes, the Prognosis NI shape and form parameter for a Weibull distribution of cumulative height of excess regeneration were applied to the Nelson data set. A uniform pseudo-random number was used to assign height to trees for all species (Model 1) regardless of the number of observations. For species with more than 10 observations of heights, the Weibull parameters were fitted with NLLS and a uniform random number used to assign a height to each tree (Model 2). As per height of advanced and subsequent regeneration in Prognosis NI, a best variable-subset based on OLS estimated coefficients in linearized equations was used to predict height of excess regeneration by species (Model 3 for excess regeneration). The number of trees in each height class were compared for all models by species.

Heights of advanced and subsequent regeneration were predicted by species with the same equation used in Prognosis NI (Model 1). This model was then re-fitted with the Nelson data to yield a second set of height predictions for advanced and subsequent regeneration (Model 2). Finally, best variable-subsets based on OLS estimated coefficients in linearized equations estimates, were applied to predict the natural log of height for advanced and subsequent regeneration per species (Model 3). Resulting height predictions were divided into height classes[3] for each model and compared to the actual frequencies of trees per height class.

The Prognosis NI equation for predicting small tree height growth is a linearized function (Wykoff 1986). The model form is:

$$LN\ HTG = HAB + LOC + 0.22157*SL*\cos(ASP) - 0.12432*SL*\sin(ASP) - 0.10987*SL + b_1*\ln(HT) + b_2*CCF + b_3(BAL/100) + \epsilon_i \quad [4]$$

where HTG is the height increment predictions for small trees, HAB is a constant that is dependent on habitat type, LOC is a constant that is dependent on location, ASP is stand aspect (degrees), SL is stand slope ratio (/100), Ht is tree height (ft or in metres), CCF is crown competition factor, BAL is the basal area in larger trees (ft^2/acre or in m^2/ha), b_1, b_2, b_3 are species-specific regression coefficients and ϵ_i is an error term. This equation was applied to the Nelson data for species more than 25 observations and for shade-tolerance groups (Model 1). The location constant for the Clearwater and Nezperce National US Forests was used for the Nelson model run as per the calibration of the large-tree growth model of Prognosis[BC] for the Nelson Region (Zumrawi 1998, pers. comm.)[4]. The Prognosis model was then re-fit using OLS for the same data categories (Model 2). Both height (Model 3-1) and natural log of height (Model 3-2) were predicted using the best subset of variables from a variable selection procedure fit using OLS.

Linear and linearized models used for height of regeneration and small tree height growth predictions were evaluated by comparing residuals, R square values, I square values (1-(SSres/SStot)), the standard error of the estimate (SEE = $\sqrt{SSres/n}$) and residual variance. In all analyses, results were evaluated at the 0.05 significance level with a few exceptions:

- acceptance levels when a forward variable selection procedure was used was 0.01. This was reduced to allow for more flexibility for variable entry in models.
- non-significant variables were eliminated from equations except: (1) those that were part of a group of dummy variables that represented a single class variable, (2) when variables were part of the Prognosis NI model form being re-fitted or evaluated, or (3) when no model form was significant, in which case the least problematic model was chosen.

All statistical analyses were performed with SAS (SAS - version 6.12 - 1996) while spreadsheet manipulations and graphs were produced with Excel (Microsoft 1997).

[3] Height classes were: (1) ≤ 50cm; (2) 50 – 100cm; (3) 100 – 130cm and (4) 130cm+;

[4] Dr. Abdel-Azim Zumrawi, Research Scientist, Research Branch, B.C. Ministry of Forests.

Chapter 4: Results

4.1 Data Summaries

4.1.1 Regeneration

Data were collected on a total of 186 regeneration plots. Table 4.1 shows the range of data for classes of some independent variables used in the models.

Table 4.1 Summary of number of plots by class for independent variables used in the regeneration predictions models.

Class	No. plots	Class	No. plots	Class	No. plots
Years since last disturbance		**Site preparation method**		**Residual basal area (m^2/ha)**	
0	15	brushing	3	0	60
2	15	burn	22	5	28
3	17	mechanic	7	10	21
4	8	none	134	15	22
5	9	Spot burn	14	20	11
6	23	Spot mech.	6	25	6
7	12			30	6
8	8	**Elevation (100 m)**		35	8
9	5	5	4	40	7
10	19	6	22	45	5
11	13	7	8	50	3
12	11	8	20	55	4
14	3	9	20	60	2
16	3	10	34	65	1
17	2	11	12	70	1
18	6	12	34	90	1
19	11	13	30		
20	2	14	2	**Topographic position**	
21	2				
29	2	**Slope percent**		crest	7
		0-10	23	depression	4
Aspect		10-20	45	level	10
E	30	20-30	46	lower	21
F	16	30-40	26	middle	111
N	12	40-50	23	toe	5
NE	18	50-60	16	top	1
NW	12	60+	7	upper	25
S	27			(blank)	2
SE	19				
SW	36				
W	16				

More than half of the plots (53%) were disturbed in the last 7 years. A large portion of plots (76%) had less then 20 m^2/ha of residual basal area, and 62% were on slopes that are 20% or less. Plots seem to be well distributed over the elevation range, and most (60%) are in a middle topographic position. The majority of plots (72%) has had no site preparation.

The amount of natural regeneration, summed by species, height class, and site series is given in Table 4.2. Western hemlock had the highest count of all species, followed by Douglas-fir and western redcedar. The high counts of western hemlock regeneration occurred on site series 01 and 04. Site series 03 had the highest count of Douglas-fir regeneration, followed by site series 04. Site series 04 had the highest count of western redcedar regeneration, followed by site series 03 and 01. Cautious interpretations accompany this table as count of species, per height class, and site series, represent only a narrow view of a multivariate space. Distribution of sampling can skew interpretation of abundance species per site series and height class.

Table 4.2 Abundance of natural regeneration by species (Sps), height class (Ht^a) and site series.

		Site series							Site series				
Sps	**Ht[a]**	**01**	**03**	**04**	**05**	**06**	**Sps**	**Ht[a]**	**01**	**03**	**04**	**05**	**06**
Bg	1	97	35	37	18		Bl	1	21	42	141	6	
	2	13	7	7	5			2	1	20	23	4	2
	3	1		3	2			3	1	13	21	2	
	4		1		7			4		6	4	1	1
Total		111	43	47	32		**Total**		23	81	189	13	3
Cw	1	379	221	634	251	15	Fd	1	193	759	636	85	2
	2	97	179	200	85	8		2	34	208	117	16	
	3	30	66	57	20	5		3	4	105	45	5	
	4	25	69	50	24	6		4	8	120	56	7	
Total		23	81	189	13	3	**Total**		239	1192	854	113	2
Hw	1	1861	254	1658	125	16	Lw	1	7	92	101	9	
	2	287	79	173	33			2	7	54	35	6	
	3	72	38	51	6	1		3	1	32	9		
	4	53	38	63	7			4		42	6	6	
Total		2273	409	1945	171	17	**Total**		15	220	151	21	
Pl	1	18	197	110	9		Pw	1	78	107	213	19	
	2	6	96	39	1			2	13	49	78	6	
	3	3	48	3	1			3	4	22	10	2	
	4	3	46	6				4	1	14	5		
Total		30	387	158	11		**Total**		96	192	306	27	
Sx	1	17	96	13	21	6							
	2	3	15	3	7	3							
	3		4	2	1								
	4		6										
Total		20	121	18	29	9							

[a] Height classes are: (1) ≤ 50cm; (2) 50 – 100cm; (3) 100 – 130cm and (4) 130cm+;

4.1.2 Small Trees

The data collection phase of this project yielded 266 height growth measurements of small trees. Only four out of nine species (Cw, Fd, Hw, Pl) had more than 25 observations of height growth. Tolerance groups are believed to share similar height growth patterns (Oliver and Larson 1996). To provide sufficient observations for model calibration and testing, species were grouped according to shade-tolerance levels. Tolerant species included grand fir, subalpine fir, western redcedar, hemlock, and spruce; semi-tolerant species included Douglas-fir and white pine; intolerant species included lodgepole pine and larch. Table 4.3 shows the average 5-year height growth of small trees by species and site series.

Table 4.3 Average 5-year height growth (in metres) by species and site series.

Tolerant Species						
Site Series	**Bg**	**Bl**	**Cw**	**Hw**	**Sx**	**Average**
01		0.910	0.206	0.471	0.445	0.354
03		1.328	0.546	0.951	0.370	0.724
04	0.040	0.445	0.271	0.425	0.393	0.331
05		1.217	0.383	0.575		0.535
06			0.160	0.675		0.366
Average	0.040	1.076	0.355	0.586	0.407	0.474
Semi-tolerant species						
Site Series	**Fd**	**Pw**				**Average**
01	1.220	0.968				1.076
03	1.145	1.210				1.151
04	1.202	1.632				1.305
05	1.265	1.430				1.298
Average	1.185	1.347				1.221
Intolerant Species						
Site Series	**Lw**	**Pl**				**Average**
01	0.320					0.320
03	2.348	1.743				1.824
04	2.010	1.424				1.483
05	2.635	2.130				2.332
Average	2.124	1.698				1.772

The intolerant species had the largest height growth, followed by the semi-tolerant, and the tolerant species. The poorest height growth was found for grand fir; however, this was based on very few observations of trees growing at the elevational limit to their distribution. The next smallest height growth was found for western redcedar. However, these species were on different sites with varying retention levels. Height growth differences between species may just be a consequence of site characteristics and not a statistically valid difference.

Five-year height growth is averaged by classes of Crown Competition Factors (CCF) and site series in Table 4.4. It can be seen that height growth decreased with increasing CCF class. Tolerant species were found in plots across all of the CCF classes, semi-tolerant species were present in plots across the first 5 classes, and intolerant species were only found in plots that fell into the first two classes. The higher height growth in tolerant species under CCF 4 is attributed to those trees being advance regeneration (ages between 37 and 82 years).

Table 4.4 Average 5-year height growth (in metres) by CCF and site series.

Tolerant species

	CCF Class[a]						
Site series	**1**	**2**	**3**	**4**	**5**	**6**	**Average**
1	0.990	0.514	0.214	0.288	0.324		0.354
3	0.977	0.589	0.165		0.090		0.724
4	0.524	0.322	0.217	0.273	0.400	0.255	0.331
5	1.144	0.255			0.216		0.535
6					0.366		0.366
Average	0.903	0.428	0.207	0.277	0.292	0.255	0.474

Semi-tolerant species

	CCF Class[b]						
Site Series	**1**	**2**	**3**	**4**	**5**	**6**	**Average**
1	1.468	0.590			0.535		1.076
3	1.765	0.552	0.427	0.160			1.151
4	1.686	0.576	0.360		0.360		1.305
5	2.043	0.180					1.298
Average	1.717	0.510	0.410	0.160	0.448		1.221

Intolerant species

	CCF Class[b]						
Site Series	**1**	**2**	**3**	**4**	**5**	**6**	**Average**
1	0.320						0.320
3	1.857	0.850					1.824
4	1.483						1.483
5	2.537	2.025					2.332
Average	1.782	1.633					1.772

[a] The CCF classes are: (1) ≤ 50; (2) 50 – 100; (3) 100 – 150; (4) 150 – 200; (5) 200 – 300; and (6) 300 – 400.

Average 5-year height growth of the small trees by aspect, slope class and grouped site series[5] is given in Table 4.5. It is apparent that trees on site series 03 had the best average height growth, followed by site series 05, 04, 01, and 06. There is no clear pattern among slope and aspect classes.

[5] Sites series are grouped by corresponding habitat types.

Table 4.5 Average 5-year height growth of small trees by aspect, slope class[a], grouped by site series.

Grouped site series	Slope Class[a]	E	F	N	NE	NW	S	SE	Sw	W	Average
		Aspect									
03	0	0.708	0.805						1.727	0.287	0.861
	1	0.765		2.010			1.632	1.215	0.720		1.494
	2			2.356		0.770	1.175	2.080	1.655	1.985	1.710
	3	1.920					1.205	1.300	0.700	0.850	1.304
	4	1.302							1.172		1.224
	5	0.160			1.763		1.415		0.090	1.700	1.129
	6	0.373			1.807						1.035
	Missing			2.573					1.620		2.486
Average		0.971	0.805	2.413	1.792	0.770	1.434	1.349	1.153	1.054	1.423
05-06	0		1.388	1.514	0.140		1.015		1.580		1.835
	1	0.490		0.080	1.017	0.661			0.760	1.470	1.212
	2	0.194		1.093	1.066	0.380	0.640	0.505	0.040		1.223
	3			2.010			2.767	0.352			1.037
	4	0.421		0.385	0.530	0.120		0.610	0.310	0.085	0.594
	6	0.325			0.413						0.397
	Missing	0.785								0.125	0.910
Average		0.709	1.388	2.267	1.079	0.551	1.828	0.687	2.202	1.018	1.323
01-04	0		0.333			0.290					0.623
	1	2.266		0.155			0.445		1.417		2.011
	2			0.198	1.383					0.790	0.731
	3	0.198									0.198
	4	1.491	0.333	0.183	1.383	0.290	0.445		1.417	0.790	1.470
	5										
	6	0.902	1.172	1.564	0.898	0.308	1.345	0.705	1.047	0.712	1.031
	Missing										
Average		1.491	0.333	0.183	1.383	0.290	0.445		1.417	0.790	1.470

[a] The slope classes are: (0) flat; (1) ≤ 20%; (2) 20-30%; (3) 30 – 40%; (4) 40 – 50%; (5) 50 – 60%; and (6) 60%+.

4.2 Equations

Results of all equations are separated in three model groups. Model 1 is the Prognosis NI equations with original coefficients, model 2 is the Prognosis NI equations with re-fitted coefficients and model 3 is an equation using a different subset of variables than that used in Prognosis NI. Model group 3 is separated into model 3-1, 3-2, etc., when more than one variable subset or modelling approach was used. All models, including those in model group 3, are outlined section 3.2, Analytical Methods.

4.2.1 Probability of stocking

Probability of stocking was calculated for each of the 186 plots in the Nelson data set. As outlined in the field sampling methods, each plot had a total of five regeneration subplots (930 regeneration subplots in total). A stocked subplot was defined as a subplot containing at least one seedling, more than two years old. Each stocked subplot contributed 0.2 stocking to the plot. Summary statistics for the probability of stocking predicted with model 1 and model 3-1 are presented in Table 4.6.

Table 4.6 Results of Prognosis NI equation (model 1) and of linear model (model 3-1) for predictions of probability of stocking for the Nelson data set.

Species grouping	No. of obs.	Model group	Variables in model[a]	r^2	SEE
PSME/VACA	73	model 1	G(x1, x2, x3, sqregt, elev, Mech, Burn)	0.461607	0.202961
THPL and TSHE	112		G(x1, x2, x3, sqregt, elev, BAA, BAA^2, x5, x6, Mech, Burn)	0.755008	0.131367
All species	**186**	model 3-1	F(asp_r, slo, elec_c, dsitep1 – 4, x2, x3, ba_ha^2)	0.27772520	0.217529
PSME/VACA	73		F(yrsince, slo, x4, x5, ba2)	0.26171285	0.180401
THPL and TSHE	112		F(asp_r, slo, elev_c, dsitep1-4, x3, ba_ha^2)	0.40313690	0.219036

[a] x1 is defined as COS(ASP)*SLO½*TIME½
x2 is defnied as SIN(ASP)*SLO½*TIME½
x3 SLO½*TIME½
x4 is defined as TIME½
x5 is defined as COS(ASP)*SLO*BAA
x6 is defined as SIN(ASP)*SLO*BAA

Figures 4.1 and 4.2 show plots of predicted probability values and residuals (measured – predicted) for model 1. Figures 4.3, 4.4 and 4.5 show the same plots for model 3-1 for all species, the PSME habitat type and the THPL/TSHE habitat types respectively.

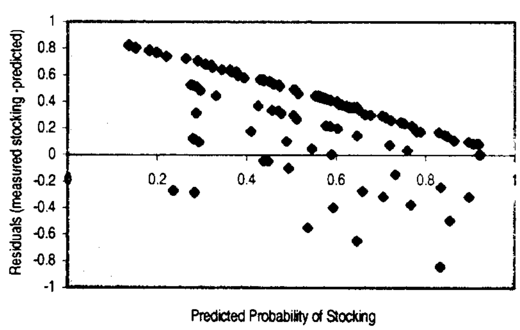


Figure 4.1 Residuals using model 1 plotted against predicted probability of stocking for habitat types THPL and TSHE.

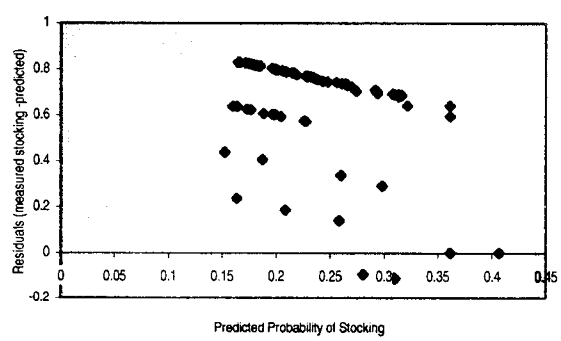


Figure 4.2 Residuals using model 1 plotted against predicted probability of stocking for habitat type PSME/VACA.

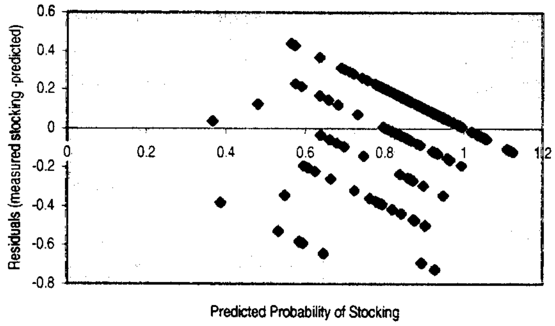


Figure 4.3 Residuals using model 3-1 plotted against predicted probability of stocking for all species.

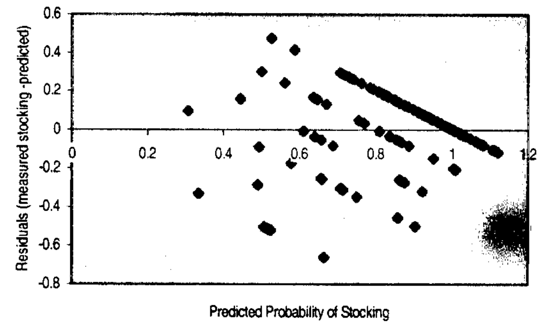


Figure 4.4 Residuals using model 3-1 plotted against predicted probability of stocking for THPL and TSHE.

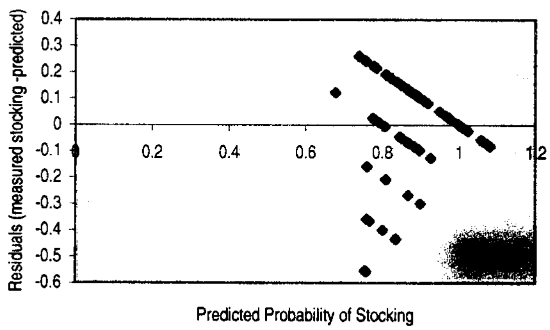


Figure 4.5 Residuals using model 3-1 plotted against predicted probability of stocking for habitat type PSME/VACA.

Based on the SEE, model 1 did not fit the data as well as model 3-1 (Table 4.6). This also seems evident from comparing the residuals displayed in Figures 4.1 and 4.2 with those displayed in Figure 4.4 and 4.5. In general, model 1 underestimated the proportion of stocked plots (positive residuals), especially for the PSME habitat type. Model 3-1 appeared to fit the data better. Separating the data into habitat series for model 3-1 reduced the SEE for the PSME habitat type (Figure 4.5) over the combined model (Figure 4.3). The THPL and TSHE habitat types had a similar SEE to the combined model. However, caution should be used when interpreting the linear models, since using OLS regression for a restricted dependent variable, like the proportion of stocked plots [0, 1], will result in biased and inconsistent estimates of the equation coefficients (LeMay *et al.* 1993, Tobin 1958). Further, binary response variables are known to have a sigmoidal-shaped response-surface; a linear model, therefore, does not fit the data (Figures 4.3, 4.4 and 4.5 show predictions above 1).

Summary statistics for the non-linear models (model 2 and model 3-2) are presented in Table 4.7. Model 2 appeared to function best overall in terms of having the highest R square for the PSME/VACA habitat type. Model 3-2 was the best predictor for the THPL and TSHE habitat types, with a slightly higher R square than model 2. The AIC and SC were always higher for the THPL and TSHE habitat type than for the PSME habitat type. The probability values (p values) of the Score statistic shows all variables in the models to be significant at a 0.05 probability level ($p<0.05$).

Table 4.7 Summary statistics for the non-linear models for predicting the probability of plot being stocked.

Grouping	Model group	Variables in model[a]	R^2	AIC	SC	Score p values
PSME	model 2	G(x1, x2, x3, sqregt, elev, Mech, Burn)	0.162	227.9	290.3	0.0001
	model 3-2	G(yrsince, slo, elev_c, x3, elev2)	0.133	220.4	243.8	0.0008
THPL and TSHE	model 2	G(x1, x2, x3, sqregt, elev, BAA, BAA², x5, x6, Mech, Burn)	0.194	423.2	483.8	0.0001
	model 3-2	G(dsitep1-5, dss1-3, asp_r, baha, slo, elev_c, x3, x4, elev2)	0.219	405.9	466.4	0.0001

[a] x1 is defined as COS(ASP)*SLO½*TIME½
x2 is defnied as SIN(ASP)*SLO½*TIME½
x3 SLO½*TIME½
x4 is defined as TIME½
x5 is defined as COS(ASP)*SLO*BAA
x6 is defined as SIN(ASP)*SLO*BAA

The residuals for model 2 and model 3-2 are shown in Figures 4.6 to 4.9 for each habitat type grouping. The residuals appear to be centered on zero for each of the habitat types and models, with considerable variation present. The variability decreased as predicted stocking approached 100 percent for model 2. The decrease in variability was less obvious for model 3-2. The residuals are truncated due to the restricted response variable. Residuals appear in five distinct lines due to of the five possible responses of the measured probabilities (0.2, 0.4, 0.6, 0.8, 1.0).

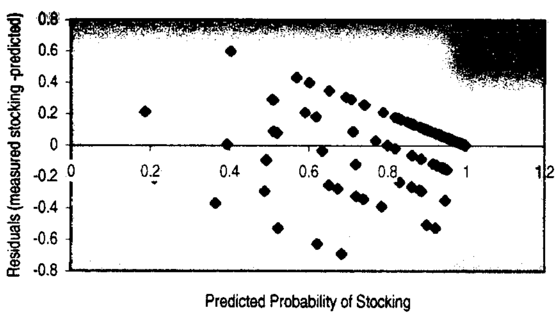


Figure 4.6 Residuals from model 2 against predicted probability of stocking for habitat types THPL and TSHE.

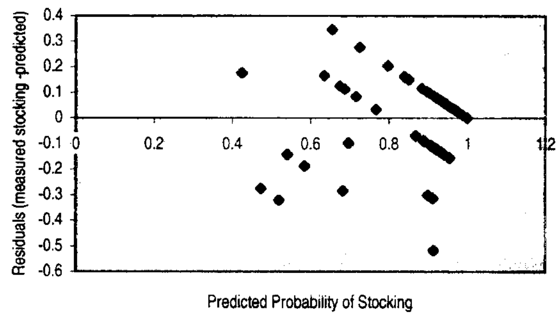


Figure 4.7 Residuals from model 2 against predicted probability of stocking for habitat type PSME/VACA.

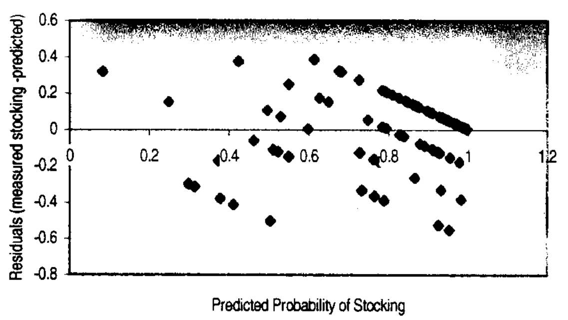


Figure 4.8 Residuals from model 3-2 plotted against predicted probability of stocking for habitat types THPL and TSHE.

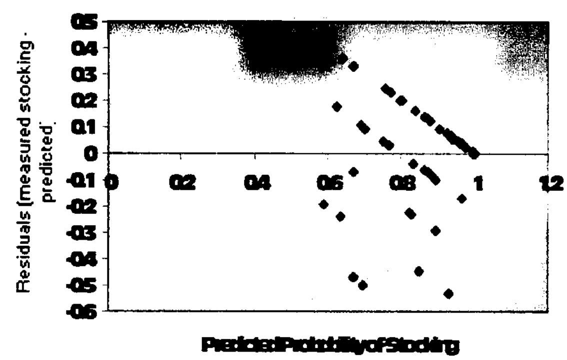


Figure 4.9 Residuals from model 3-2 against its predicted probability for habitat type PSME/VACA.

4.2.2 Number of Stems per Hectare

Only the stocked plots were used in the analysis of the number of stems per hectare; the Nelson data set has 809 stocked plots (n = 809). The number of observations per category and the data category definitions are presented in Table 4.8. Categories with more than 20 observations are shaded. Only these categories were used for estimating the number of trees per hectare.

Table 4.8 Number of observations of stocked plots and definition of data categories for the number of trees per stocked plot in the Nelson data set.

	Douglas-fir habitat series						Hemlock and cedar habitat series					
	< 7 yrs	Category number	8 12 yrs	Category number	12+ yrs	Category number	< 7 yrs	Category number	8 12 yrs	Category number	12+ yrs	Category number
North	9	1	15	5	30	9	38	13	55	17	34	21
East	54	2	20	6	24	10	111	14	50	18	7	22
South	79	3	16	7	15	11	67	15	20	19	10	23
West	30	4	36	8	0	12	32	16	40	20	17	24

Model 3-1 (SUR) and model 3-2 (NLLS) out-performed both model 1 and model 2 in all data-categories. The coefficients resulting from model 3-1 were compared to those from model 3-2. Both models performed similarly and varied only slightly per data category. Model 3-1 and model 3-2, are comparatively assessed in Table 4.9. Observations in Table 4.9 are based on plotted residuals (Appendix 2). Model 1 did not perform well for estimating *B* and *C* in any data category; re-fitting the coefficients of this equation in model 2 improved the predictions in all data categories. Model 3 yielded values closer to the actual cumulative density function than either model 1 or model 2. The linear coefficients in model 3 for predicting the *B* and *C* Weibull parameters, re-fitted with the SUR method (model 3-1), only slightly changed the coefficients of the equation for predicting *B* and did not change the coefficients of the equation for predicting *C*. Models 3 and 3-2 produced identical, predictions but model 3-2 yielded smaller standard errors of coefficients for the *B* predictions than model 3 (see Appendix 1). Consequently, the CDFs were almost identical for all data categories. Estimations from model 3-2, in the case of data category 2, produced a slightly better estimate than model 3-1 or model 3. Trees per stocked plot were better estimated in categories 2, 4, 15, 16 and 20 using model 3-2, while categories 3, 6, 8, 9, 10, 14, 17, 18, and 21 were better estimated using model 3-1. Coefficients and variables for estimating Weibull parameters B and C with model group 3, 3-1, 3-2 are presented in Table 4.10.

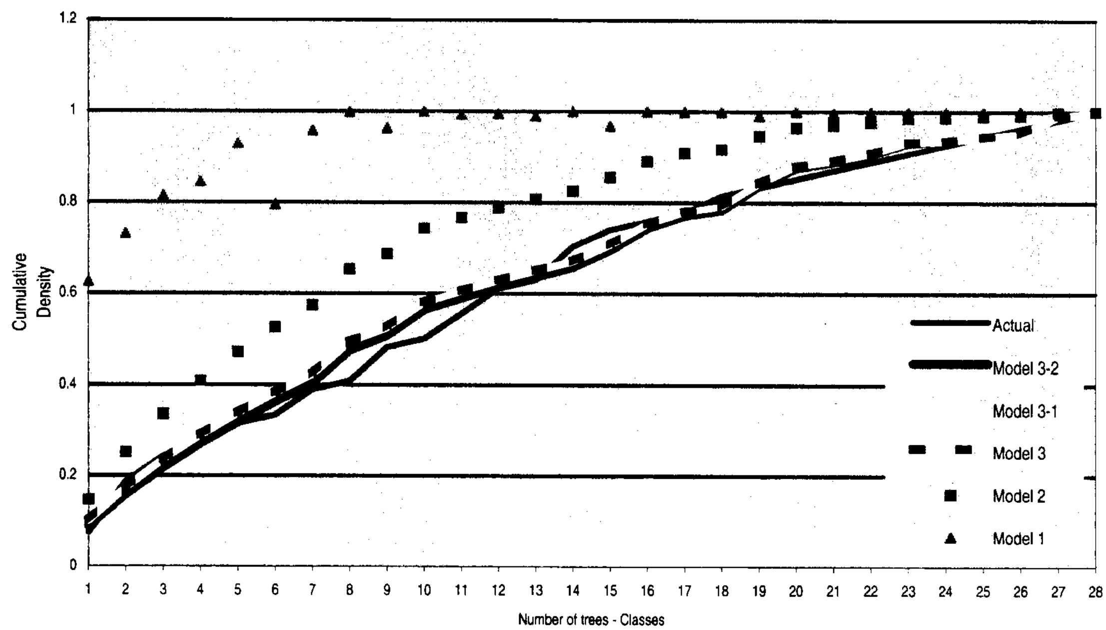
Table 4.9 Performance observations comparing the NLLS (model 3-2) and SUR estimates (model 3-1).

Data Category	Model 3-2 Non-linear estimations*	Model 3-1 SUR estimations*
2	Slightly closer to actual CDF**	Slightly farther form the CDF than the model 3-2**
3	Over-estimates the number of trees	Better performance
4	Better performance	Under-estimates the number of trees
6	Over-estimates	Even spread of residuals – better performance
8	Spread of residuals not as even	Even spread of residuals – better performance
9	Slightly larger spread of residuals	Less spread of residuals – better performance
10	Slightly larger spread of residuals	Less spread of residuals – better performance
13	Very similar in performance	Slightly more even spread of residuals
14	Even spread of residuals – better performance	Slightly larger spread of residuals
15	Even spread of residuals – better performance	Slightly larger spread of residuals
16	Even spread of residuals – better performance	Slightly larger spread of residuals
17	Slightly larger spread of residuals	Even spread of residuals – better performance
18	Spread of residuals not as even	Even spread of residuals – better performance
19	Spread of residuals not as even	Even spread of residuals – better performance
20	Even spread of residuals – better performance	Spread of residuals not as even
21	Spread of residuals not as even	Even spread of residuals – better performance

*Comments are based on only slight differences observables in plotted residuals in Appendix 1 or in Graph 1 in the case of data category 2.

**See Figure 4.10.

Results are graphically presented for data category 2 (<7 years since disturbance, east facing, PSME habitat type) in Figure 4.10. CDFs for other categories with more than 20 observations are presented in Appendix 3.



Note: X-axis are classes, continous lines are for ease of comparison.

Figure 4.10 Cumulative density functions based on *B* and *C* estimates and actual cumulative density for data category 2, the youngest (<7 years), east facing, PSME habitat type.

Table 4.10 Coefficients from model 3-1 and model 3-2 for estimation of Weibull parameters *B* and *C*.

	Model for estimating ln *B* Coefficients		**Model for estimating ln *C* Coefficients**	
Averaged Variables[a]	**SUR Model 3-2**	**Non-linear Model 3-2**	**SUR Model 3-2**	**Non-linear Model 3-2**
Intercept	-9.901183	-9.763019127	1.528704	1.477677808
yrs	-0.977419	-0.967698367	0.024540	0.021577838
asp	-0.012110	-0.006687009	-0.019524	-0.019852181
slope	-0.032616	-0.024796689	-0.023624	-0.023708609
elev	0.001949	0.001129709	0.276545	0.274641333
baha	-0.211891	-0.204691320	-0.143244	-0.129351792
Dsitep1	0.183233	0.104535875	-0.118227	-0.114367373
Dsitep2	-0.026616	0.014233875	-0.622592	-0.607056208
Dsitep3	0.224771	-0.047052693	0.036588	-0.013474713
Dsitep4	0.008995	0.002097957	-0.063547	-0.063269804
CCF	0.070659	0.071202997	0.060206	0.058293902
x1	-1.219738	-1.180844480		
x2	-1.387640	-1.315628313		
x3	6.518250	6.559046730		
dhab	-0.694315	-0.651511515		

[a] x1 defined as COS(ASP)*SLO
x2 defined as SIN(ASP)*SLO
x3 defined as $SLO^{1/2}$*$TIME^{1/2}$

Models were tested on the remaining categories with less than 20 observations. Categories were paired in terms of site characteristics and the best performing models from the calibration categories were applied to their pairs. Out of seven data categories with less than 20 observations, only two showed CDFs with similar trends; however, none of the estimates performed well. Figure 4.11 through 4.16 show the cumulative density of each of the seven categories, along with an estimate of their cumulative percentages.

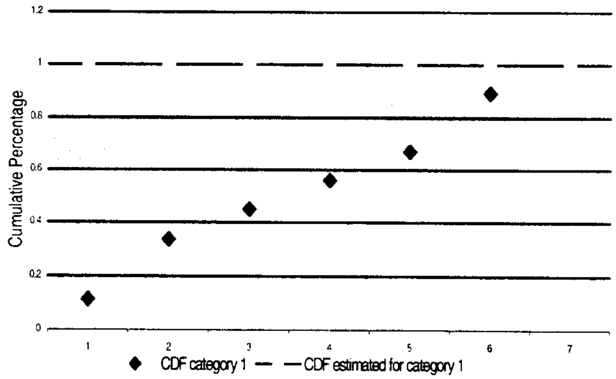


Figure 4.11 Cumulative density and estimated cumulative density for data category 1.

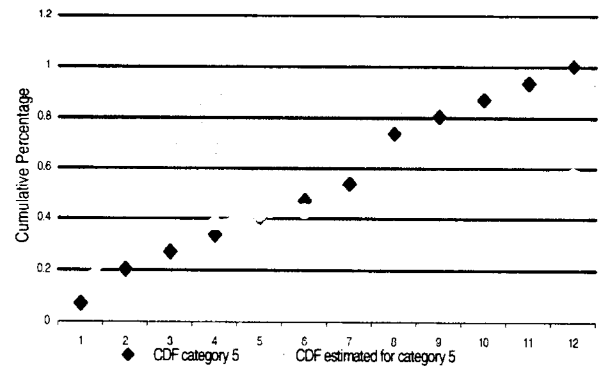


Figure 4.12 Cumulative density and estimated cumulative density for data category 5.

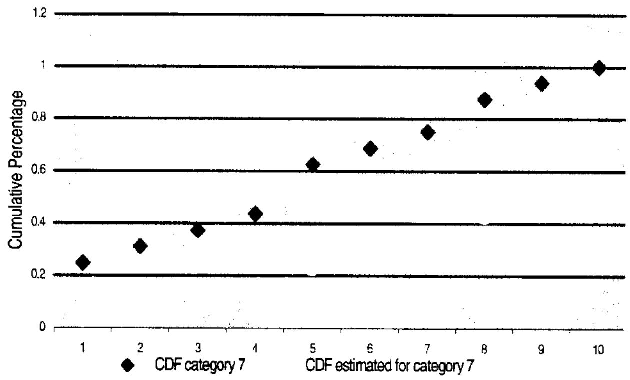


Figure 4.13 Cumulative density and estimated cumulative density for data category 7.

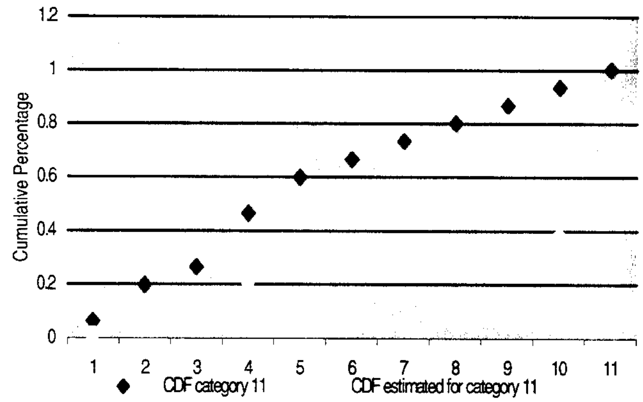


Figure 4.14 Cumulative density and estimated cumulative density for category 11.

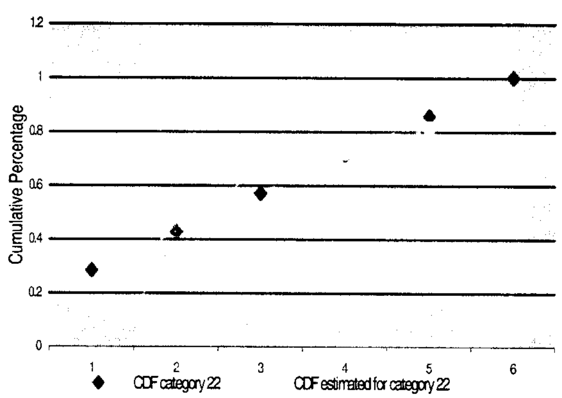


Figure 4.15 Cumulative density and estimated cumulative density for data category 22.

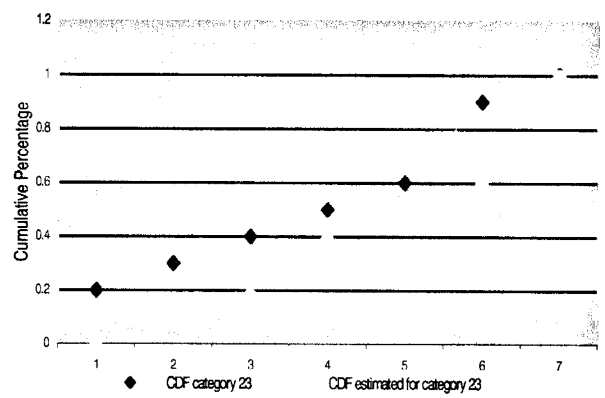


Figure 4.16 Cumulative density and estimated cumulative density for data category 23.

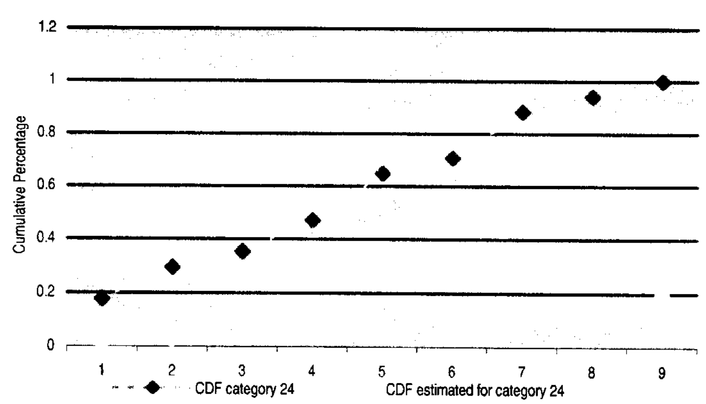


Figure 4.17 Cumulative density and estimated cumulative density for data category 24.

4.2.3 Number of Species

As outlined in the analytical methods, six separate probability functions were used estimate the probability of 1, 2, 3, 4, 5, and 6+ species. All models were closer to the actual number of species than Model 1. Coefficients for Models 2 and 3 are presented in Table 4.11. Table 4.12 summarizes the statistics for Model 2 and Model 3.

Table 4.11 Coefficients for the re-fitted Prognosis NI equation Models (Model 2) and for the best performing variable subset from a variable selection procedure in a logistic equation (Model 3), for predicting probability of number of species on a plot.

	1 species Model		2 species Model		3 species Model		4 species Model		5 species Model		6 species Model	
Variables[a]	2	3	2	3	2	3	2	3	2	3	2	3
Intercept	1.4390	-2.0056	0.7185	-0.5933	0.3683	-0.5891	0.7668	-1.2727	-3.8174	-3.5384	-3.7486	-11.597
x1			0.1697		-0.2103		-0.2920					
x2			0.3234		0.0382		-0.1919					
Slo			0.4410		-0.2295		1.1166					
Asp_r				-0.0101								
Yrsince	-0.0133		-0.0317		-0.0102		0.0074	0.0436		0.0564		0.1425
Elev*	0.0135	0.0012	-0.0366		-0.0189	-0.007		-0.001	0.0188			0.0037
ba_ha**	0.0976	0.0951		-0.0584								
Ntrees			-0.0255		0.0004		0.0023		0.0085		0.0038	
Dhab	-0.2843	-0.3344	-0.042		0.0349		0.2748					1.4502
CCF		-0.0184		0.0125								
Dsitep				-0.5248								2.5333
Ln_TPSP	-1.7757											
TPSP2					-0.0408		-0.1641					

*Elevation for the Prognosis model form was in feet, while it was in meters for the BW model.
**Basal area in the Prognosis model-form was in square feet per acre while it was in square meters per hectare in the BW model.
[a]x1 is defined as COS(ASP)*SLO
x2 is defined as SIN(ASP)*SLO

The statistics indicate that Model 2 is performing slightly better than Model 3 for the probability of one species, two and three species. Differences between Model 2 and Model 3 were less evident for the probability of four and five species, but Model 2 still seemed to perform better slightly better than Model 3. The probability of six species seemed to be better predicted with Model 3. The significance of the variables in both model forms were different; all variables in the variable selection set of equations were significant (α = 0.05) while variables in the Prognosis model form were not all significant.

Table 4.12 Summary statistics for predicting the number of species per plot with the Prognosis NI re-fitted equation (Model 2) and a different subset of site variables (Model 3).

Predicted probability	Model form[a]	R2	-2*log L	AIC	SC	Score
1 species	Model 2	0.37	620.161	632.161	660.336	0.0001
	Model 3	0.0454	956.317	966.317	989.796	0.0001
2 species	Model 2	0.041	922.636	938.636	976.202	0.0037
	Model 3	0.02	940.155	950.155	973.634	0.0030
3 species	Model 2	0.243	819.836	837.836	880.098	0.0078
	Model 3	0.0048	835.891	839.891	849.282	0.0488
4 species	Model 2	0.2027	448.802	464.802	502.369	0.0001
	Model 3	0.0152	619.678	625.678	639.765	0.0018
5 species	Model 2	0.0127	296.308	302.308	316.395	0.0001
	Model 3	0.0056	302.029	306.029	315.421	0.0254
6 species	Model 2	0.0015	186.267	190.267	199.659	0.1194
	Model 3	0.0506	145.531	155.531	179.010	0.001

[a]Variables for each models are presented in Table 4.11 with model coefficients.

Figure 4.18 shows the averaged frequencies of number of species for all three model groups after 1000 iterations using a pseudo-random number, compared to the actual frequency distribution of the number of species per plot. Model 1 had the poorest performance in terms of approaching the actual frequency of number of species per plot. Despite the results in Table 4.11, Figure 4.18 shows that the closest frequencies to the actual frequencies were generated by Model 2.

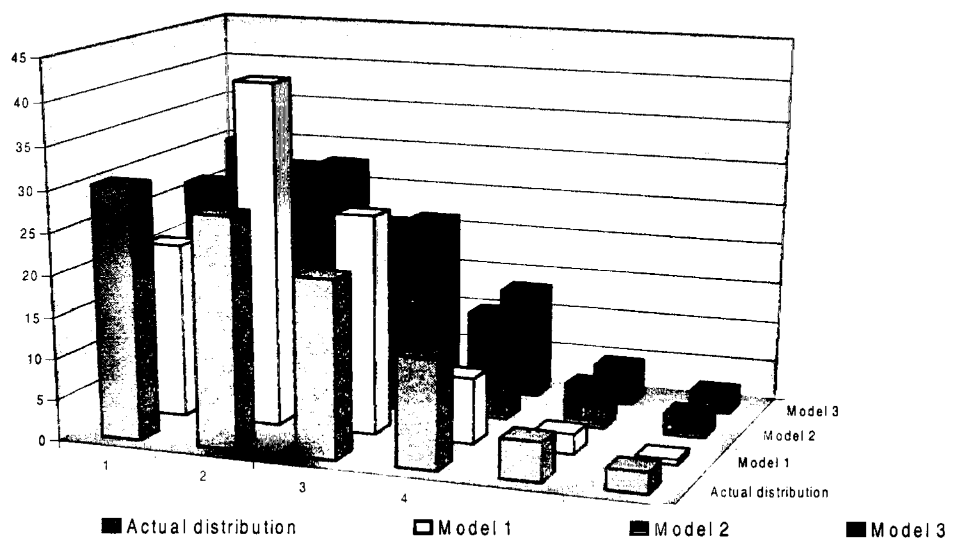


Figure 4.18 Comparison of frequencies of the number of species per plot estimated with three modeling approaches to the actual number of species per plot.

4.2.4 Species Composition

Figures 4.19 and 4.20 compare the results of the Prognosis NI equations (Model 1), the re-fitted Prognosis NI equations (Model 2), and a logistic equation using site variables (Model 3) for estimation of probabilities for each type of regeneration (advanced, subsequent and excess) of Douglas-fir and western redcedar, respectively. These species were chosen as they had the highest number of observations of all the tree species present. They also have different shade tolerances and were expected to display different regeneration patterns.

None of the modeling approaches produced distributions similar to the actual distributions. Model 2 and Model 3 presented the same trends in both cases. The cumulated excess regeneration values from Models 2 and 3 were similar to the actual cumulative values for both species. The cumulated values for the Douglas-fir advanced regeneration resulting from Model 3 were close to the actual values. Douglas-fir subsequent and redcedar advanced and subsequent values were not close to the actual cumulative values for any equations. In all cases, Model 1 produced cumulative values furthest from the actual cumulative values. Cumulative values of actual regeneration and predictions from all three model groups are compared in Table 4.13 for all species.

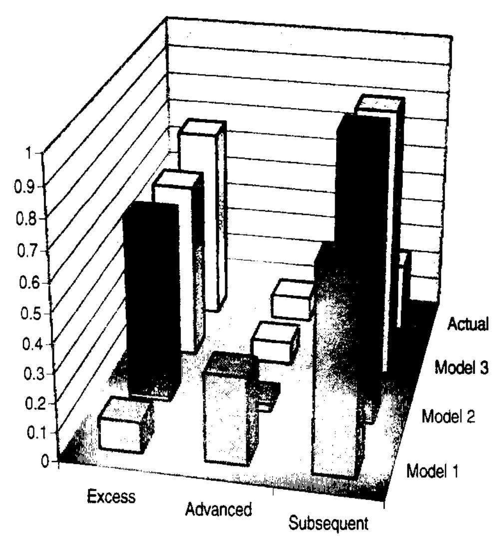


Figure 4.19 Probabilities of advanced, subsequent, and excess regeneration of Douglas-fir.

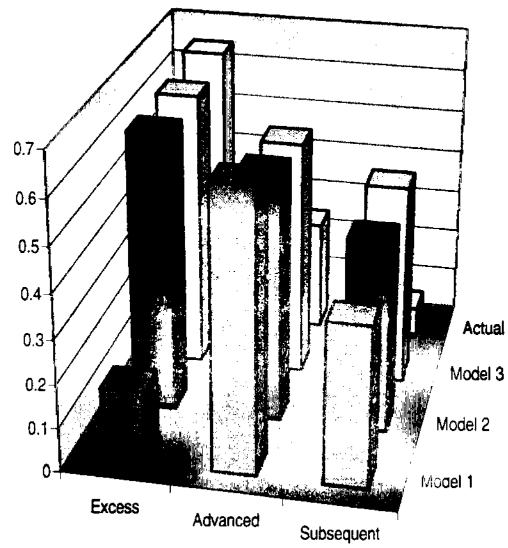


Figure 4.20 Probabilities of advanced, subsequent, and excess regeneration for western redcedar.

Table 4.13 Actual and predicted cumulative values for advanced, subsequent and excess regeneration.

Species	Regen. Type	Actual regeneration	Prognosis NI equation - Model 1	Re-fitted Prognosis NI equation Model 2	Logistic equation with other variables Model 3
	Advanced	0.02381	0.36803	0.167373	0
Bl	Subsequent	0.190476	0.63197	0.832627	1
	Excess	0.785714	0.379231	0.636923	0.779231
	Advanced	0.179245	0.484405	0.497904	0.423394
Bg	Subsequent	0.132075	0.515595	0.502096	0.576606
	Excess	0.669811	0.022857	0.431905	0.421905
	Advanced	0.252022	0.634292	0.563271	0.539769
Cw	Subsequent	0.066038	0.365708	0.436729	0.460231
	Excess	0.652291	0.164255	0.629255	0.630851
	Advanced	0.086116	0.301563	0.028613	0.077668
Fd	Subsequent	0.240773	0.698437	0.971387	0.922332
	Excess	0.667838	0.106757	0.628468	0.609099
	Advanced	0.071357	0.530483	0.342021	0.34266
Hw	Subsequent	0.064322	0.469517	0.657979	0.65734
	Excess	0.81407	0.201169	0.636234	0.642597
	Advanced	0.030303	0.227875	0.081451	0
Lw	Subsequent	0.353535	0.772125	0.918549	1
	Excess	0.616162	0.010345	0.496207	0.496552
	Advanced	0.033333	0.004693	0.003315	0
Pl	Subsequent	0.361111	0.995307	0.996685	1
	Excess	0.511111	0.005556	0.329556	0.432889
	Advanced	0.054187	0.004652	0.092098	0.032465
Pw	Subsequent	0.197044	0.995348	0.907902	0.967535
	Excess	0.650246	0.04463	0.646111	0.595
	Advanced	0.047619	0.207931	0.446281	0.025988
Sx	Subsequent	0.166667	0.792069	0.553719	0.974012
	Excess	0.571429	0.0165	0.516	0.519

The coefficients for Model group 2 and Model group 3 are presented in Appendix 4. The maximum likelihood estimates for some of the Prognosis NI re-fitted equations (Model group 2) presented complete or quasi-complete separation of data point (equations for grand fir, advanced subalpine fir, hemlock, advanced white pine, and spruce). Estimates using Model group 3 presented the same problem for the advanced regeneration of grand fir. Even a one-variable model, with any site-variable or transformation of site variable, resulted in separation of the grand fir data. Table 4.13 presents all the estimates for Model group 2, regardless of data separation. A two-variable model was used for grand fir advanced regeneration that resulted in quasi-complete separation of data points.

The non-conclusive analysis of maximum likelihood estimates for certain data categories for both Model group 2 and Model group 3 could result from the low number of observations for regeneration of certain species. For example, grand fir had only 13 observations. A backward stepwise variable selection procedure with 11 variables results in an over-specified model; hence, non-conclusive maximum likelihood estimates.

4.2.5 Germination Delays

Predictions of germination delay using the Model 2 were consistently closer to the actual cumulative density of germination delay than the cumulative density of germination delay estimated using Model 1. Figure 4.21 shows the actual cumulative density of germination delay and the predictions for advanced Douglas-fir regeneration using Model 1 and Model 2. Advanced Douglas-fir was chosen because it had cumulative delay predictions using Model 1 closest to the actual cumulative distribution for all regeneration categories (advanced or subsequent). The NLLS estimates of Weibull parameters (Model 2), for each species with more than 20 observations, are presented in Appendix 5. Graphs comparing actual cumulative densities, cumulative densities predicted with Model 1, and cumulative densities predicted with Model 2, for all species, are presented in Appendix 6.

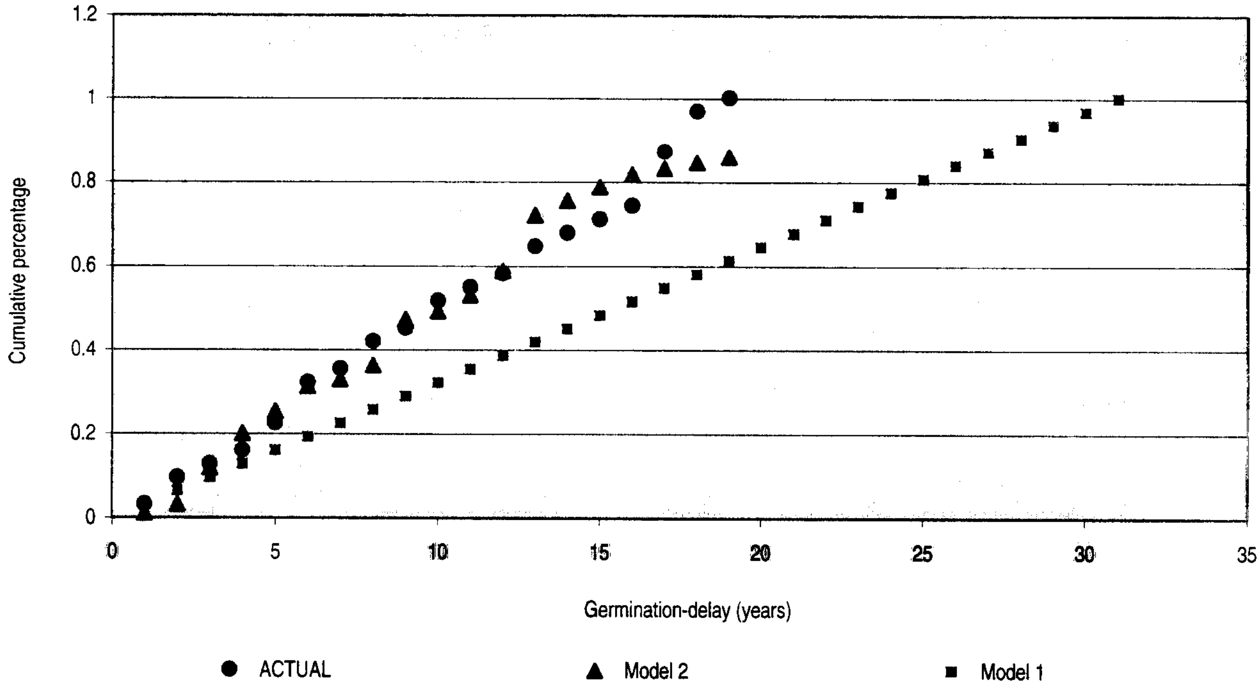


Figure 4.21 Cumulative density distribution of actual, Prognosis NI equation (Model 1), and re-fitted Prognosis NI equations (Model 2)estimates of germination delay for Douglas-fir regeneration.

Cumulative density distributions of germination delay estimates for data categories with above 20 observations (11 categories) were all very close to the actual density distribution using Model 2. These include germination delay for advanced and subsequent western redcedar, advanced and subsequent Douglas-fir, advanced and subsequent hemlock, subsequent subalpine fir, subsequent larch, subsequent lodgepole pine, subsequent white pine, and subsequent spruce.

4.2.6 Seedling Height

Some tree species for which height prediction equations were developed in Prognosis NI had only a few observations in the Nelson data set. Despite this lack of data, the Prognosis NI equations (Model 1) were applied and re-fitted (Model 2) for each species for subsequent and advanced regeneration. Model 3 was only applied to categories with more than 10 observations (13 out of 18 categories). The number of observations per species and regeneration type, are presented in Table 4.14.

Table 4.14 Number of observations of height for advanced and subsequent regeneration by species.

Species	Number of Observations Advanced	Subsequent
Bg	1	16
Bl	10	24
Cw	80	83
Fd	31	140
Hw	50	76
Lw	2	36
Pl	6	72
Pw	6	69
Sx	6	26

Figure 4.22 shows the residuals (actual - predicted) for height predictions against the actual heights of advanced western redcedar; predictions were made using Model 1, 2, and 3. Graphs comparing residuals for all other species are presented in Appendix 7.

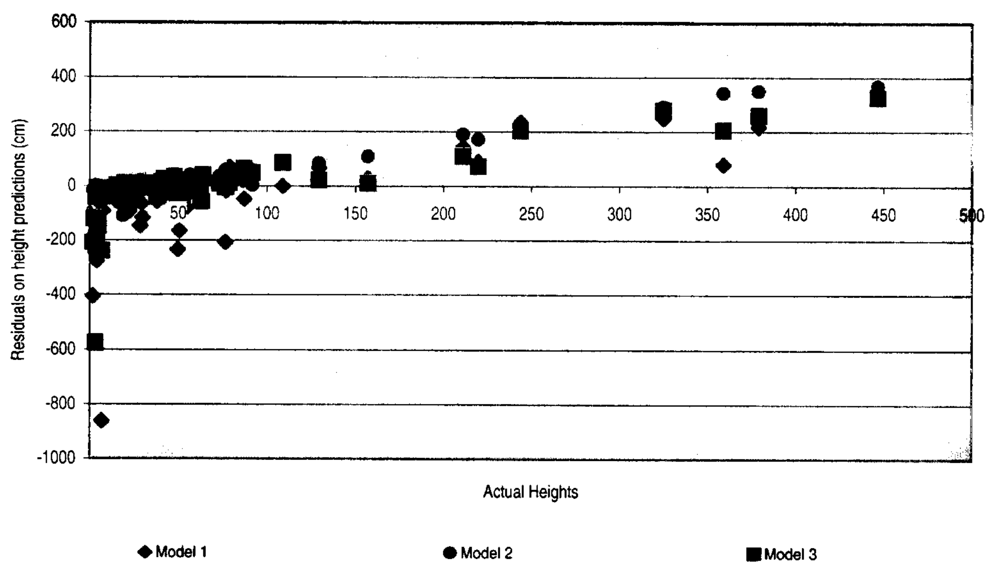


Figure 4.22 Comparison of height prediction residuals from Model 1 (Prognosis NI equation), Model 2 (re-fitted Prognosis NI equations) and Model 3 (linear equation with site variables) of advanced western redcedar.

Height predictions from Model 2 for data categories with less then 10 observations were all closer to the actual heights than those from Model 1. These categories were advanced regeneration of grand fir, larch, white pine, lodgepole pine, and spruce. Model 2 for advanced grand fir, larch, and white pine did not present unique solutions for least squares estimates. Of the categories with above 10 observations, only Model 2 for subalpine fir advanced regeneration did not present unique solutions to OLS estimates. Height predictions for advanced and subsequent subalpine fir, advanced hemlock, subsequent lodgepole pine, and subsequent larch were closer to the actual heights when Model 3 was used. Height predictions using Model 3 were only slightly closer to the actual heights than those from Model 2 for advanced western redcedar, advanced Douglas-fir, subsequent grand fir, subsequent western redcedar, Douglas-fir, hemlock, and spruce. The coefficients and analysis of variance for Model 2 and Model 3 are given in Appendix 8.

Prediction models for height of excess regeneration were compared based on the number of trees in each height class. Figure 4.23 shows a comparison of the number of trees per height class for excess regeneration for western redcedar. Graphs for other species are given in Appendix 9. Coefficients for height of excess regeneration equations are presented in Appendix 10.

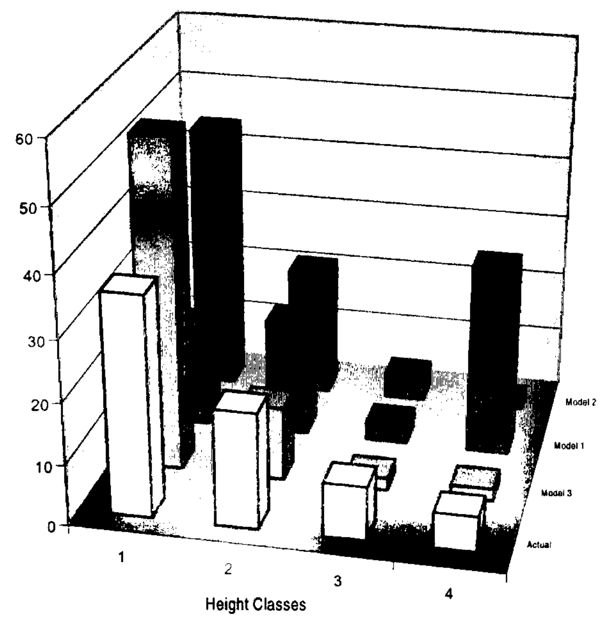


Figure 4.23 Comparison of models of height of excess regeneration for western redcedar.

Figure 4.23 indicates that Model 2 (re-fitted Prognosis NI equation) is closer to the actual distribution of heights than Model 3 (linear model) or 1 (Prognosis NI equation). Model 1 had the poorest performance of all models for all 9 species. The western redcedar, Douglas-fir, hemlock, larch, and white pine distributions using Model 2 were all closer to the actual height distribution than Model 3. Model 3 predictions were closer to the actual heights for grand fir, subalpine fir, lodgepole pine, and spruce.

4.3 Small Tree Height Growth

Variables and statistics presented in Table 4.15, and Table 4.16 are in metres unless otherwise indicated. Natural logarithm units are indicated with an asterisk. Table 4.15 summarizes the statistics for Model 1 and Model 2 predictions.

Table 4.15 Summary of predictions of height growth of small trees by species and tolerance groups using Model 1 (Prognosis NI equation) and Model 2 (re-fitted Prognosis NI equation) for species with more than 25 observations and species by tolerance groups.

Species or Group	n	Model	R^{2*}	I^2	SEE (m)
Cw	93	Model 1	N/A	-1.194	0.450
		Model 2	0.320*	0.241	0.265
Fd	44	Model 1	N/A	-0.204	1.006
		Model 2	0.526*	0.372	0.727
Hw	55	Model 1	N/A	-0.207	0.586
		Model 2	0.211*	0.226	0.469
Pl	38	Model 1	N/A	-0.912	1.116
		Model 2	0.493*	0.429	0.610
Tolerant	165	Model 1	N/A	-0.202	0.480
		Model 2	0.266*	0.193	0.393
Intermediate	57	Model 1	N/A	-0.680	0.967
		Model 2	0.531*	0.775	0.414
Intolerant	44	Model 1	N/A	-0.756	1.093
		Model 2	0.462*	0.834	0.336

*Values are in natural logarithmic units (ln m).

The negative I^2 values associated with all of the species and tolerance groups for the equations with Model 1 are a strong indicator of poor performance (Table 4.15). Negative I square values result from the variance of the residuals being larger than the variance of the total regression for that equation. Graphs of the residuals by species and tolerance group (Appendix 11) for Model 1, indicate that 5-year height growth was overestimated on average. Refitting these equations to the data (Model 2) improved equation performance. Graphs of the residuals by habitat series (Appendix 11) for Model 2 show that 5-year height growth estimates were no longer biased. SEE from Model 2 were lower and the I^2 values higher for Model 2. With the exception of western redcedar, which had the most height growth observations of any single species, the standard errors of the re-fitted equations for the tolerance groups were lower than those of the single species. This may be due, at least in part, to the larger number of observations for each of the tolerance groups. However, the fits obtained remained moderate at best, with R square values ranging from slightly above 0.2 to slightly above 0.5.

Summary statistics and variables used in Models 3-1 and 3-2 are presented in Table 4.16. Models 3-1 and 3-2 have different dependent variables (ln(HTG) and HTG) and different predictor variables for each tolerance class. For the tolerant and intermediate groups, the fit obtained was slightly better than that of Model 3, based on lower standard errors of estimate. For the intolerant group, the fit was slightly poorer than that obtained using Model 2. Prognosis NI does not use tree age nor years since disturbance of site as predictor variables. When these were removed (i.e., Prognosis NI variables only were used) predictions were not as good for all three tolerance groups. Residuals for models using the natural logarithm of height growth as a dependent variable are presented in Appendix 12. Coefficients for the models in Table 4.16 are presented in Appendix 13. Height growth used as a dependent variable yielded better values for I^2 or R^2 for tolerant and intolerant species, while using the natural logarithm of height growth as a dependent variable had a higher I^2 value intermediate shade tolerance group.

Table 4.16 Summary of the resulting height growth model form and fit from Model 3.

Group	n	Model form	R^{2*}	I^2	SEE (m)
		Prognosis variables			
		Ln(HTG) = F(dspp1-2-3-4, dbh, ln(ht), dss1-2-3-4, elev., slope, ccf)	0.491*	-0.357	0.522
		HGT = F(dspp1-2-3-4, dbh, ln(ht), dss1-2-3-4, aspect, elev., slope, ccf, sin_asp)	0.502		0.317
Tolerant	**165**	**Site variables**			
		Ln(HTG) = F(dspp1-2-3-4, ln(ht), age, dss1-2-3-4, elev., slope, ccf)	0.622*	0.582	0.290
		HTG = F(dspp1-2-3-4, ln(ht), age, time, dss1-2-3, slope, ccf, cos_asp)	0.617		0.280
		Prognosis variables			
		Ln(HTG) = F(dspp1, dhb, dss1-2-3, aspect, slope, ccf, cos_asp, sin_asp, x1, x2)	0.702*	-16.4975	3.57907
Intermediate	**57**	HTG = F(dspp1, dbh, aspect, ccf, sin_asp, x2)	0.601		0.551
		Site variables			
		Ln(HTG) = F(dbh, age, time, ccf)	0.880*	0.861	0.319
		HTG = F(dbh, age, time, aspect, elev., ccf, cos_asp, sin_asp)	0.821		0.377
		Prognosis variables			
		Ln(HTG) = F(dbh, dss1-2-3, aspect, slope, ccf, cos_asp, sin_asp, BALM-100, x2)	0.790*	0.654	0.499
Intolerant	**44**	HTG = F(dbh, dss1-2-3, aspect, slope, ccf, cos_asp, sin_asp, BALM-100, x2)	0.704		0.482
		Site variables			
		Ln(HGT) = F(dbh, age, dss1-2-3, cos_asp, sin_asp, x2)	0.858*	0.741	0.456
		HGT = F(dbh, age, dss1-2-3, cos_asp, sin_asp, ln(ht), x2)	0.769		0.421

*Values are in natural logarithm of metres units.

A substantial proportion of the height growth data was obtained from advanced regeneration. Table 4.17 outlines the proportion of advanced regeneration by species and species groupings.

Table 4.17 Proportion of advance regeneration in the small tree height growth observations.

Species or Tolerance Group	n	Proportion of Advanced Regeneration
Cw	93	0.989
Fd	44	0.568
Hw	55	0.964
Pl	38	0.263
Tolerant	165	0.952
Intermediate	57	0.526
Intolerant	44	0.295

Chapter 5: Discussion

The regeneration components and the small tree height growth equation of Prognosis NI were tested against the Nelson data. In all cases, the refitted equations or other tested model forms performed better than the Prognosis NI equations. Performances varied with the equation. Identifiable errors and biases in the calibration efforts stem from two major sources: the nature of Prognosis NI itself and the Nelson data set.

As previously stated, Prognosis NI was developed in the United States and uses a site classification system to represent site productivity. The true factors determining site productivity are poorly understood and very difficult to measure (Monserud 1987). The use of a classification system is just one method of estimating site quality. Like all other methods, it has advantages and disadvantages (Carmean 1975, Klinka 1990, Thrower and Willing 1996). To date, no method perfectly estimates site productivity. They all may transmit errors to the growth models that use them.

Further, the equations presented here use correspondences between BC site series and Idaho habitat types (Robinson 1997). Despite the similarities in the classification systems, the criteria for site classifications in both systems result in different sites (i.e., no site referred to as a specific habitat series corresponds exactly with a site series in the BEC). For example, the ICHmw2 site series of the BEC system ranges from dry to wet in the following order: 02, 03, 04, 01, 05, 06, 07 and 08. The mesic site series were targeted in this project: 03 to 05. These correspond to three different habitat types, which in Prognosis NI, are grouped in two habitat series. This separates the Nelson into two data sets, one per habitat series. One habitat series (the Douglas-fir habitat series) contains one sampled site series (ICHmw2 03), while the other (the Cedar-Hemlock habitat series) encompasses all other sampled site series (ICHmw2 04, 01, 05, 06). The site classification system is used in Prognosis NI to represent site productivity. The separation employed does not adequately represent the variance in site productivity between site series. The variability between site series 03 and site series 04 is not greater than the variability between site series 04 and 01 nor greater than the difference between site series 05 and site series 06. Introducing dummy variables into the Prognosis NI equations to represent site series might have captured some of the residual variability. However, site series and habitat series correspondence needs to be perfected if site productivity is to be represented by a site classification system.

The Nelson data set is much smaller and slightly different than the data set used in calibrating the original Prognosis NI equations. One hundred and eighty six plots were established over the data collection phase. The data set used for developing Prognosis NI was comprised of large inventory databases. Height of advanced regeneration equations, for example, were developed with 5,649 observations of advanced regeneration seedlings, while the Nelson database had only 192. Some data categories used in the Prognosis NI model had more predictor variables than the number of observations in the corresponding data category in the Nelson data set. This lack of data sometimes caused non-conclusive least squares or maximum likelihood estimates or non-robust models.

Plots were selected from sites that had been disturbed in the last two to 20 years. Most of the sites were partially cut. These sites do not represent all possibilities of regeneration for the species modelled. Partially cut sites imply a certain amount of shade; regeneration of shade intolerant species was probably not well represented. Further, management practices might have contributed to changing the probability of establishment of some species. For example, larch regeneration is purposely not encouraged in areas infected with larch mistletoe.

Partial cutting is a relatively recent method of harvesting in the Nelson region; 53% of plots had been disturbed in the last seven years. This might result in a low representation of tolerant species with slow ingress. Partially cut areas are not site-prepared because of possible damage to the residual stems when using common site preparation methods. Representation of species that require disturbed seedbeds for germination is therefore low. Partial cutting systems are harder to implement on steep slopes, consequently most of the plots were on slopes between 20% and 60% and were in a mid-slope topographic position. This plot distribution did not include steep drier slopes or wetter site sites. The species that would have captured growing space on these sites were more than likely not well represented in the data set.

Similarly, the range of small trees measured does not represent the complete range of conditions. Individual tree growth varies with the species mixture and is influenced by the structure of the residual stand. For example, seven-year-old sites do not necessarily represent the mix of small trees on a 20-year-old site.

Hardwoods are an important part of stand dynamics and may even have a more important role in mixed species stands than in stands dominated by one or a few tree species (Clinton *et al.* 1994, Ishiwaka and Ito 1989, Kneeshaw and Bergeron 1996, Monserud 1987, Oliver and Larson 1996). However, hardwoods were not modelled in Prognosis NI or Prognosis^{BC}. This decision was mostly founded on the fact that hardwoods are not currently considered as commercial species in most of British Columbia and Prognosis^{BC} is being developed for timber supply purposes. Balsam fir (*Abies balsamea*) was considered a weed species in eastern north America as little as 30 years ago and is now one of the leading commercial species in eastern Canada; hardwoods in western Canada might become important as commercial species with the diminishing supply in old growth timber. Further, adequate representation of how multi-cohort and/or mixed species stands develop cannot be complete or accurate without all the factors, including hardwood trees.

Despite these general concerns, the equations resulting from this calibration process provide better estimates of small tree height growth and regeneration in multi-cohort and mixed species stands in the southern interior of BC than were previously available. Equations for both components are examined individually in the following text.

The regeneration modelling approach of Prognosis NI predicts the probability of stocking, the number of trees per plot, the species composition, the probability of regeneration types (advanced, subsequent, and excess), the germination delay for subsequent regeneration, the age of advanced regeneration, and the height of seedlings. In this study, data were modelled by habitat series, or by a combination of habitat series and species or site characteristics, similar to the approach used in Prognosis NI. Regeneration was very variable. Many factors drive regeneration; each of the factors are themselves variable (Clinton *et al.* 1994, Kneeshaw and Bergeron 1996, Oliver and Larson 1996). Only a very large and wide-ranging data set can capture that variability and produce an accurate regeneration model. The major problem for all regeneration equations presented here is the lack of data. Nevertheless, some of the regeneration equations performed adequately.

The probability of stocking was best predicted using a logistic equation with a subset of site variables resulting from a maximum likelihood variable selection procedure, for both habitat type groupings. Although linear model forms were tested, the actual distribution of a binary response for the probability of stocking is expected to follow more closely a logistic form than a linear form. The best logistic equation for predicting stocking differed for each habitat type grouping. The probability of stocking for habitat type PSME, which only includes site series 03 of the BEC system, was better predicted with the re-fitted Prognosis NI equation. The probability of stocking for the THPL/TSHE habitat types, which include all other site series in the Nelson data set, was better predicted with the logistic equation using a subset of site variables resulting from a variable selection procedure. These models were the best of the calibrated models, and did not seem to include any biases. However, the better fit of the Prognosis NI equation for site series 03 might just be a reflection of better correspondence between a PSME habitat type and a site series 03 than THPL/THSE habitat types and site series 04, 01, 05, and 06.

The number of trees per stocked plot was modelled using a cumulative density distribution (Weibull function). The Prognosis NI equation had the poorest performance in terms of approaching the actual frequency of number of species per plot. Weibull parameters, determined with NLLS, were predicted for data categories that had more than 20 observations using linear models (16 out of 24 possible data categories). The best performing model for the *B* and *C* Weibull parameters resulted from a linear model using a subset of site variables from a variable selection procedure. These models were then re-fitted using two approaches: a joint-generalized least squares approach and by NLLS within the Weibull function. When compared to the actual cumulative density of trees per stocked plot, both models were acceptable for all 16 data categories tested. However, none of the models performed well for categories with less than 20 observations. Extrapolation of these models to data-categories with less than 20 observations did not produce cumulative density functions comparable to the actual cumulative density functions in any of the seven data categories with less than 20 observations. Although this might be a result of insufficient observations or non-representative sampling, extrapolation of these refitted models have not proven suitable other than for data categories used in calibration.

The number of species was determined with separate probability equations for one, two, three, four, five, and six or more species. Separately predicting these probabilities might not reflect the real probability of a certain number of species occurring on a plot. The probability of two species occurring on one plot is dependent on one species occurring, the probability of three species is dependent on the probability on two, and so on. Other modelling approaches, like discriminant analysis, might take into account the multivariate context in which the number of species per plot occurs. Consequently they may better reflect the real probability of a particular number of species occurring. Logistic equations, with a subset of site variables from a maximum likelihood variable selection process, estimated the number of species very closely to the actual cumulative distribution of the number of species. The performance of the refitted Prognosis NI equations was also very close to the actual cumulative distribution. However, this was not evident when the statistics were examined.

For predicting the probabilities of all three types of regeneration, the refitted Prognosis NI equation and the logistic equation using site variables showed similar trends; both performed better than the Prognosis NI equation. However, none of the equations produced distributions similar to the actual distribution, especially with respect to subsequent regeneration, where all the approaches overestimated the probability. The situations where predicted cumulative values approached the actual cumulative values were for the probability of advanced regeneration of Fd/Pw/Sx, the probability of excess regeneration of Bg/Hw/Bl/Lw/Pl/Sx predicted with a logistic equation using site variables, and the probability of advanced regeneration of Lw and probability of excess regeneration of Cw/Pw/Fd predicted with the re-fitted Prognosis NI logistic equation. This might be the result of insufficient observations or sampling. Advanced and excess regeneration might also simply be better represented in stands disturbed within the last two to seven years than subsequent regeneration.

Predictions of germination delay for subsequent regeneration and age of advanced regeneration were made using a cumulative density function (Weibull function) for data categories with more than 20 observations. For these 11 categories, the cumulative density for the germination delay from the re-fitted Prognosis NI functions were all close to the actual density distribution.

The best height predictions for most advanced and subsequent regeneration resulted from a linear model that used a subset of site variables resulting from a variable selection procedure. Height of excess regeneration was estimated equally well by the refitted Weibull function used in Prognosis NI and the linear equation with a subset of site variables, depending on the species. The re-fitted Prognosis NI equation for predicting height of advanced and subsequent regeneration did not present unique solutions for the ordinary least squares estimates when there were insufficient data for the number of variables in the Prognosis NI model form. These models should be re-fitted with more data and compared to the height estimates from the linear equation with a subset of site variables. The Weibull functions, used in Prognosis NI for predicting of height of excess regeneration, did not result in adequate predictions for estimating of heights of excess regeneration for the Nelson sites. Weibull functions fitted to the data performed better for height estimates of excess regeneration of western redcedar, Douglas-fir, hemlock, larch, and white pine. The linear model resulting from the variable selection process is recommended for estimating height of excess regeneration of grand fir, subalpine fir, and spruce. The early stages of height growth, when many species occur on a plot, might be more accurately represented in a multivariate context, since all species present have an affect on the height growth of the neighbouring species. The height growth of all species could be predicted simultaneously, in a multivariate approach, from site factors.

Versions of Prognosis used in other areas of the U.S. have proven effective for modelling regeneration (Stage 1998, pers. comm.)[6]. Different model forms might also improve predictions of regeneration and early growth in multi-cohort, mixed species stands (Clinton *et al.* 1994, Fröhlich and Quenan 1995, Ishiwaka and Ito 1989).

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[6] Dr. Albert Stage, Retired Scientist, USDA For. Serv., Interm. Res. Sta., Moscow, ID.

The small tree height growth equation in Prognosis NI is a linear prediction of the natural logarithm of height growth. In the Nelson data, only four species had more than 25 observations of small tree height growth. Therefore, small trees were grouped by shade tolerance levels to provide sufficient data for model calibration. For the tolerant and intermediate tolerance groups, the best performing height growth equation for small trees was a linear model using a subset of site variables from an OLS variable selection procedure. The re-fit Prognosis NI equation performed best for the intolerant group. In the small tree height growth equations for the Prognosis NI equation, tree age and time since disturbance are not used for height predictions since this information was not available in the inventory data used for model building. Linear equations using both the same set of variables as Prognosis NI, and a set of variables including tree age and time since disturbance, were compared. Even though the resulting model using age and time since disturbance performed better the one that did not include these variables, Prognosis^{BC} might be accessible to a larger audience if the equation without these variables was used. These variables are not easily measured in the field and most existing data sets will not contain this information.

Improvements to the fit of the small tree height growth equations could possibly be obtained if more data were available. Different forms of prediction equations could also yield better height predictions. The variable selection procedure did this, but only for linear equation forms.

A possible confounding factor specific to the small tree height growth data is that a substantial proportion of the height growth observations in the test data was obtained from advanced regeneration. The data set for the small tree height growth equation in Prognosis NI consisted mainly of height growth of trees that regenerated following a disturbance (Stage 1998, pers. comm.). Although predictions were poor, the re-fit Prognosis NI equation performed the best for the shade intolerant group, where 70% of the trees regenerated subsequent to disturbance. This suggests that the Prognosis NI model form applied to other species groupings might still produce good height estimates for trees regenerated post-disturbance. It may also be beneficial to estimate the height growth of small tree advanced regeneration separately from that of trees that regenerated post-disturbance. Not enough data from trees that regenerated subsequent to disturbance were available to examine this possibility.

Using height growth as a dependent variable seemed to produce a better model than using the natural logarithm of height growth for tolerant and intolerant species groupings, while the natural logarithm of height growth seemed to produce a better model for the intermediate tolerance species. This can be attributed to the different height growth patterns of different species even in the early stages of height growth. Most height growth models use the natural logarithm of height as a dependent variable (Goesler and Hasenauer 1997, Froese 1997). However, for both the small tree height growth equations and the height of regeneration equations, only a portion of the total growth of tree height is being modelled. A number of non-linear height growth functions are described in the literature (Favrichon 1998, Gosler and Hasenauer 1997, Huang and Titus 1994 and 1992) and some of these may prove more applicable to these data than the equations that were tested.

Existing models, like Prognosis NI, are important tools as they present a quantified view of how forests or stands grow and change. However, models are rarely mobile; they produce relatively accurate scenarios only for the area in which they were developed and within the range of data used for calibration. The more growth factors encompassed by variables within the model, the more plausible the application of the model to another geographic area. If the target area is very similar to the original area, the model might be applicable in its original form. However, as the case was in this paper, forest and stands are variable and rarely have the exact same growth pattern in different geographic areas. The refitting of a model then becomes the best option. However, growth patterns, species dynamics, and sometimes management approaches need to be similar between stands for which the model was originally developed and the stands that the model is being calibrated for. If this similarity does not exist, perhaps a completely different modelling approach would be more suitable.

Like any model, Prognosis^{BC} should be used with caution; it is only a model and should be used for guiding decisions, not of making decisions. The context in which the model is calibrated and the logical foundation of the model need to be well understood by users. The data used for calibration also indicate the limitations of the model. The Prognosis NI equations presented in this thesis were calibrated to the Nelson data. These equations were not tested on independent data. More testing is required to validate the Prognosis^{BC} equations. The level of testing required is dependent on how comfortable the users are with the state of the Prognosis^{BC} equations. Goudie (1997) states that a model is never validated; it is only tested to a level at which users are comfortable with. Validating a model would imply that it is a perfect representation of reality, and models are not.

Monserud (1987) did not view modelling regeneration as a conceptually difficult problem. The processes leading to the establishment of a seedling are fairly well understood. The main hurdle is that a good regeneration or early growth model would require an excellent and extensive experimental design that results in sampling the full range of important factors. In irregular stands, this simple statement becomes a difficult achievement. Various species in these stands usually respond differently to a given set of environmental factors. Species-specific models that consider both time and space of individual trees would be ideal. However, the problem of site productivity estimation remains. The solution might reside in changing the way we see the forest. In reality, each tree has its own growth curve dependent on species, site, stand structure, and where the tree sits in terms of that stand's particular structure. It comes down to finding a suitable balance for each stand, within each landscape, for each region, based on each tree as an individual production unit. Ecosystems are dynamic through these individual production units and through disturbances. Humans are part of this ecosystem, contributing another source of change. Thus, regeneration modeling is difficult to do well in practice despite its simplicity in concept. Processes like the calibration of Prognosis NI for the southern interior of BC permits a better understanding of the dynamics of that ecosystem. Through data collection and observation of the growth of individual trees in various conditions in this ecosystem, more is learned about changes through time and space of these stands.

Prognosis NI was built on many years of experience, involving a pooling of expert and professional minds. It has proven effective for modelling irregular stands. The logic it uses is an important source of information for building other models elsewhere. However, geographically displacing a model may introduce many errors and biases. Perhaps using the same logical paths, but re-developing equations based on systems and data available to the targeted area, would avoid many of these errors and biases. This approach would yield a model that encounters local problems to which local solutions could possibly be applied. Another approach is to apply the site classification system used in Prognosis NI (Cooper *et al.* 1975, Pfister *et al.* 1977) as the site classification in the targeted area, so that data are collected in units of land that are comparable to those for which the model was developed. Prognosis NI was developed with a high dependency on the Idaho and Montana site classification. Successfully transferring that dependency to other geographical areas classified on different variables, especially when site productivity estimates within the model depend on land classification, is difficult.

Chapter 6: Conclusion

The main objective of this thesis was to calibrate the basic equations of the early height growth and regeneration components of Prognosis NI for the southern interior of BC. In summary, all the small tree height growth equations performed poorly for the individual tree species modelled (Cw, Fd, Hw, Pl); pooling of species in tolerant groups improved the performance of the re-fitted model. The best performing model was the re-fitted Prognosis NI equation for the intolerant species grouping; this is also the group were most trees were regenerated subsequent to disturbance. Advanced regeneration did not seem to respond as the Prognosis model implied; their height growth was better predicted with an equations based on selected variables.

The regeneration equations need to be validated with more data. The plot distribution does not present the entire range of site series or species mixtures. Some of the calibrated equations presented in this thesis are appropriate for use in Prognosis^{BC} and others are not. Table 6.1 briefly outlines equations that were assessed as best performing based on this research, and comments on the use of these equations in Prognosis^{BC}.

Table 6.1 Summary of equations and recommendations for use in Prognosis^{BC}.

Prognosis Component	**Data grouping**	**Best performing model**	**Use in Prognosis^{BC}**
Small tree height growth	Tolerant	Variable selection - OLS	Acceptable within the range of sampled sites and trees
	Intermediate	Variable selection - OLS	Acceptable within the range of sampled sites and trees
	Intolerant	Prognosis refitted	Acceptable within the targeted population [a]
Regeneration			
Probability of stocking	03 site series	Prognosis refitted	Acceptable within the targeted population
	other site series	Variable selection logistic model - maximum likelihood	Acceptable within the targeted population
No. of trees per plot	groupings > 20 obs.[b]	Weibull parameters with SUR estimations or NLLS estimates within the Weibull	Acceptable within the range of data groupings calibrated
	Others	No model performed adequately	No model tested was acceptable
No. of species per plot	Prob. of 1 to Prob. of 6	Variable selection logistic model - maximum likelihood	Acceptable within the range of sampled sites

Table 6.1 Summary of equations and recommendations for use in Prognosis^{BC} (continued).

Prognosis Component	**Data grouping**	**Best performing model**	**Use in Prognosis^{BC}**
Probability of advanced regeneration	Fd/Pw/Sx	Variable selection logistic model - maximum likelihood	Acceptable within the range of sampled sites
	Lw	refitted Prognosis	Acceptable within the range of sampled sites
	Others	No model performed adequately	No model tested was acceptable
Probability of excess regeneration	Bg/Hw/Bl/Lw/ Pl/Sx	Variable selection logistic model - maximum likelihood	Acceptable within the range of sampled sites
	Cw/Pw/Fd	refitted Prognosis	Acceptable within the range of sampled sites
Probability of subsequent regeneration	All species	No model performed adequately	No model tested was acceptable
Germination delay	11 combinations of Sps/regen. type[c]	refitted Prognosis (Weibull) - NLLS	Acceptable within the range of sampled sites
Height of advanced regeneration	Bl/Hw/Cw/Fd	Variable selection - OLS	Acceptable within the range of sampled sites
	Others	No model performed adequately	No model tested was acceptable
Height of subsequent regeneration	Bl/Hw/Cw/Fd Pl/Lw/Bl/Sx	Variable selection - OLS	Acceptable within the range of sampled sites
	Others	No model performed adequately	No model tested was acceptable
Height of excess regeneration	Cw/Fd/Hw/Lw Pw	refitted Prognosis (Weibull) - NLLS	Acceptable within the range of sampled sites
	Bg/Bl/Sx	Variable selection - OLS	Acceptable within the range of sampled sites
	Others	No model performed adequately	No model tested was acceptable

[a] Extrapolation to the targeted population are based on the assumptions that sites of with the same ecosystem classification designation and site characteristics will respond in the same way.
[b] See table 4.8, shade categories
[c] See p44.

The regeneration and small tree height growth approaches incorporated in Prognosis NI appear to be applicable to sites in the ICHmw2 in the southern interior of BC. However, these approaches will need to be tested (and possibly recalibrated) using a much broader data base before Prognosis^{BC} will be ready for use on all southern interior sites.

The same caution applies to Prognosis^{BC} as to any model: they are only models of reality and carry biases. Nevertheless, once it is available, Prognosis^{BC} should improve predictions for multi-cohort and/or mixed species stands in the southern interior of BC. Prior to the calibration efforts for Prognosis^{BC}, no quantitative tools were in place to aid silviculturists in their predictions in these irregular stands. More data and localization of some of the equations should remedy most errors and biases discussed in this text. Work continues on calibrating the various components of Prognosis^{BC} for use on a variety of different sites and conditions. The equations produced in this thesis represent an improvement over the existing equation forms and coefficients and can serve to supplement and guide silvicultural decisions in irregular stands in the ICHmw2.

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APPENDIX 1: Number of trees per stocked plot.

Using Ordinary Least Squares (OLS) for linear estimation of scale and shape parameters of the Weibull function.

Using Ordinary Least Squares (OLS) for linear estimation of scale and shape parameters of the Weibull function.

Ordinary Least Squares Estimation of Natural Logarithm of C

Model: LOG_C
Dependent variable: LOG_C

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	10	13.18299	1.31830	60.283	0.0001
Error	709	15.50482	0.02187		
C Total	719	28.68781			

Root MSE	0.14788	R-Square	0.4595
Dep Mean	-0.10496	Adj R-SQ	0.4519
C.V.	-140.88946		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	1.528704	0.081206	18.825	0.0001
MYRS	1	0.024540	0.001481	16.575	0.0001
MASP	1	-0.019524	0.001097	-17.799	0.0001
MSLOPE	1	-0.023624	0.001269	-18.615	0.0001
MBAHA	1	0.276545	0.014305	19.332	0.0001
DSITEP1	1	-0.143244	0.043748	-3.274	0.0011
DSITEP2	1	-0.118227	0.018870	-6.265	0.0001
DSITEP3	1	-0.622592	0.040517	-15.366	0.0001
DSITEP4	1	0.036588	0.022348	1.637	0.1020
MCCF	1	-0.063547	0.003183	-19.966	0.0001
X1	1	0.060206	0.030155	1.997	0.0463

Ordinary Least Squares Estimation of Natural Logarithm of B

Model: LOG_B
Dependent variable: LOG_B

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	14	191.80441	13.70032	2770.403	0.0001
Error	705	3.48640	0.00495		
C Total	719	195.29081			

Root MSE	0.07032	R-Square	0.9821
Dep Mean	2.29826	Adj R-SQ	0.9818
C.V.	3.05981		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-9.879562	0.145973	-67.681	0.0001
MYRS	1	-0.975669	0.009960	-97.962	0.0001
MASP	1	-0.012067	0.000604	-19.965	0.0001
MSLOPE	1	-0.032535	0.000952	-34.159	0.0001
MELEV	1	0.001945	0.000055624	34.962	0.0001
MBAHA	1	-0.212821	0.007719	-27.571	0.0001
DSITEP1	1	0.181798	0.025288	7.189	0.0001
DSITEP2	1	-0.026894	0.009068	-2.966	0.0031
DSITEP3	1	0.226260	0.021750	10.403	0.0001
DSITEP4	1	0.009082	0.010771	0.843	0.3994
MCCF	1	0.070781	0.001684	42.021	0.0001
X1	1	-1.214915	0.019303	-62.939	0.0001
X2	1	-1.387264	0.030703	-45.183	0.0001
X3	1	6.505929	0.066133	98.376	0.0001
DHAB	1	-0.689581	0.012610	-54.683	0.0001

Using Seemingly Unrelated Regressions (SUR) for estimation of scale and shape parameters of the Weibull function.

Seemingly Unrelated Regression Estimation of Natural Logarithm of C

System Weighted MSE: 0.99988 with 1414 degrees of freedom.
System Weighted R-Square: 0.9685

Model: LOG_C
Dependent variable: LOG_C

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	1.528704	0.081206	18.825	0.0001
MYRS	1	0.024540	0.001481	16.575	0.0001
MASP	1	-0.019524	0.001097	-17.799	0.0001
MSLOPE	1	-0.023624	0.001269	-18.615	0.0001
MBAHA	1	0.276545	0.014305	19.332	0.0001
DSITEP1	1	-0.143244	0.043748	-3.274	0.0011
DSITEP2	1	-0.118227	0.018870	-6.265	0.0001
DSITEP3	1	-0.622592	0.040517	-15.366	0.0001
DSITEP4	1	0.036588	0.022348	1.637	0.1020
MCCF	1	-0.063547	0.003183	-19.966	0.0001
X1	1	0.060206	0.030155	1.997	0.0463

Model: LOG_B
Dependent variable: LOG_B

Seemingly Unrelated Regression Estimation of Natural Logarithm of B

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-9.901183	0.140830	-70.306	0.0001
MYRS	1	-0.977419	0.009584	-101.987	0.0001
MASP	1	-0.012110	0.000599	-20.229	0.0001
MSLOPE	1	-0.032616	0.000931	-35.034	0.0001
MELEV	1	0.001949	0.000053514	36.412	0.0001
MBAHA	1	-0.211891	0.007655	-27.682	0.0001
DSITEP1	1	0.183233	0.024982	7.335	0.0001
DSITEP2	1	-0.026616	0.009061	-2.937	0.0034
DSITEP3	1	0.224771	0.021575	10.418	0.0001
DSITEP4	1	0.008995	0.010760	0.836	0.4035
MCCF	1	0.070659	0.001672	42.253	0.0001
X1	1	-1.219738	0.018978	-64.270	0.0001
X2	1	-1.387640	0.029539	-46.977	0.0001
X3	1	6.518250	0.063624	102.449	0.0001
DHAB	1	-0.694315	0.012132	-57.230	0.0001

USING NON-LINEAR LEAST-SQUARES FOR ESTIMATING COEFFICIENTS OF LINEAR FUNCTIONS REPLACING SCALE AND SHAPE PARAMETERS OF THE WEIBULL FUNCTION.
THE FITTED WEIBULL WITH NON_LINEAR PROCEDURE
USING LINEAR FUNCTONS FOR PARAMETERS ESTIMATION
MARQUARDT Method

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CUMPER

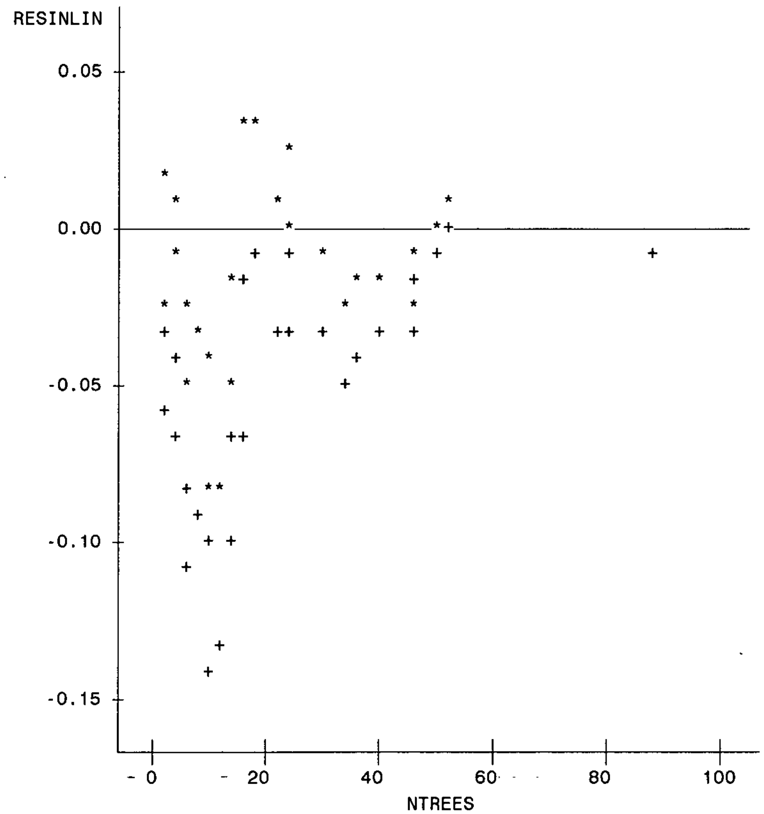
Source	DF	Sum of Squares	Mean Square
Regression	26	258.74548920	9.95174958
Residual	694	2.52392031	0.00363677
Uncorrected Total	720	261.26940950	
(Corrected Total)	719	52.47327141	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
A	-9.763019127	5.2903114070	-20.150122864	0.624084610
A1	-0.967698367	0.4343044066	-1.820420368	-0.114976367
A2	-0.006687009	0.0204706553	-0.046879505	0.033505487
A3	-0.024796689	0.0326681996	-0.088938088	0.039344711
A4	0.001129709	0.0015879113	-0.001988028	0.004247446
A5	-0.204691320	0.3400609855	-0.872373893	0.462991253
A6	0.104535875	1.0500337102	-1.957121414	2.166193165
A7	0.014233875	0.2624676299	-0.501100344	0.529568095
A8	-0.047052693	0.9210623780	-1.855485077	1.761379690
A9	0.002097957	0.2913633844	-0.569970767	0.574166682
A10	0.071202997	0.0794152448	-0.084722491	0.227128484
A11	-1.180844480	0.8417650436	-2.833582884	0.471893923
A12	-1.315628313	1.1256629490	-3.525777570	0.894520944
A13	6.559046730	2.8086742750	1.044439212	12.073654248
A14	-0.651511515	0.5125297344	-1.657822695	0.354799666
D	1.477677808	0.1764173308	1.131296475	1.824059141
D1	0.021577838	0.0030547887	0.015580004	0.027575671
D2	-0.019852181	0.0024192852	-0.024602255	-0.015102108
D3	-0.023708609	0.0025484230	-0.028712234	-0.018704984
D4	0.274641333	0.0292270909	0.217256275	0.332026390
D5	-0.129351792	0.1000436388	-0.325779484	0.067075899
D6	-0.114367373	0.0308395109	-0.174918288	-0.053816457
D7	-0.607056208	0.0863651961	-0.776627369	-0.437485046
D8	-0.013474713	0.0476984135	-0.107126737	0.080177311
D9	-0.063269804	0.0065356843	-0.076102098	-0.050437511
D10	0.058293902	0.0569179512	-0.053459947	0.170047752

APPENDIX 2:Number of tree per stocked plot.

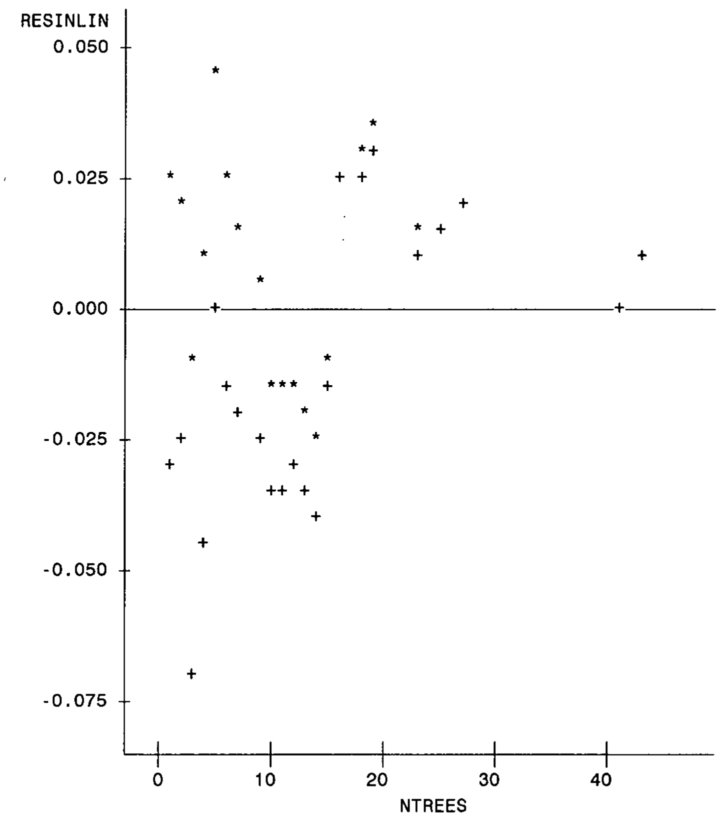
Comparing residuals from non-linear estimates of *B* and *C* and non-linear estimates of the Weibull function.

Comparing different non-linear estimates of B and C and non-linear estimates of the function to the actual cumulative density
Cat_2 Fd series, east, <7yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



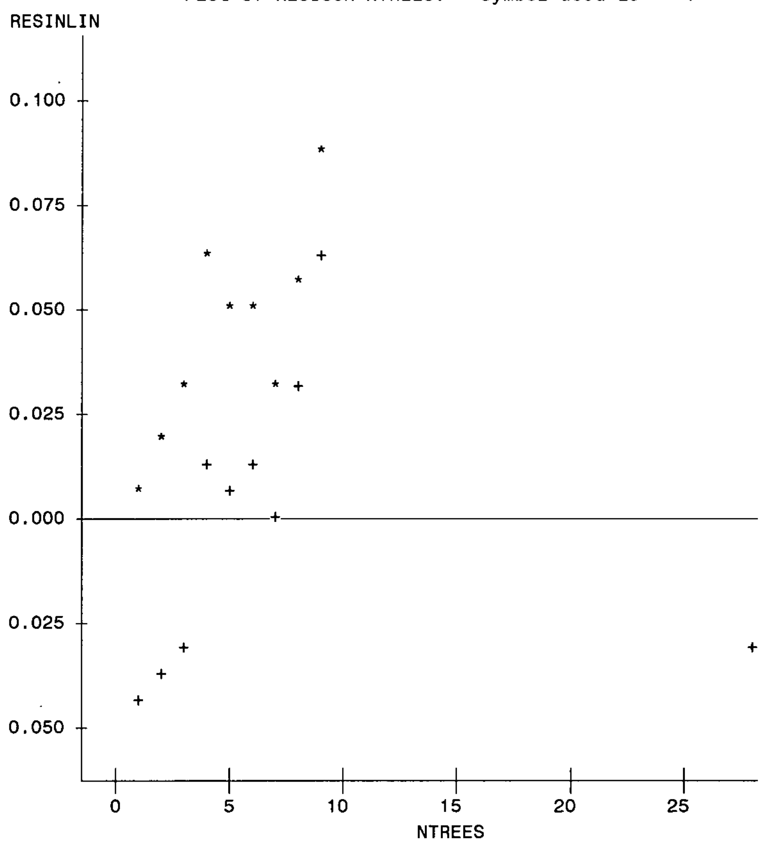
NOTE: 3 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions to the actual cumulative density
Cat_3 Fd series, south, <7yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



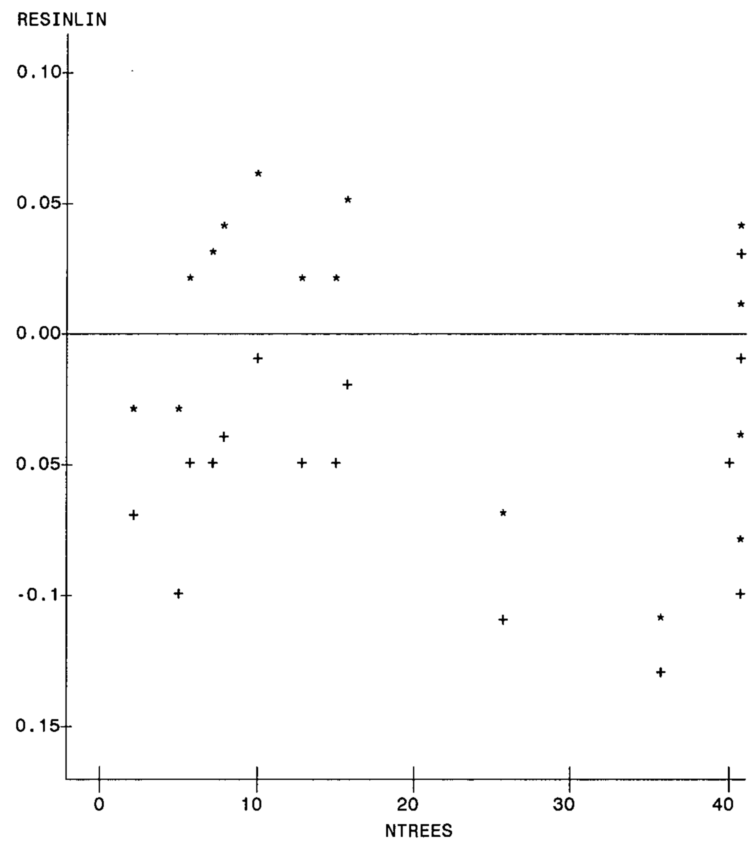
NOTE: 5 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_4 Fd series, west, <7yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.

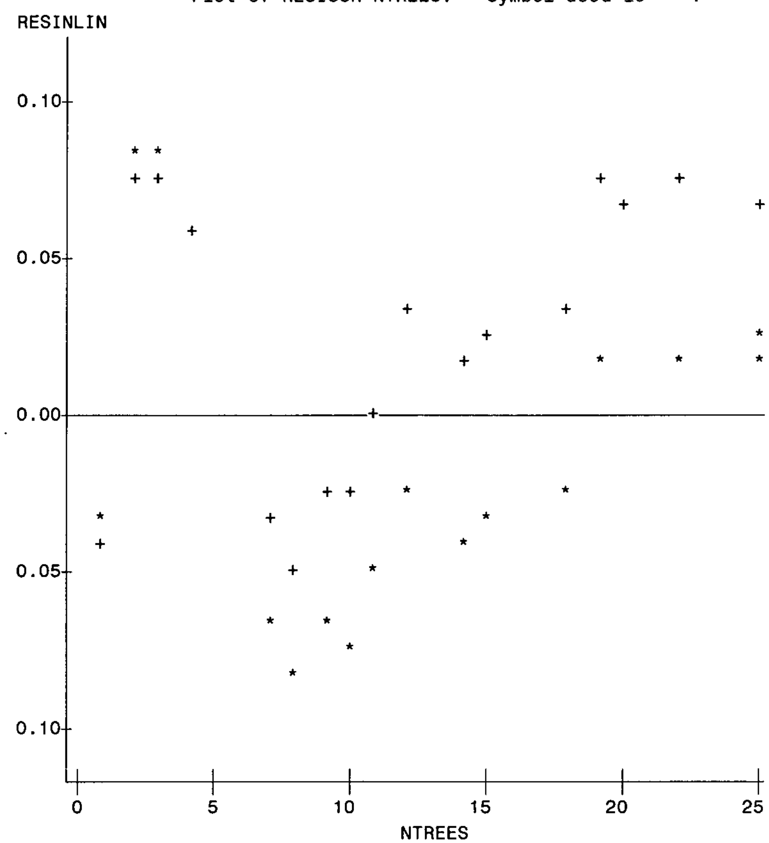


NOTE: 2 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_6 Fd series, east, 8-12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.

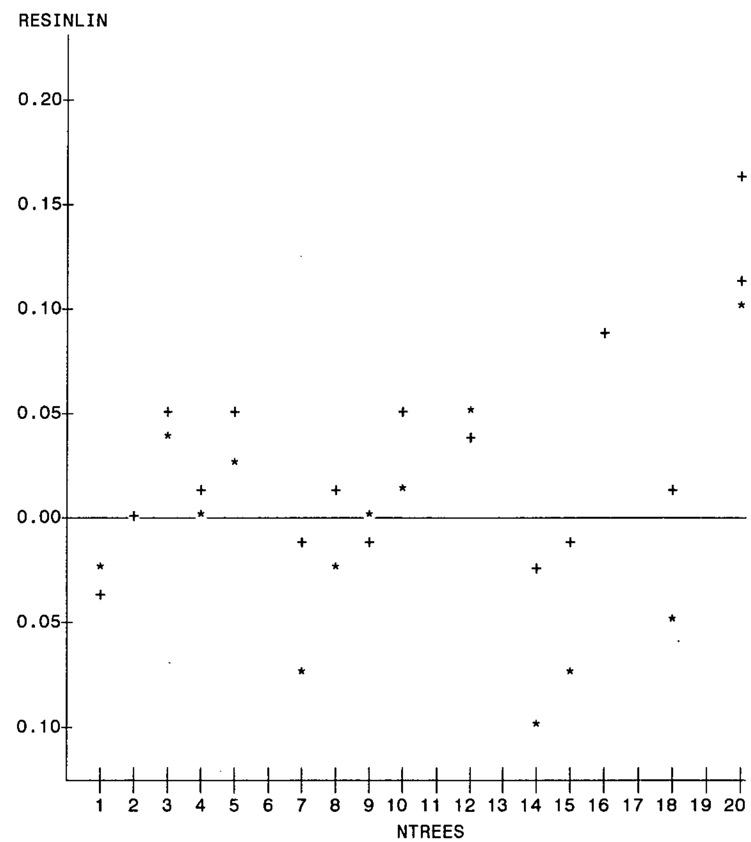


Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_8 Fd series, west, 8-12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



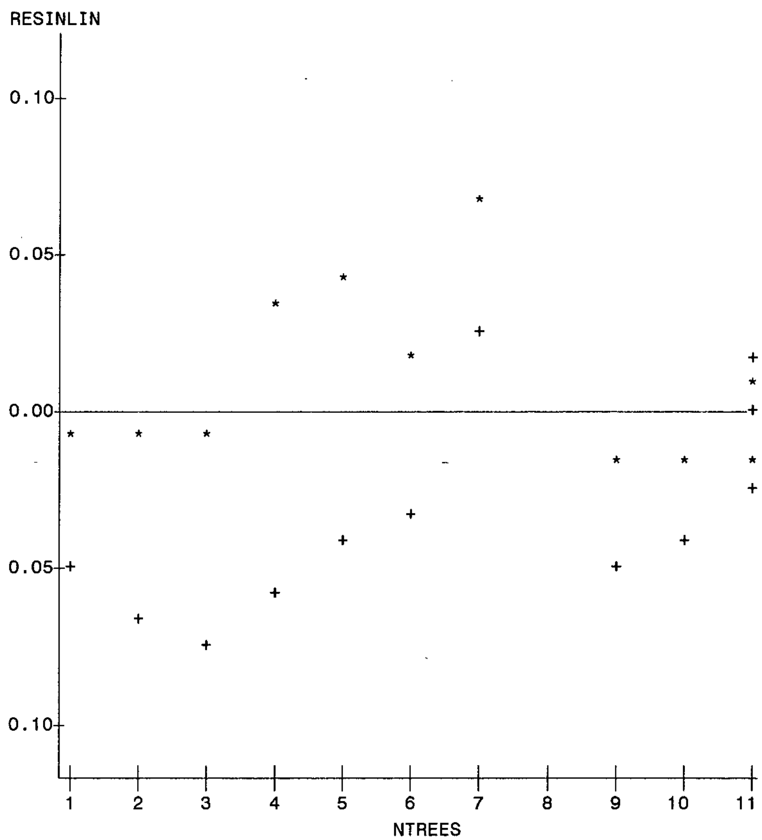
NOTE: 1 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_9 Fd series, north, >12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



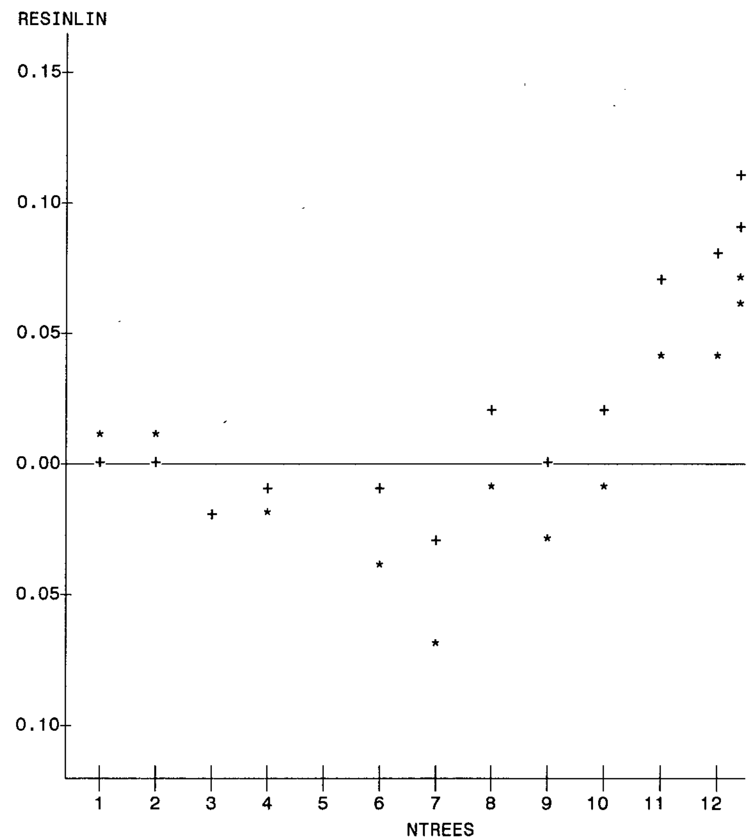
NOTE: 3 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_10 Fd series, east, >12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



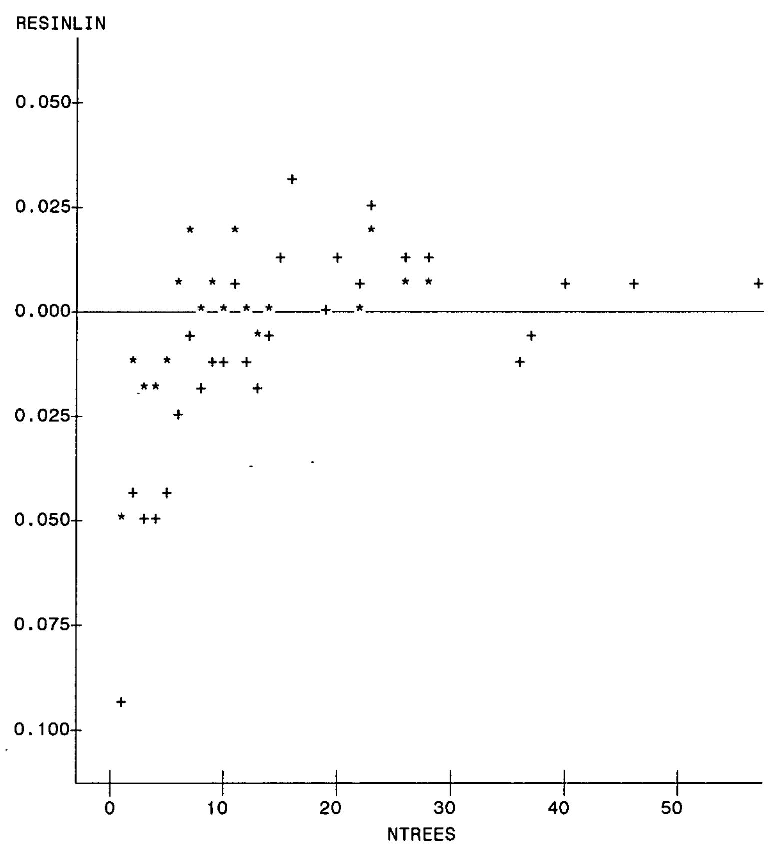
NOTE: 1 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_13 Hw/Cw series, north,<7yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



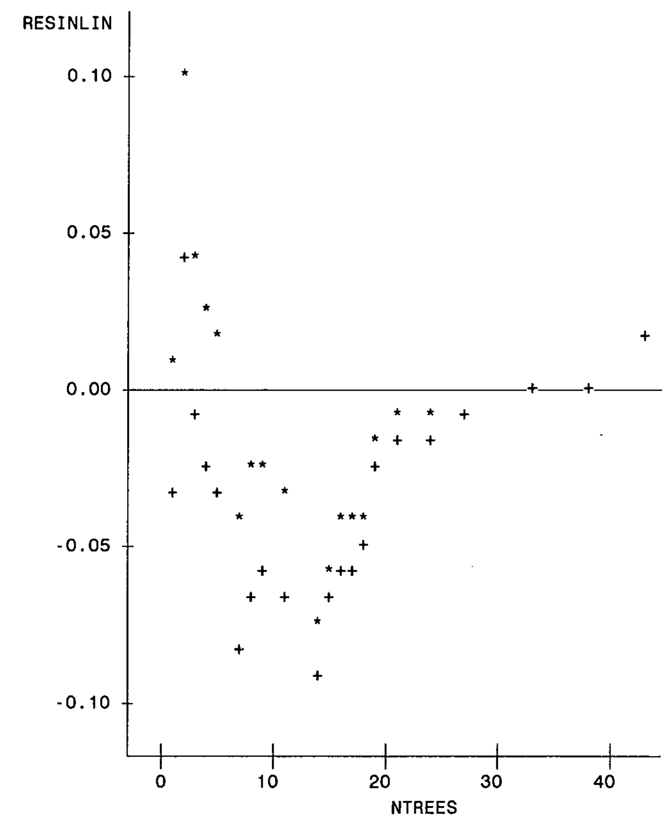
NOTE: 1 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions to the actual cumulative density
Cat_14 Hw/Cw series, east, <7yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



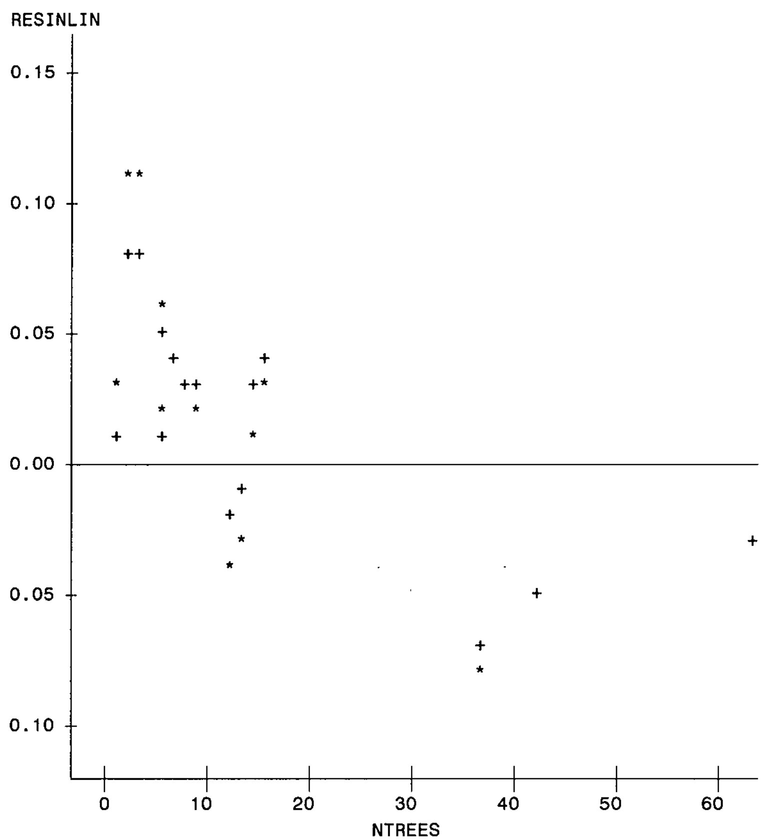
NOTE: 9 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions to the actual cumulative density
Cat_15 Hw/Cw series, south, <7yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



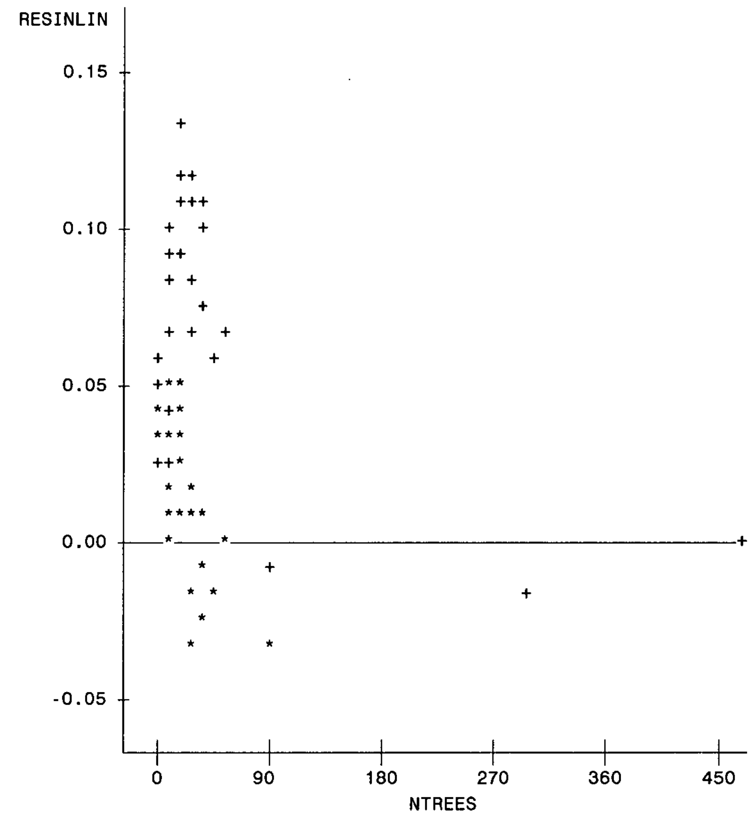
NOTE: 4 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_16 Hw/Cw series, west, <7yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



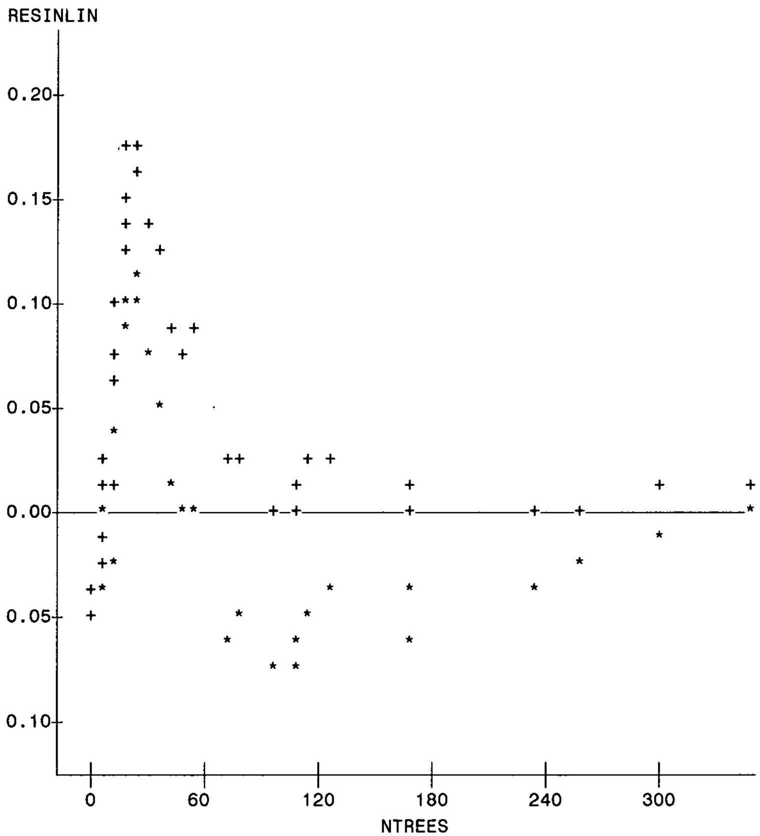
NOTE: 5 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_17 Hw/Cw series, north, 8-12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



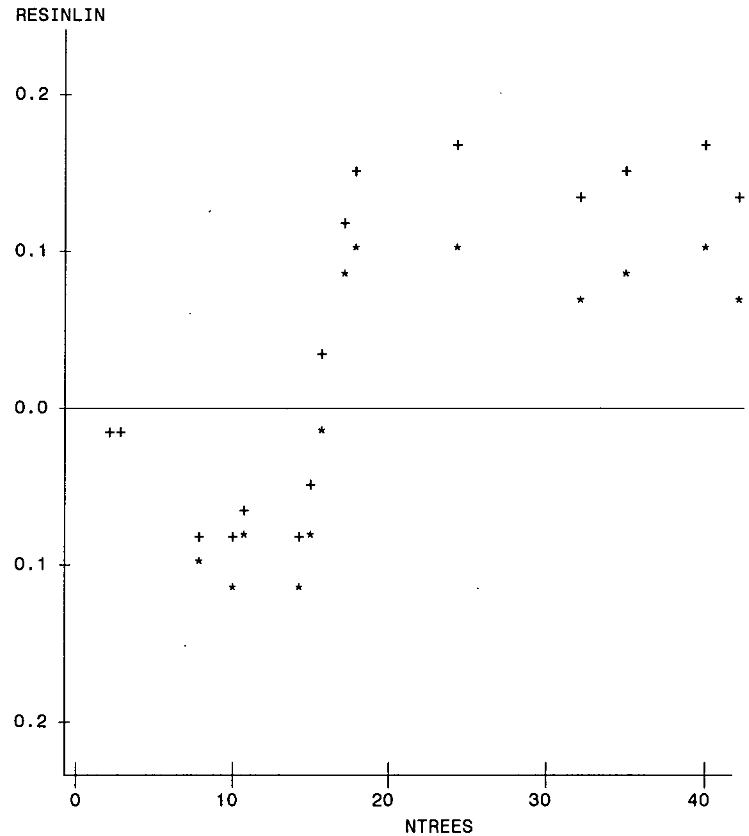
NOTE: 15 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_18 Hw/Cw series, east, 8-12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



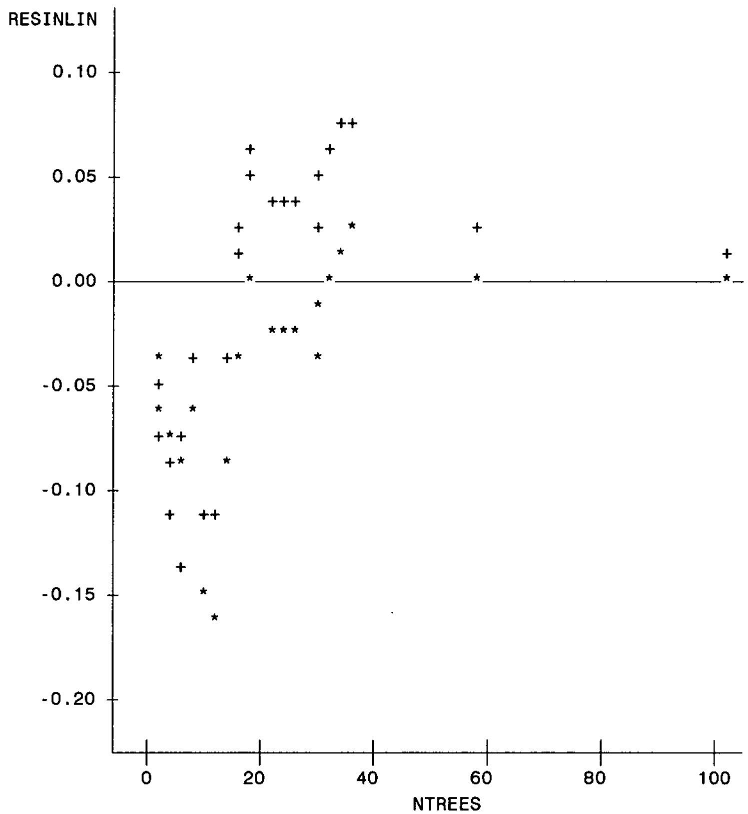
NOTE: 12 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_19 Hw/Cw series, south, 8-12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



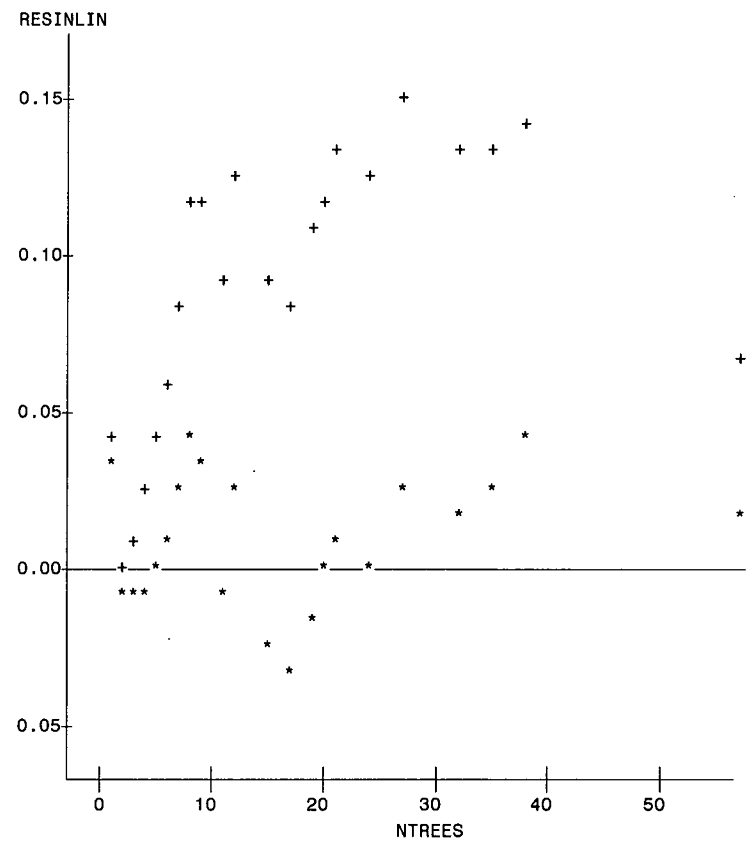
NOTE: 2 obs hidden.

Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_20 Hw/Cw series, west, 8-12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



NOTE: 6 obs hidden.

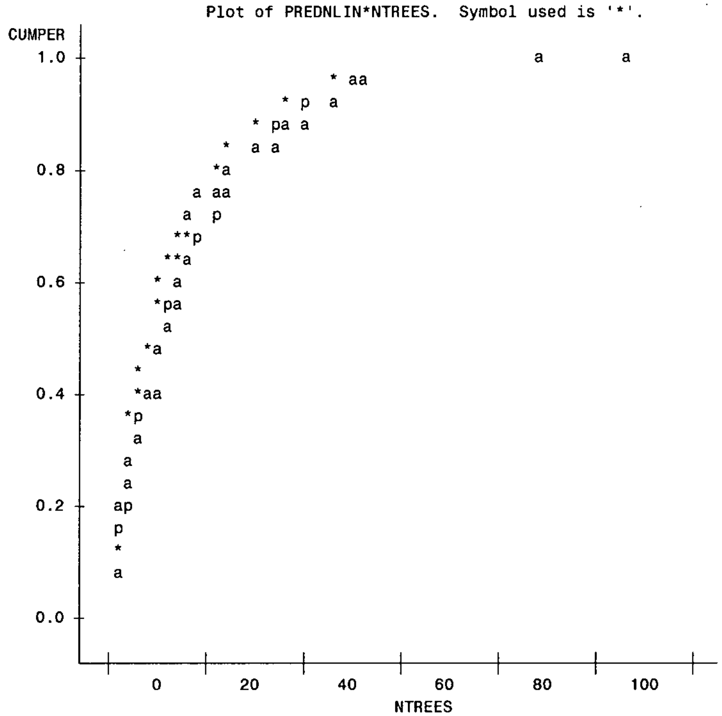
Comparing non-linear estimates of B and C and non-linear estimates of the linear functions
to the actual cumulative density
Cat_21 Hw/Cw series, north, >12yrs
Plot of RESINLIN*NTREES. Symbol used is '+'.
Plot of RESISUR*NTREES. Symbol used is '*'.



APPENDIX 3:Number of tree per stocked plot.

Comparing non-linear estimates within the Weibull, of linear coefficients of *B* and *C*
To actual CDF and CDF with predicted *B* and *C*.

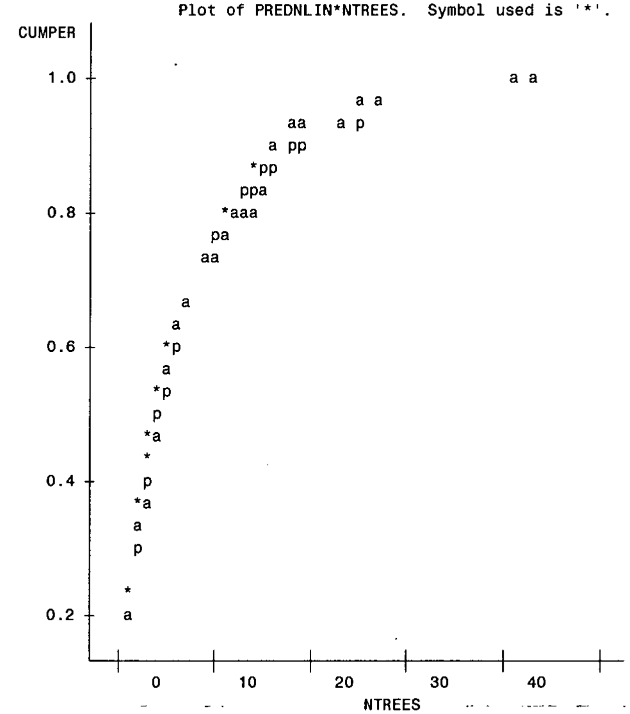
Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C
Cat_2 Fd series, east, <7yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 112 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

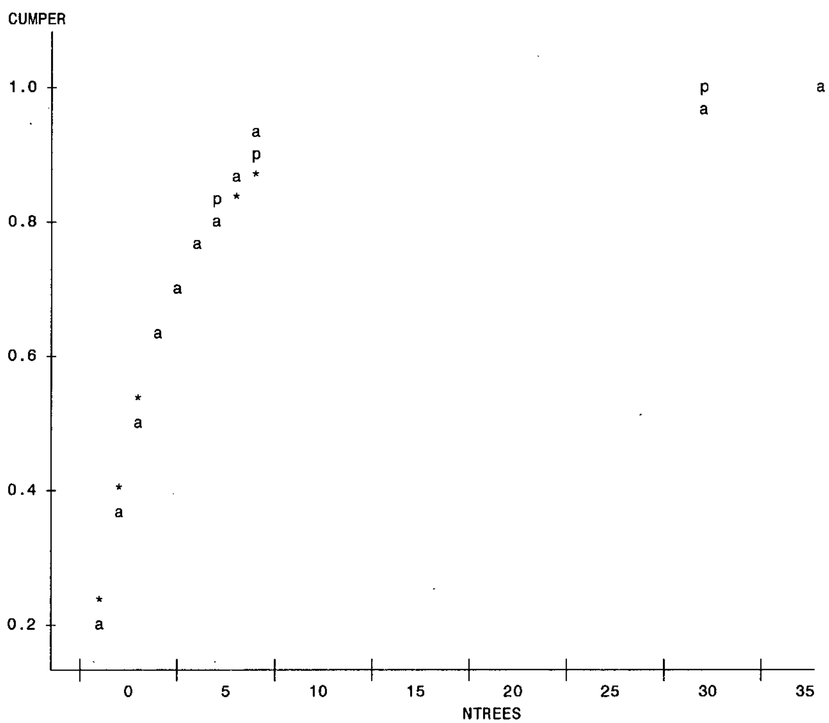
Cat_3 Fd series, south, <7yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 194 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

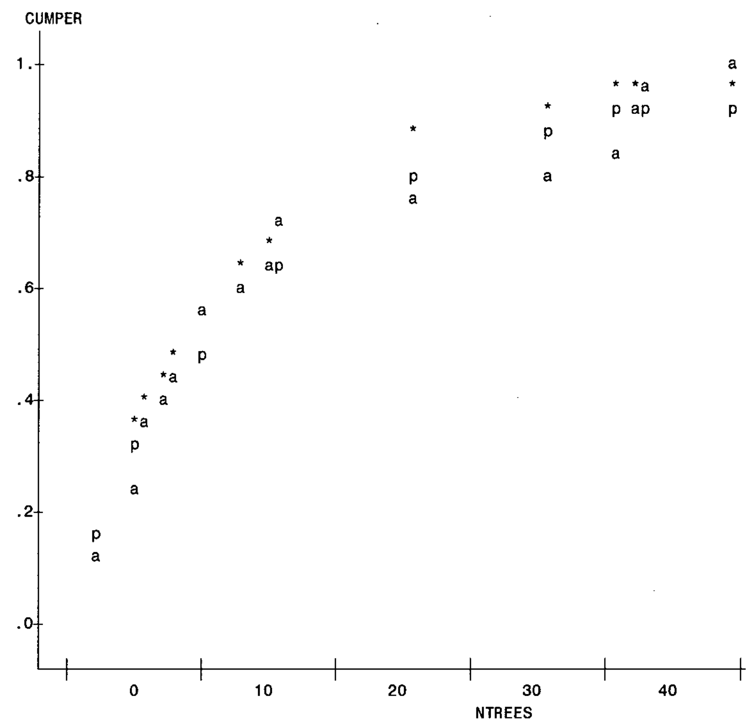
Cat_4 Fd series, west, <7yrs
Plot of CUMPER*NTREES.   Symbol used is 'a'.
Plot of PRED*NTREES.   Symbol used is 'p'.
Plot of PREDNLIN*NTREES.   Symbol used is '*'.



NOTE: 71 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

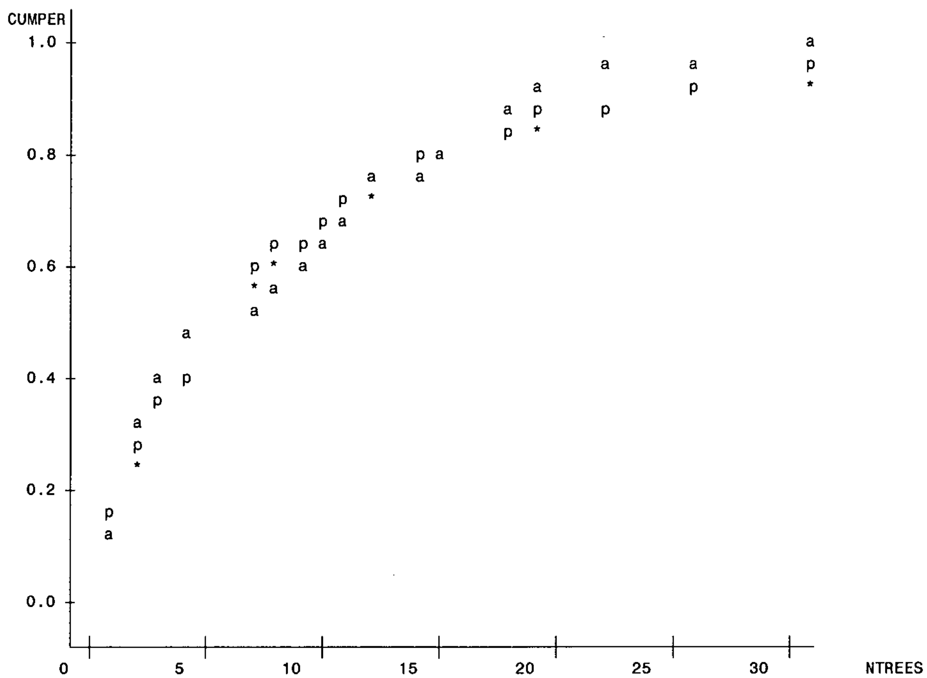
Cat_6 Fd series, east, 8-12yrs
Plot of CUMPER*NTREES.   Symbol used is 'a'.
Plot of PRED*NTREES.   Symbol used is 'p'.
Plot of PREDNLIN*NTREES.   Symbol used is '*'.



NOTE: 25 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

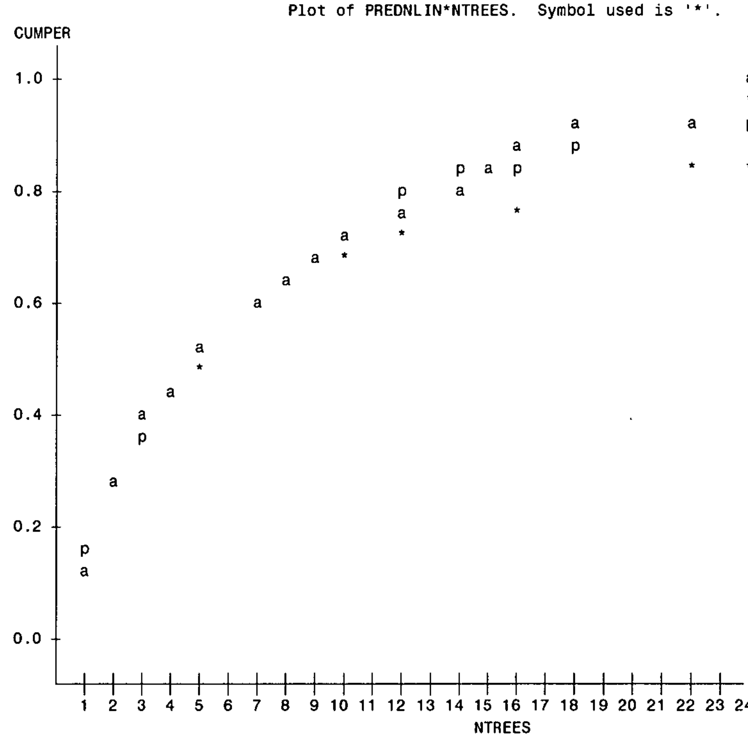
Cat_8 Fd series, west, 8-12yrs
Plot of CUMPER*NTREES.   Symbol used is 'a'.
Plot of PRED*NTREES.   Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 70 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

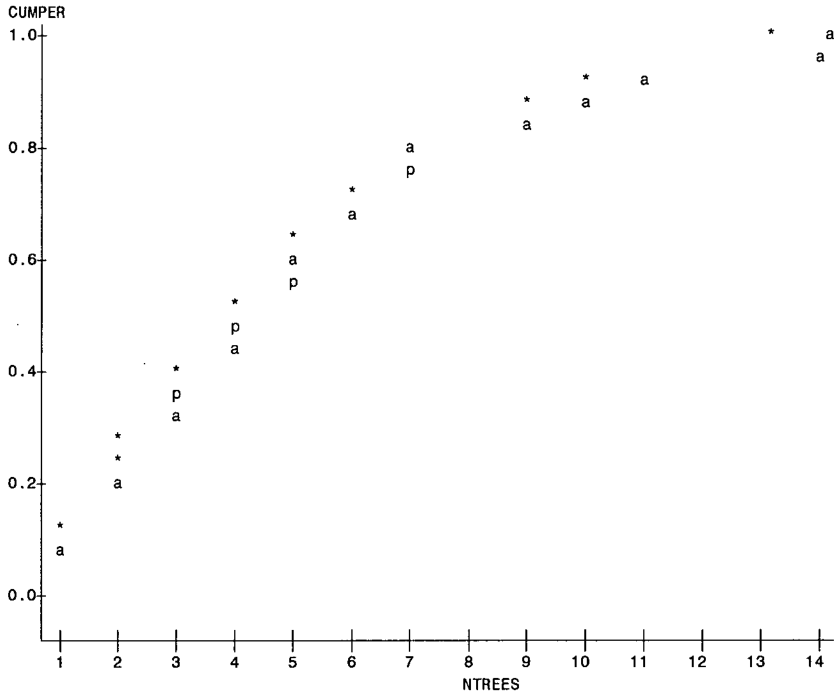
Cat_9 Fd series, north, >12yrs
Plot of CUMPER*NTREES.   Symbol used is 'a'.
Plot of PRED*NTREES.   Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 60 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

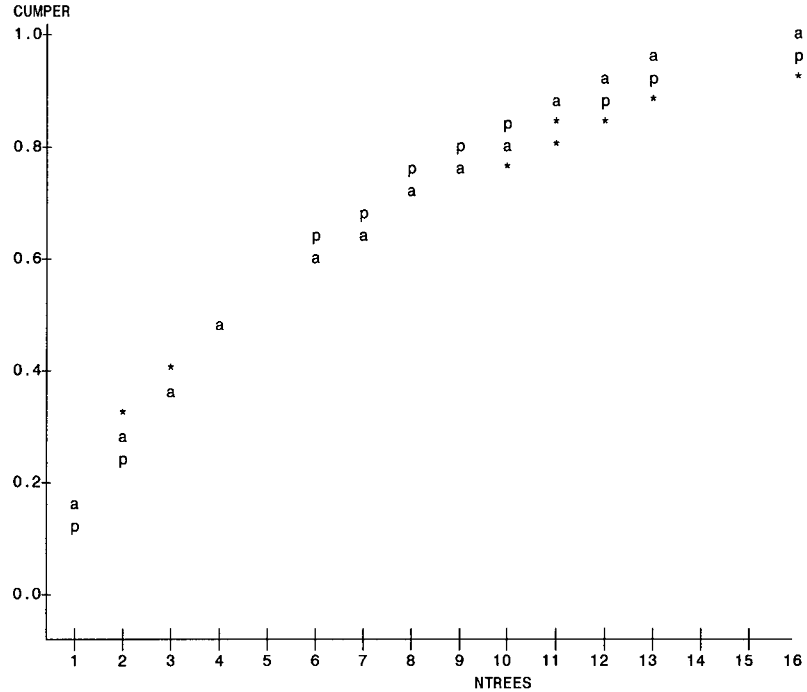
Cat_10 Fd series, east, >12yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 46 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

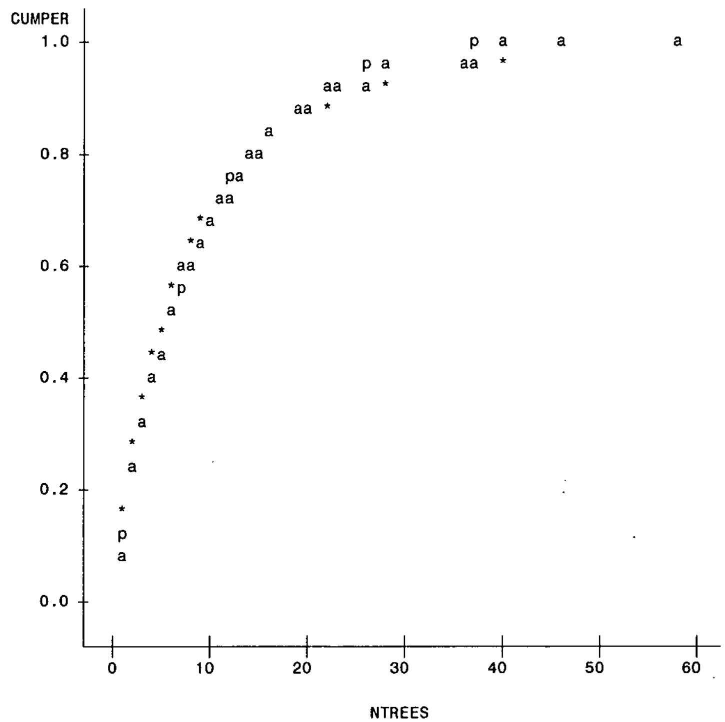
Cat_13 Hw/Cw series, north,<7yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 83 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

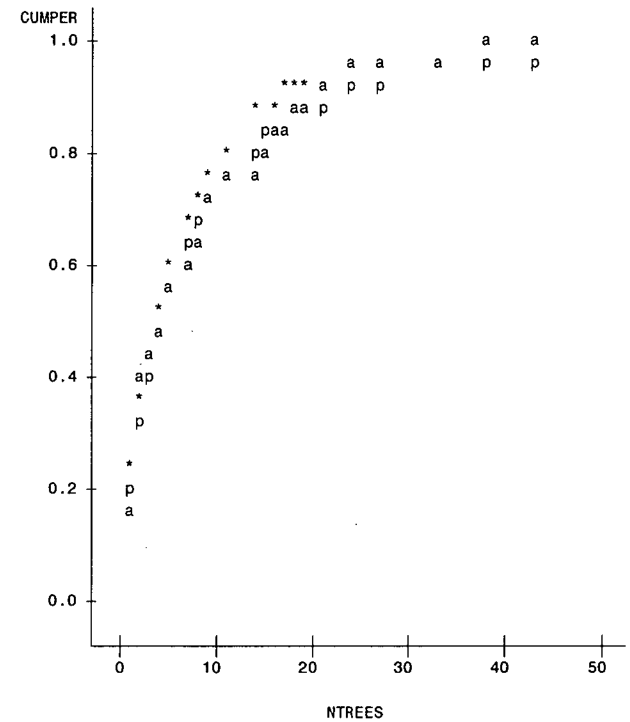
Cat_14 Hw/Cw series, east, <7yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 290 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

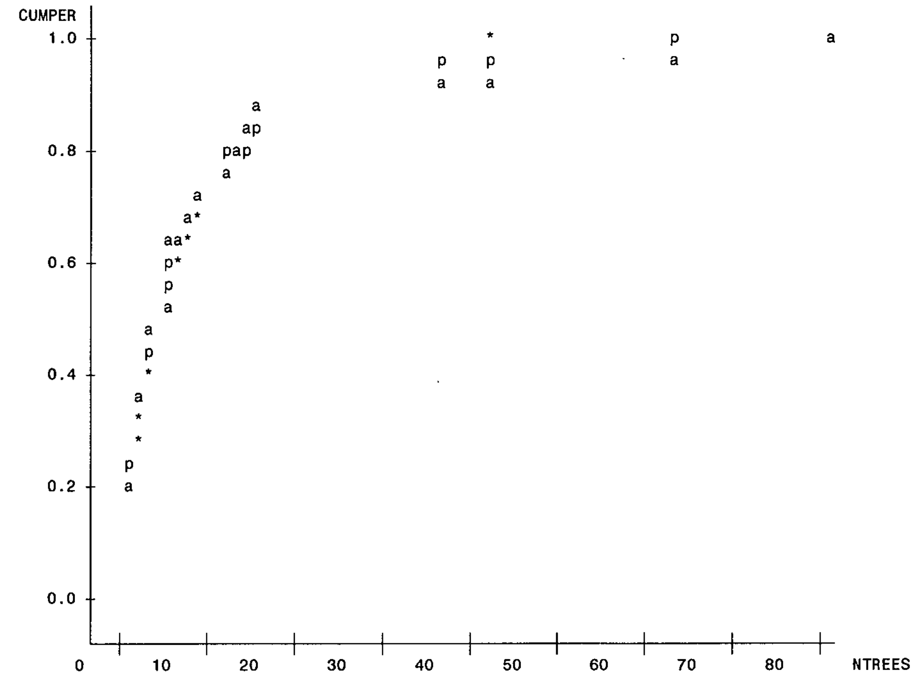
Cat_16 Hw/Cw series, west, <7yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 155 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

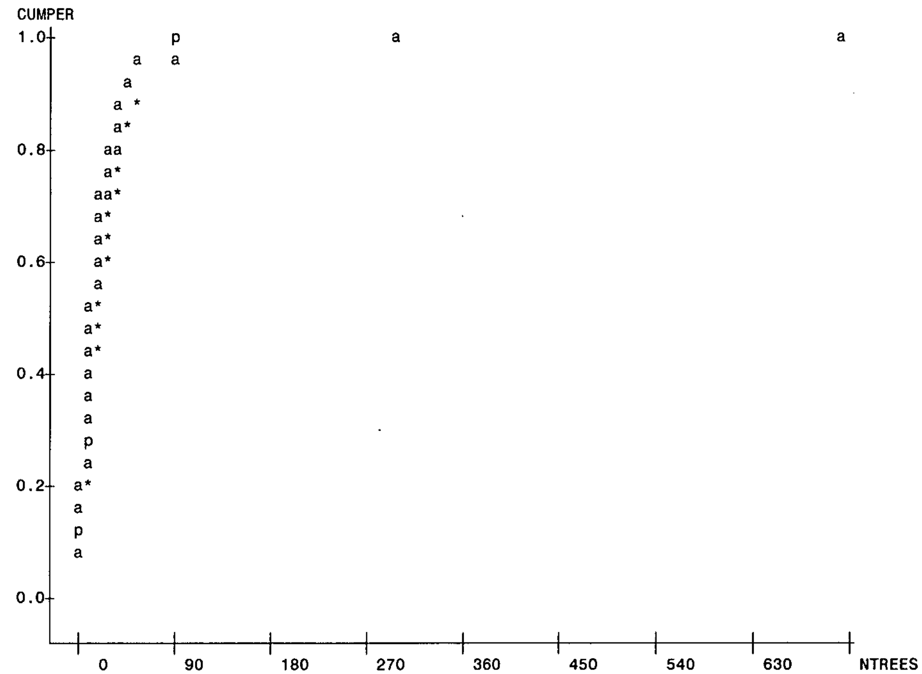
Cat_16 Hw/Cw series, west, <7yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 63 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

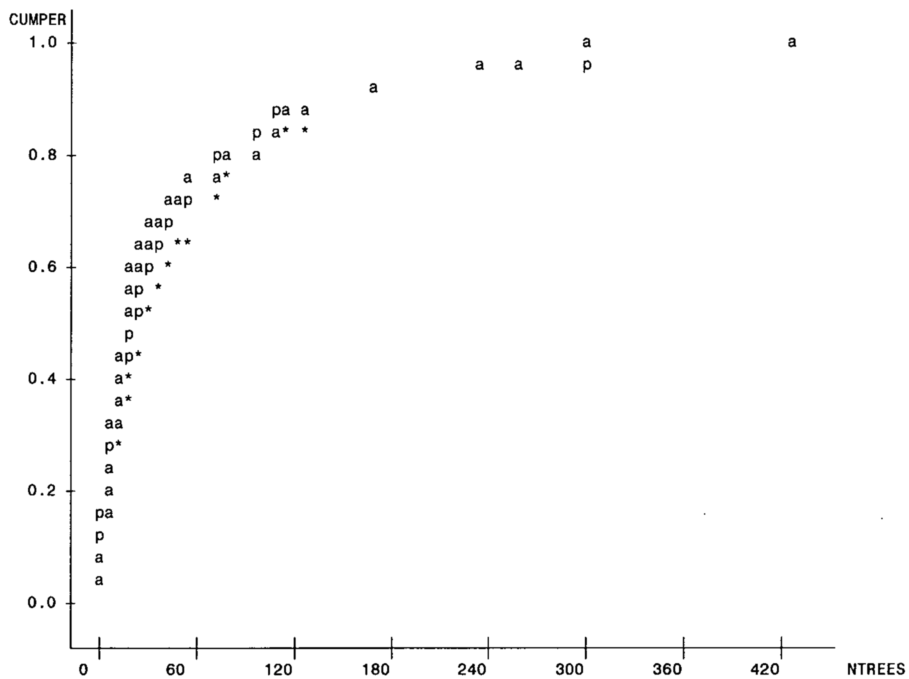
Cat_17 Hw/Cw series, north, 8-12yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 125 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

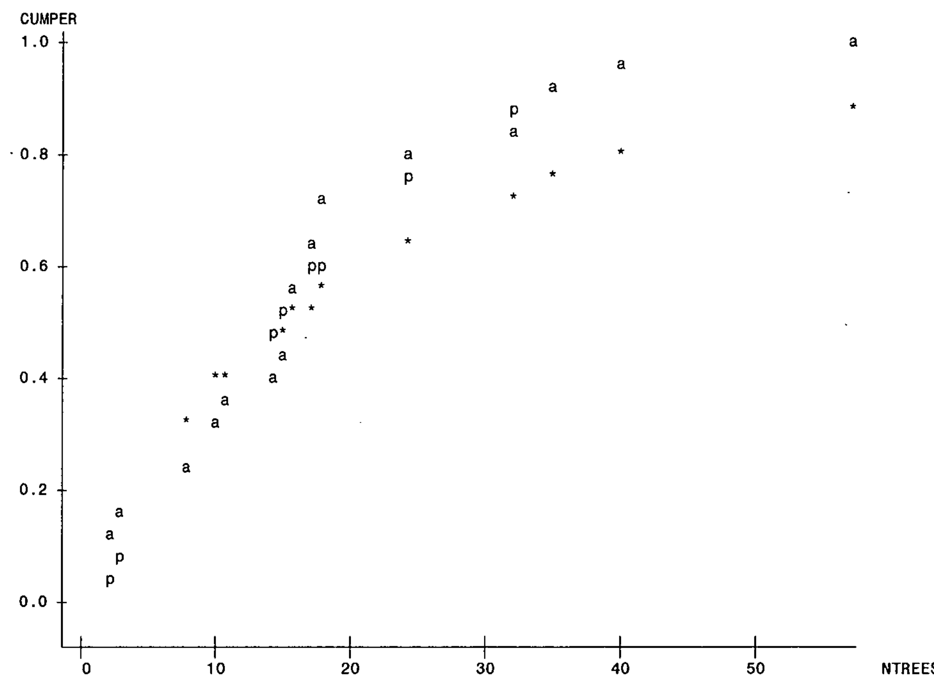
Cat_18 Hw/Cw series, east, 8-12yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 90 obs hidden.

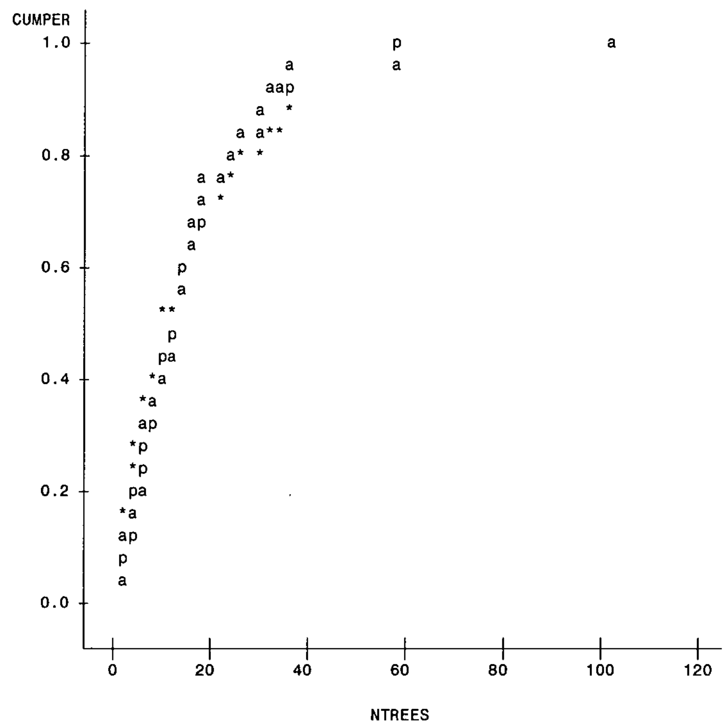
Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

Cat_19 Hw/Cw series, south, 8-12yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 25 obs hidden.

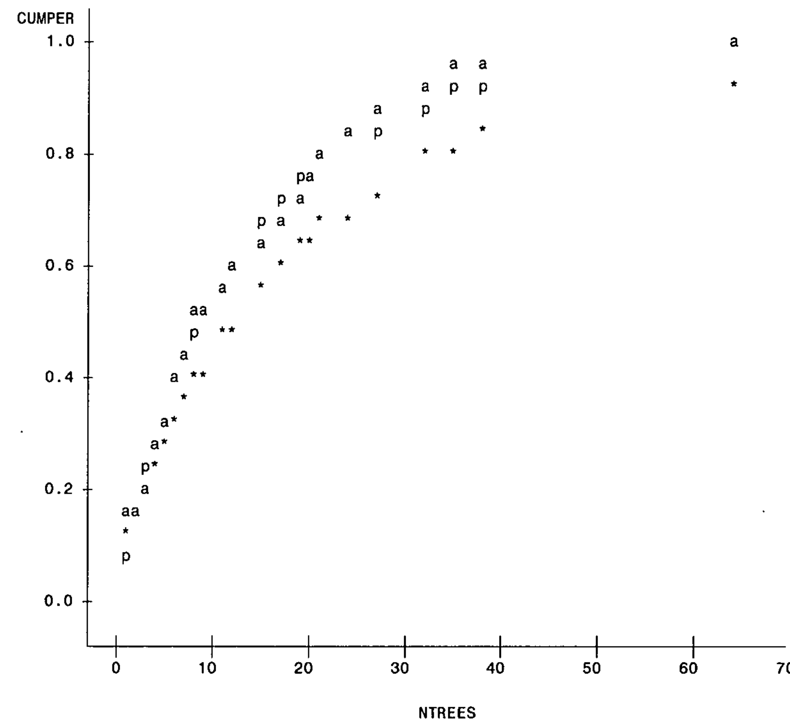
Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C
Cat_20 Hw/Cw series, west, 8-12yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 71 obs hidden.

Comparing non-linear estimates within the Weibull, of linear coefficients of B and C
To actual CDF and CDF with predicted B and C

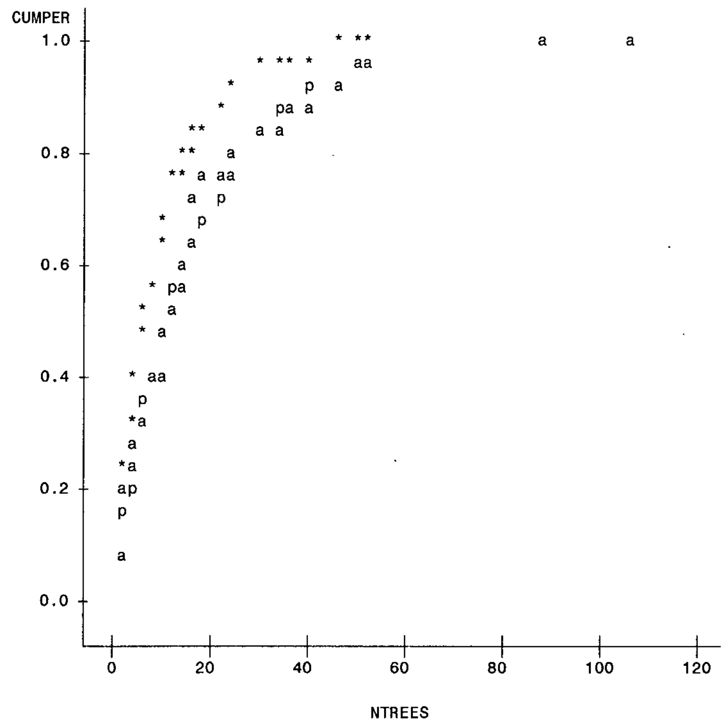
Cat_21 Hw/Cw series, north, >12yrs
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PREDNLIN*NTREES. Symbol used is '*'.



NOTE: 50 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_2 Fd series, east, <7yrs

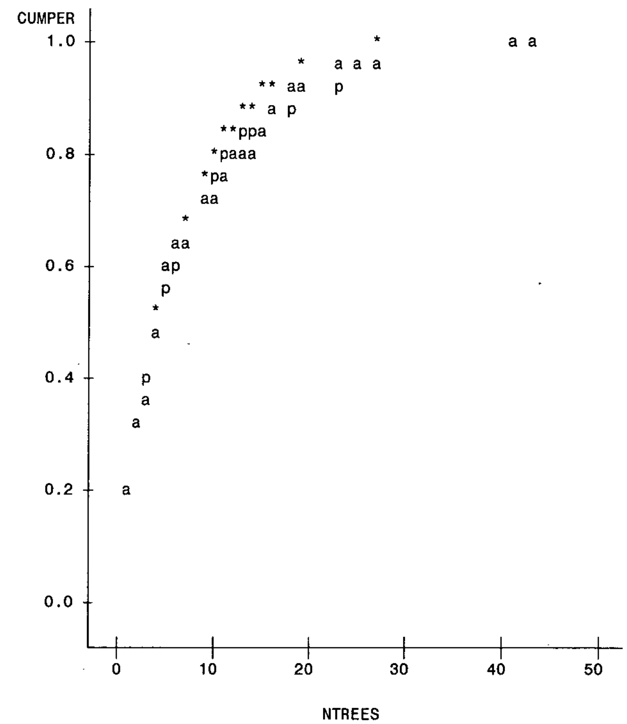
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 27 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_3 Fd series, south, <7yrs

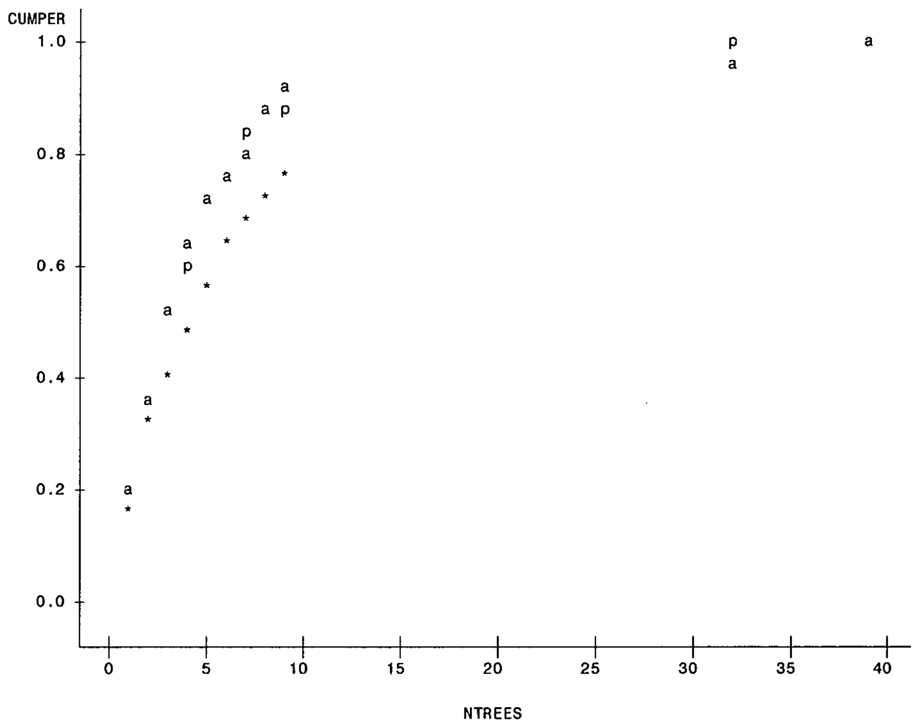
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 23 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_4 Fd series, west, <7yrs

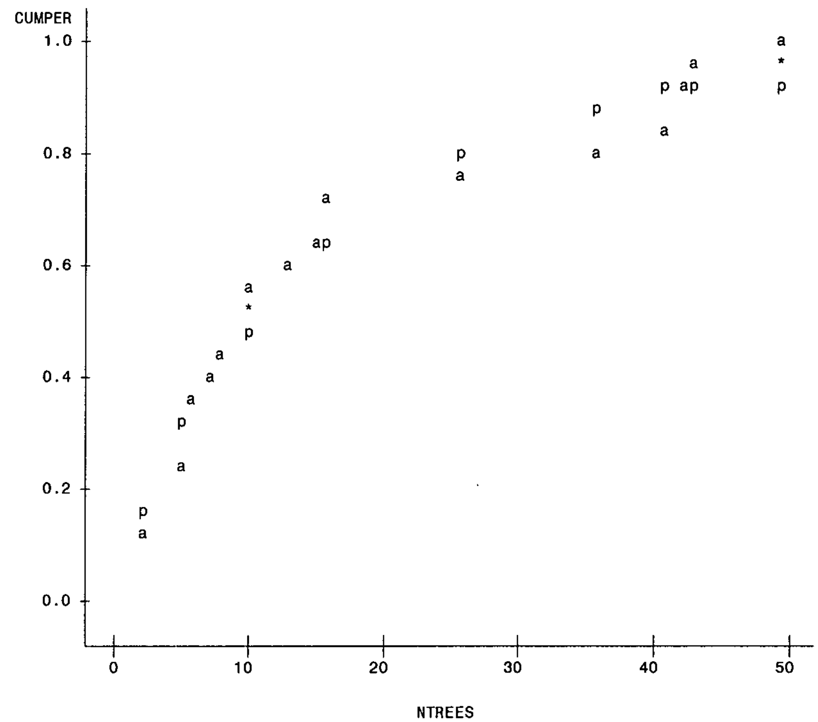
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 9 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_6 Fd series, east, 8-12yrs

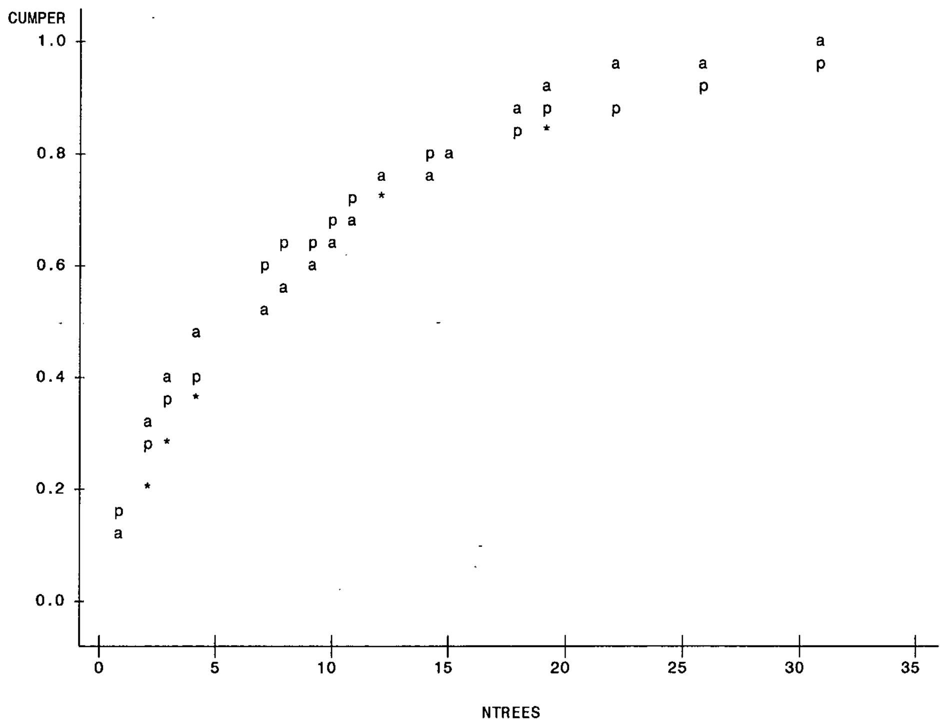
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 19 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_8 Fd series, west, 8-12yrs

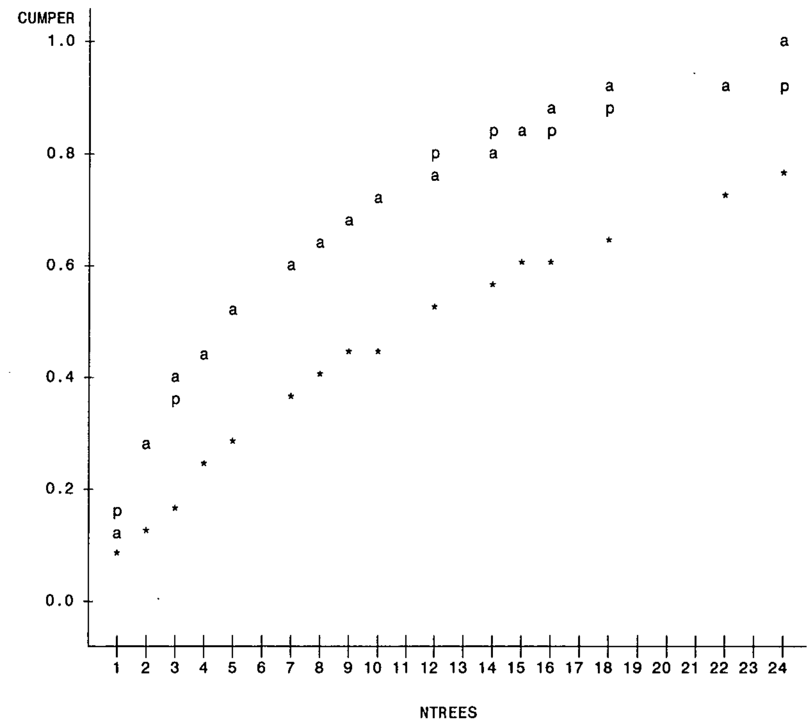
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 14 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_9 Fd series, north, >12yrs

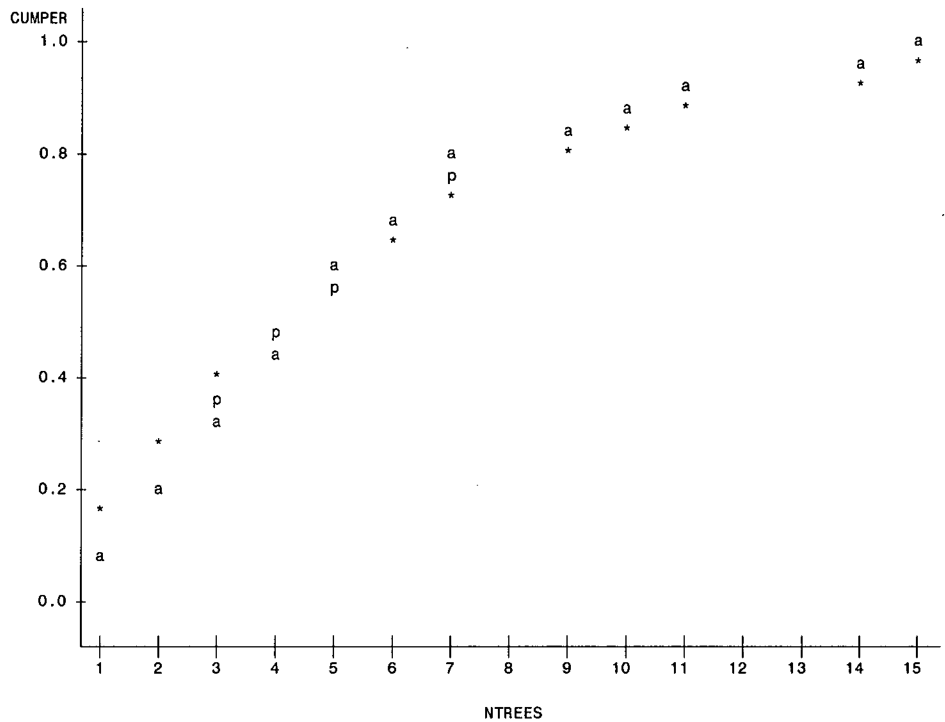
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 9 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_10 Fd series, east, >12yrs

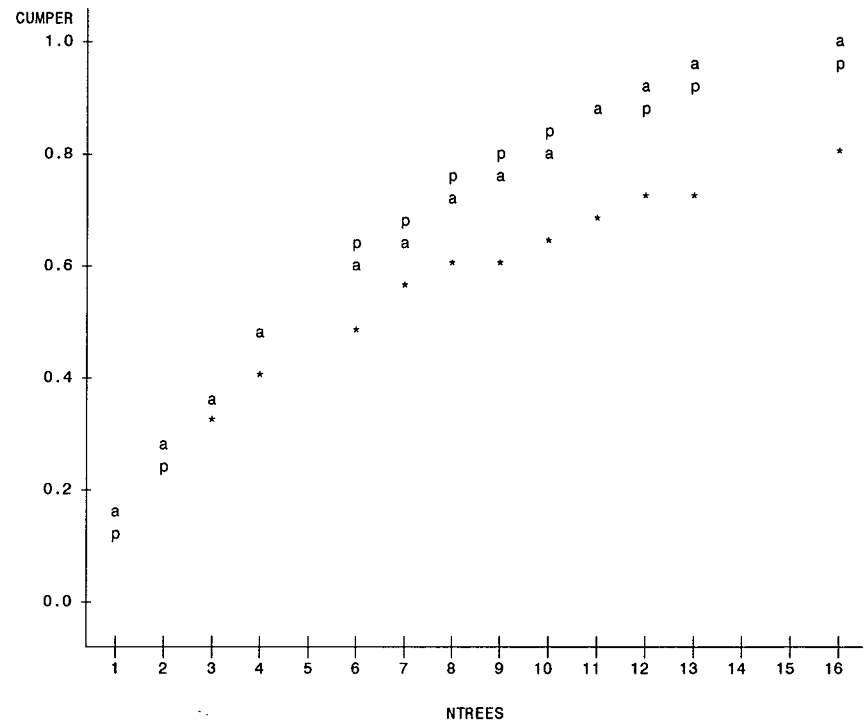
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 10 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_13 Hw/Cw series, north,<7yrs

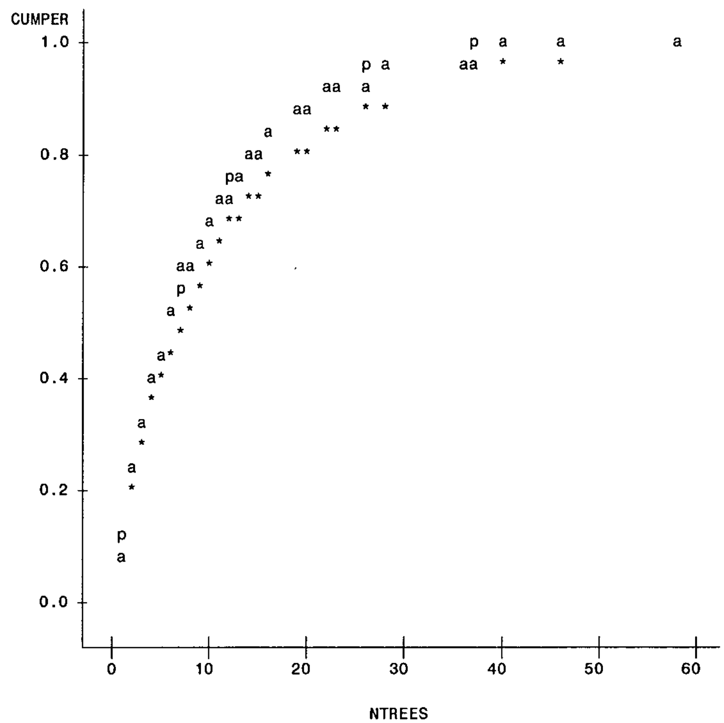
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 5 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_14 Hw/Cw series, east, <7yrs

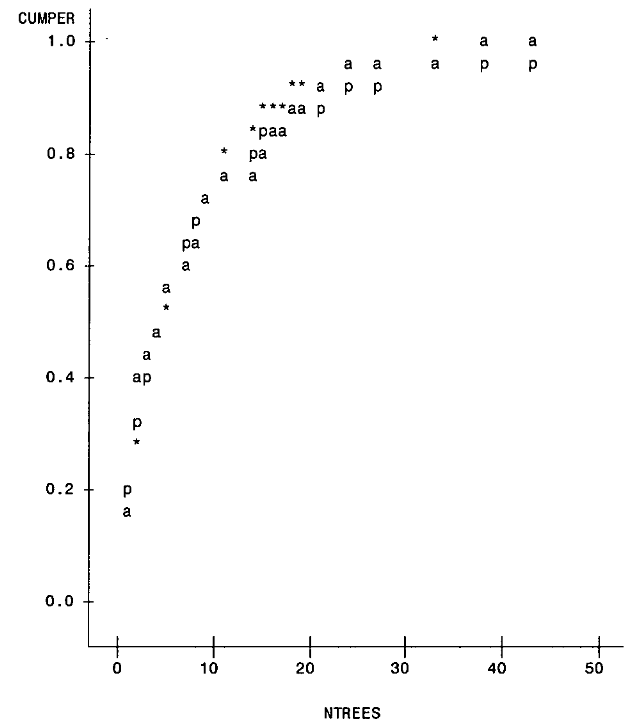
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 26 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_15 Hw/Cw series, south, <7yrs

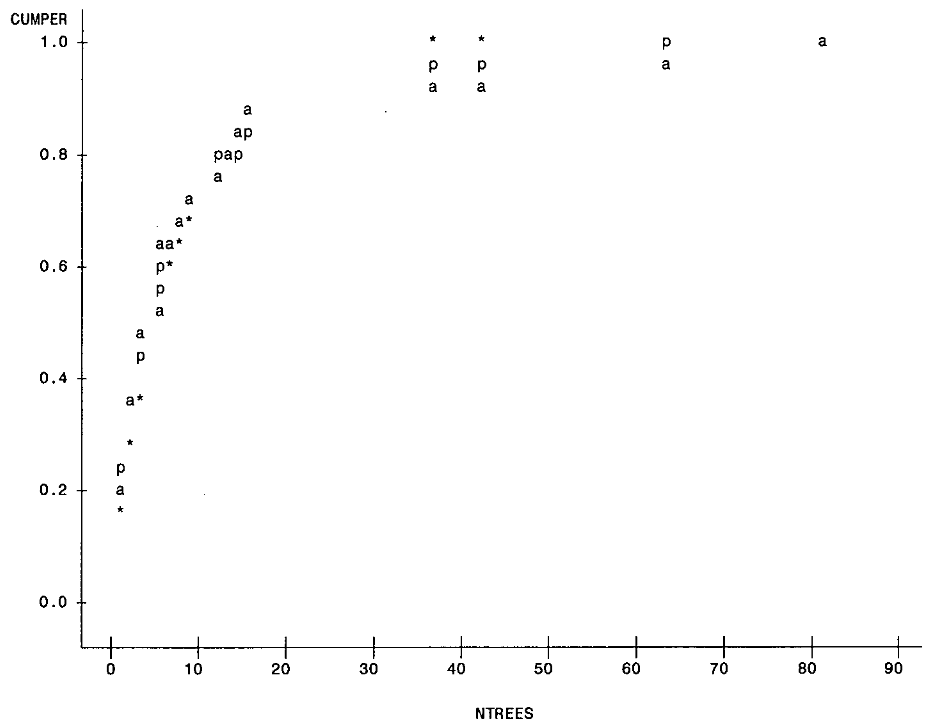
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 20 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_16 Hw/Cw series, west, <7yrs

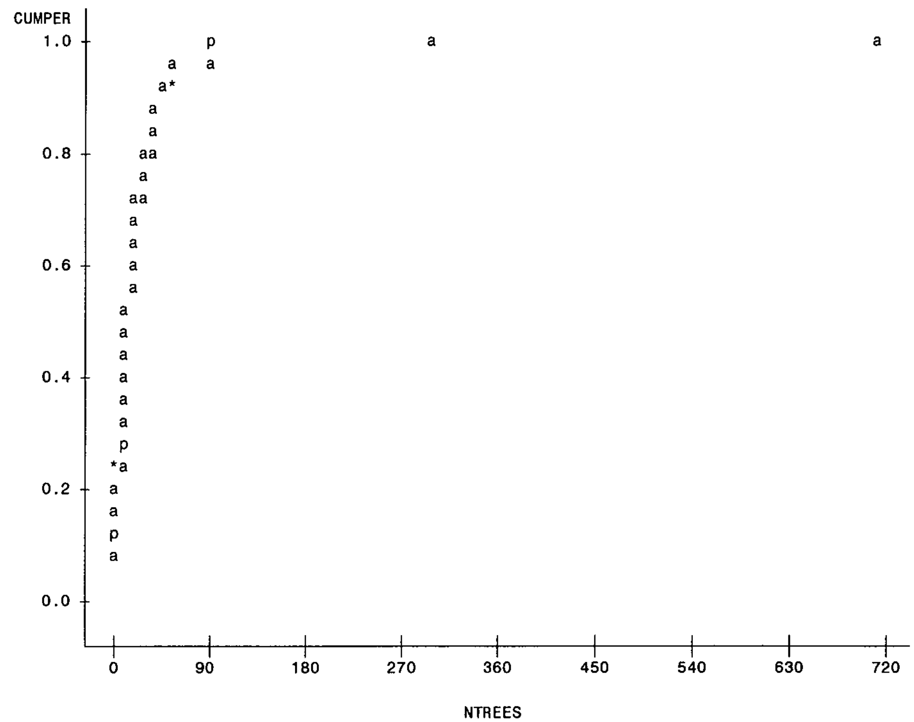
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 14 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_17 Hw/Cw series, north, 8-12yrs

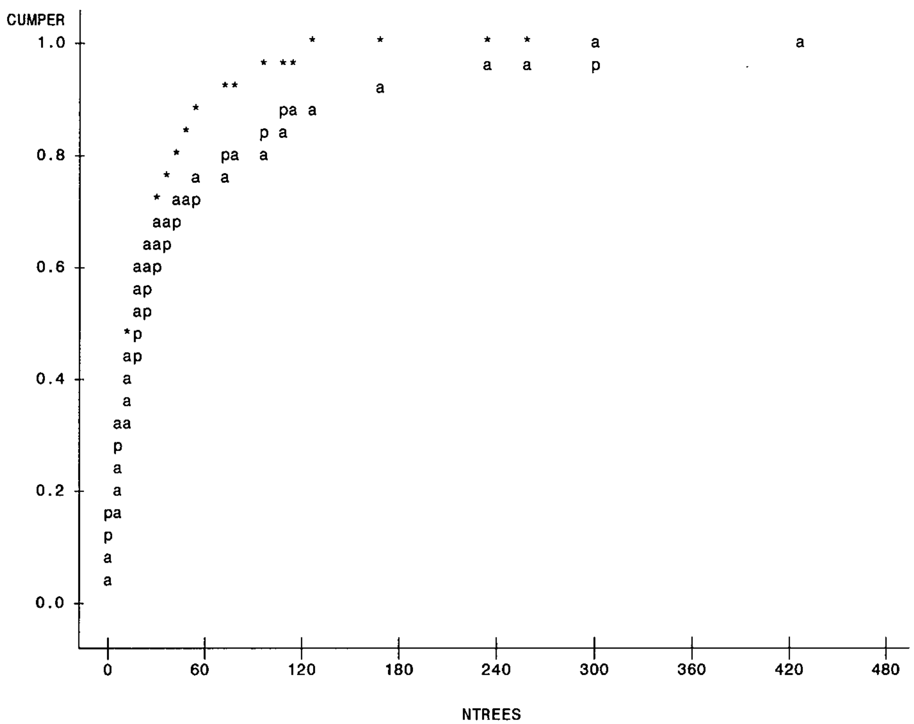
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 62 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_18 Hw/Cw series, east, 8-12yrs

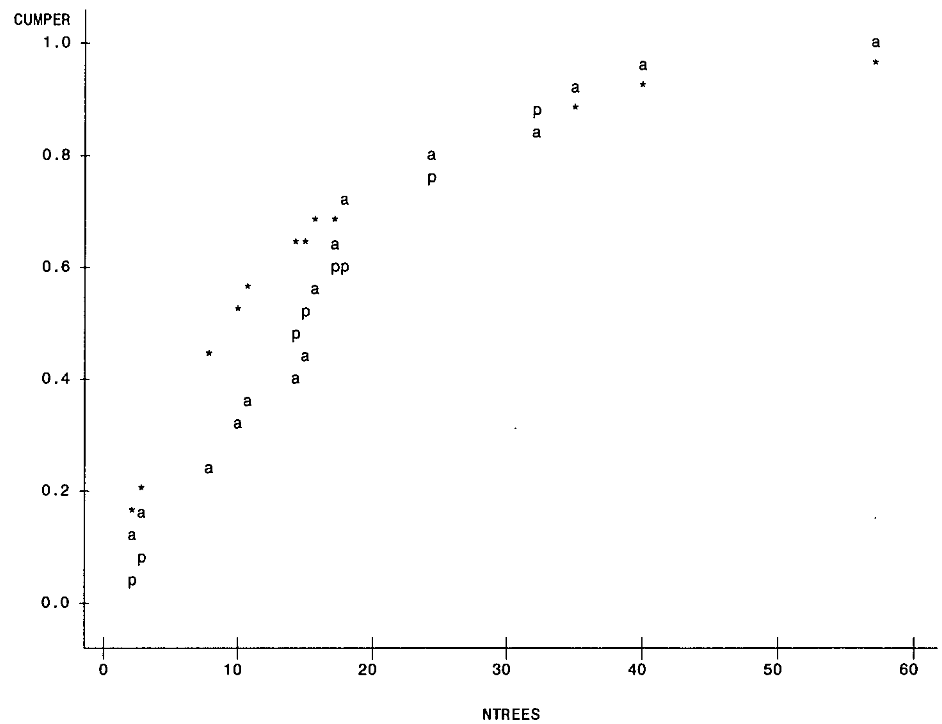
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 46 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_19 Hw/Cw series, south, 8-12yrs

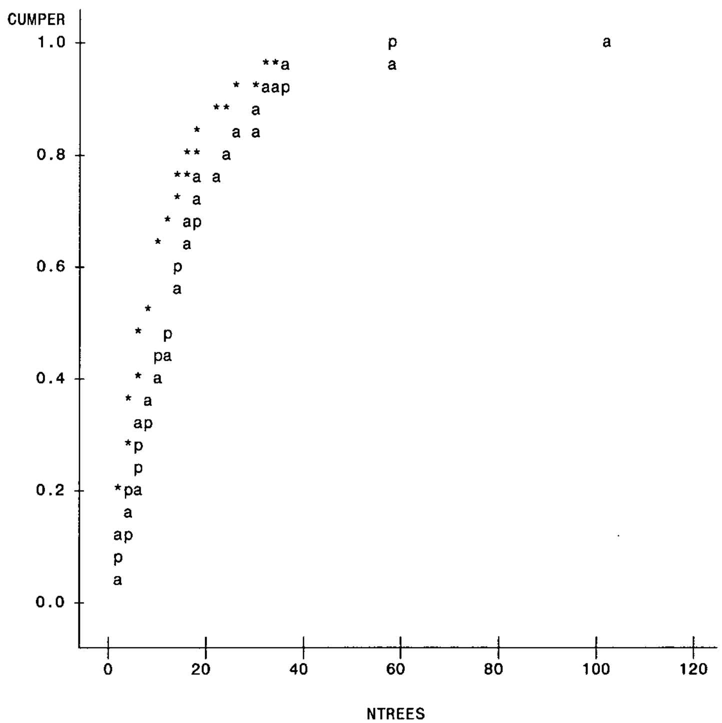
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 10 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_20 Hw/Cw series, west, 8-12yrs

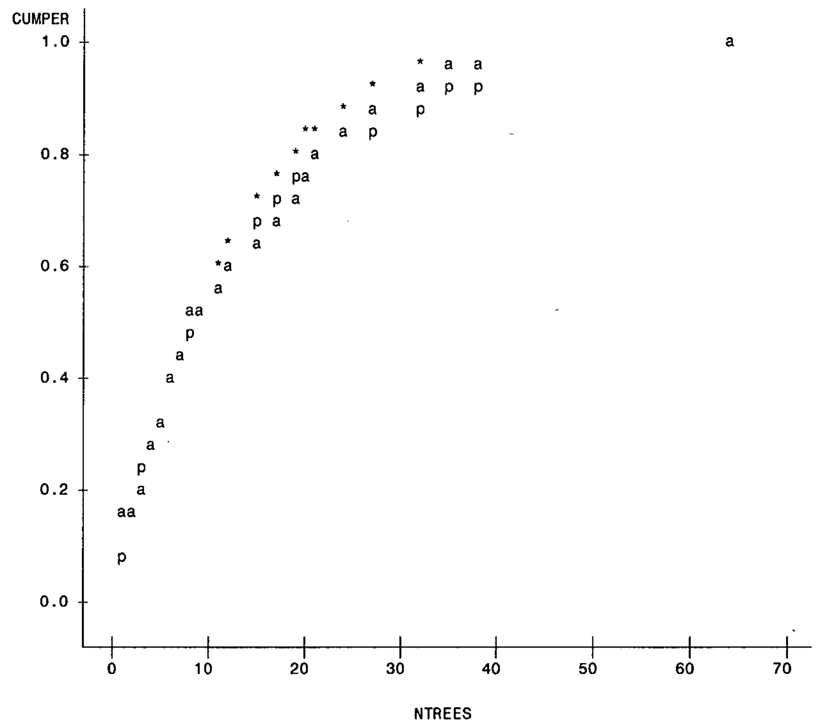
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 20 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_21 Hw/Cw series, north, >12yrs

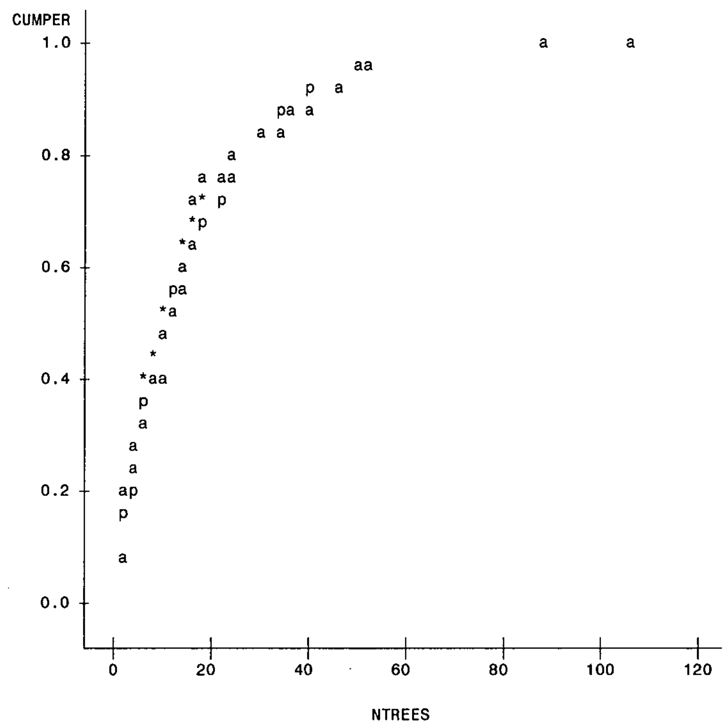
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of PROGNOSISCUM*NTREES. Symbol used is '*'.



NOTE: 24 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_2 Fd series, east, <7yrs

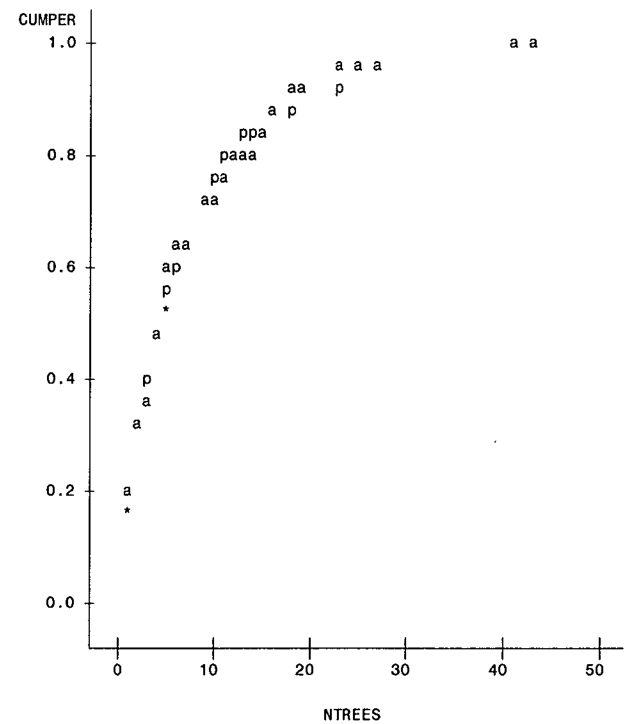
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 44 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_3 Fd series, south, <7yrs

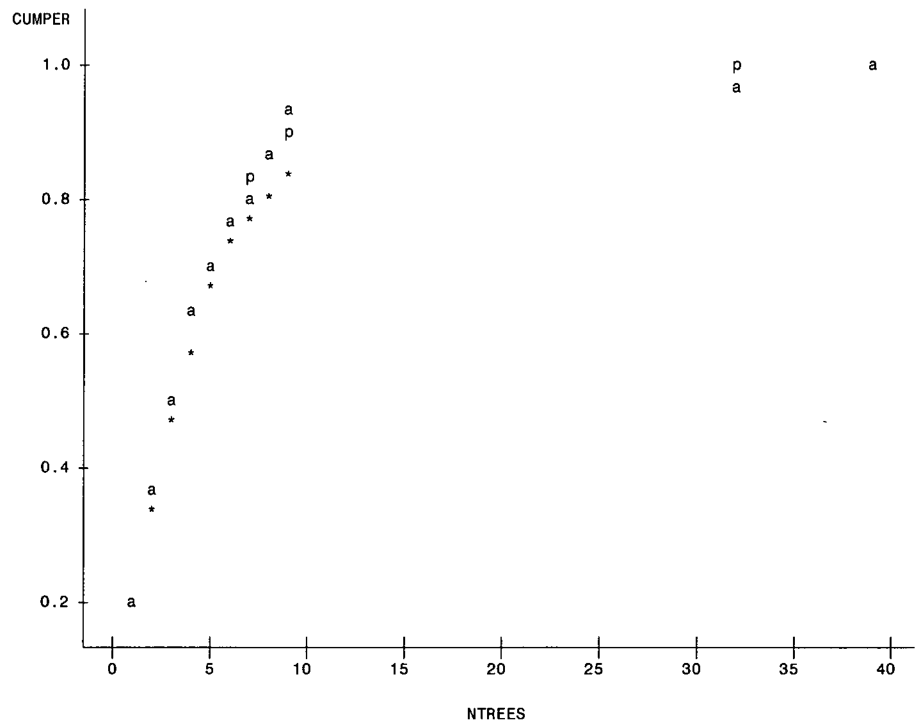
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 33 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_4 Fd series, west, <7yrs

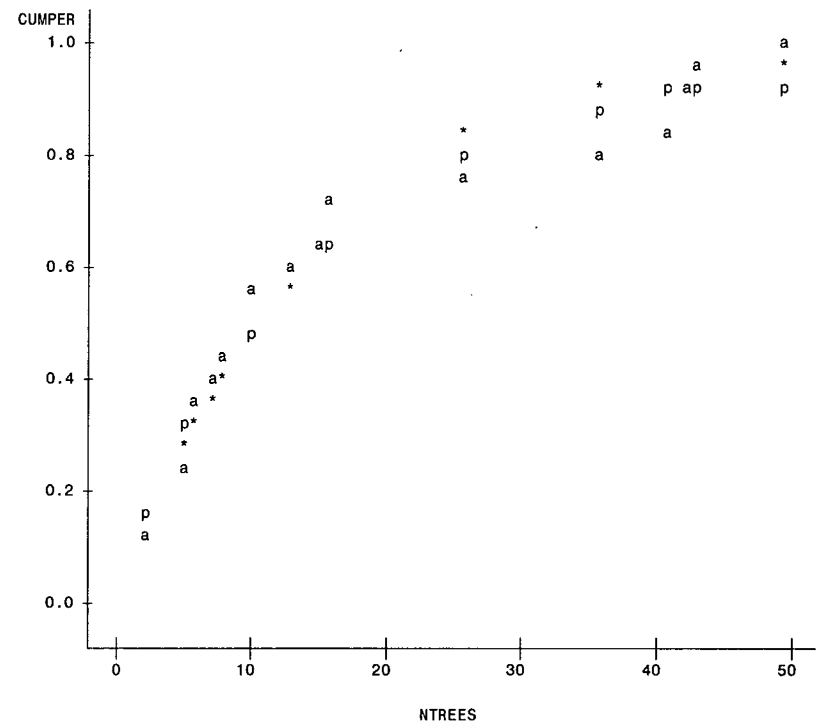
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 11 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_6 Fd series, east, 8-12yrs

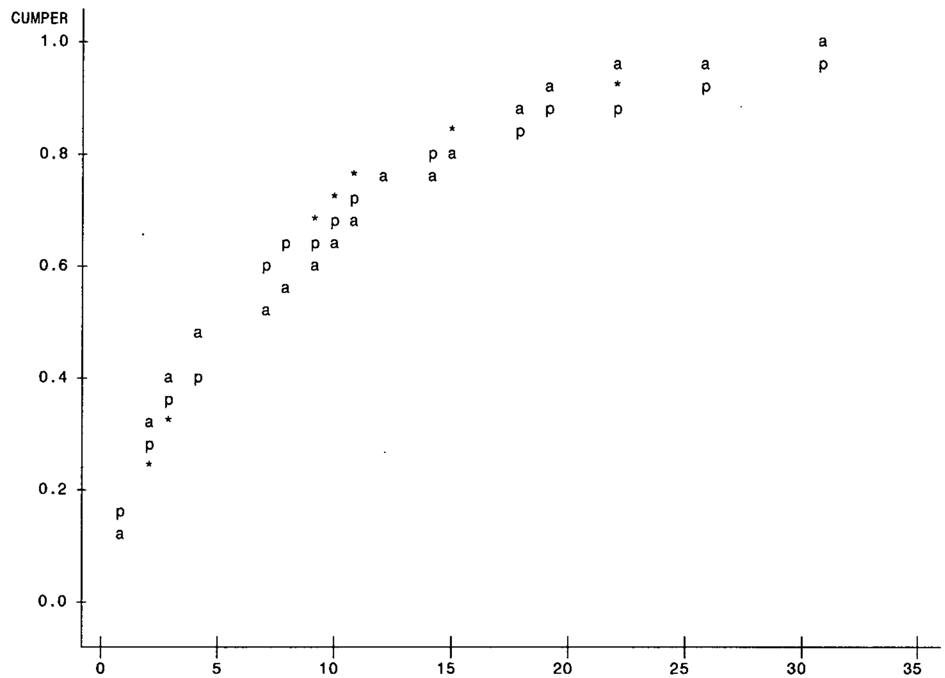
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 13 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_8 Fd series, west, 8-12yrs

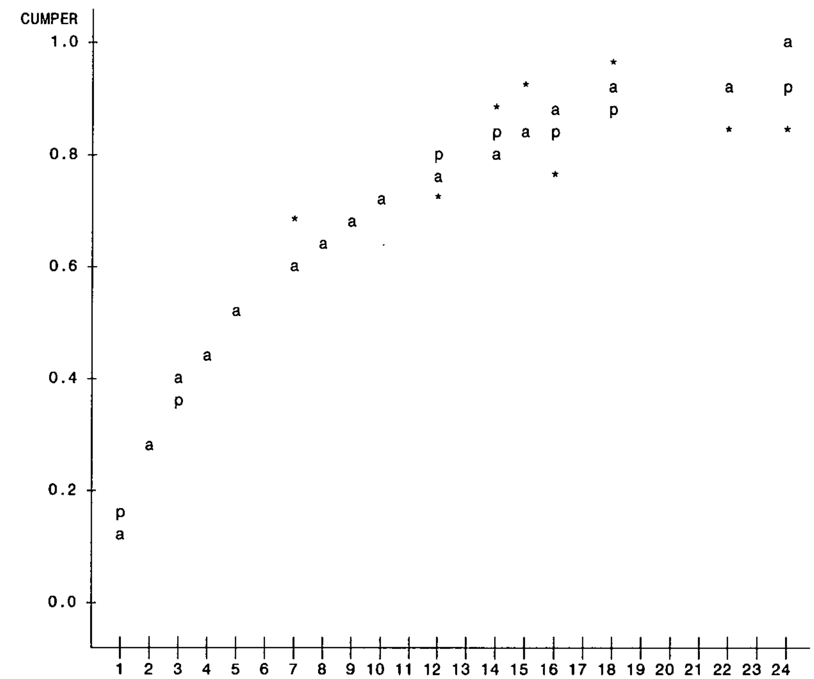
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES.   Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 12 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_9 Fd series, north, >12yrs

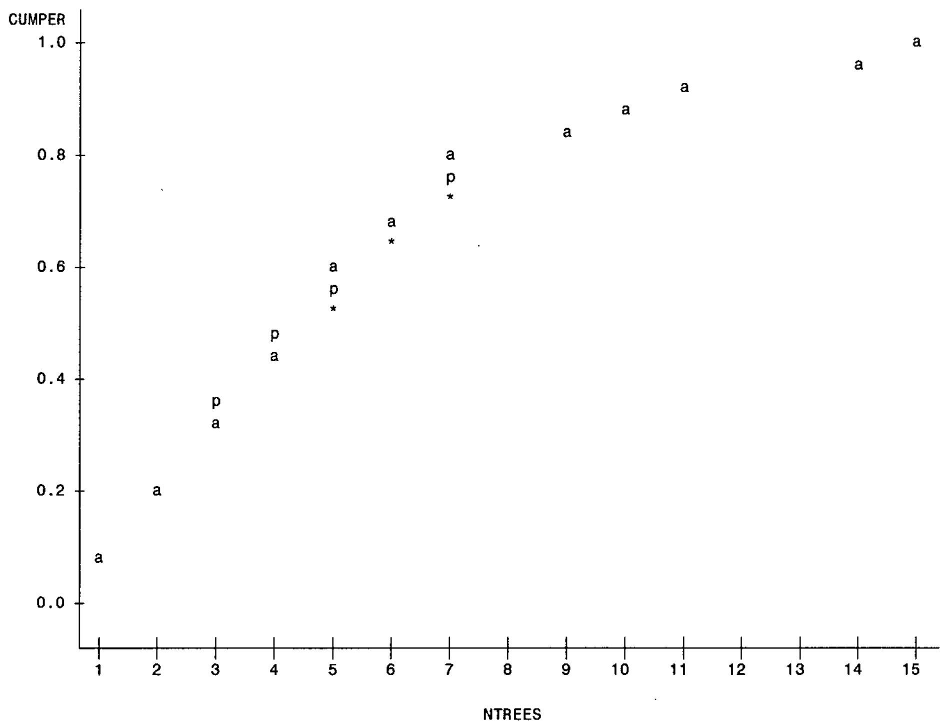
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES.   Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 17 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_10 Fd series, east, >12yrs

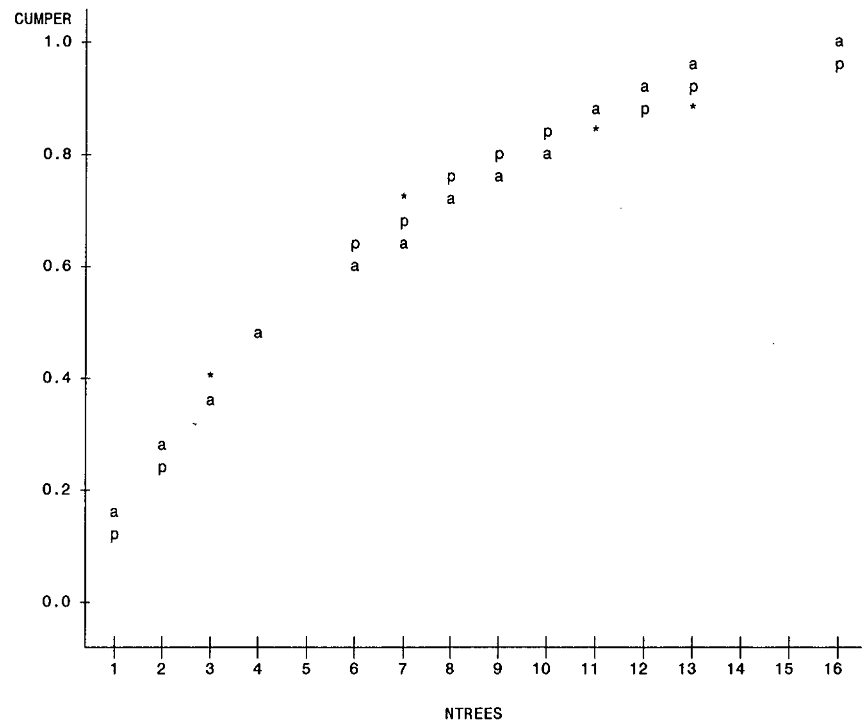
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 17 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_13 Hw/Cw series, north,<7yrs

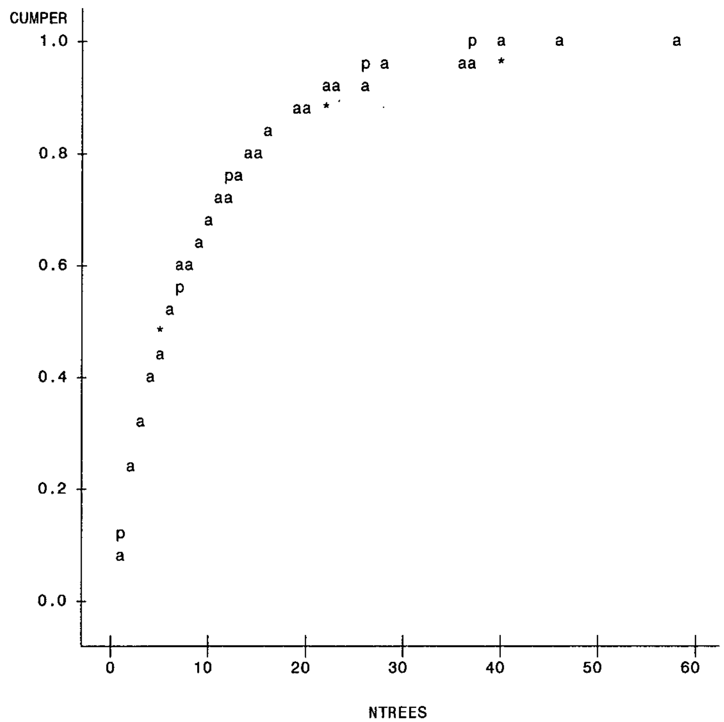
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 12 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull
Cat_14 Hw/Cw series, east, <7yrs

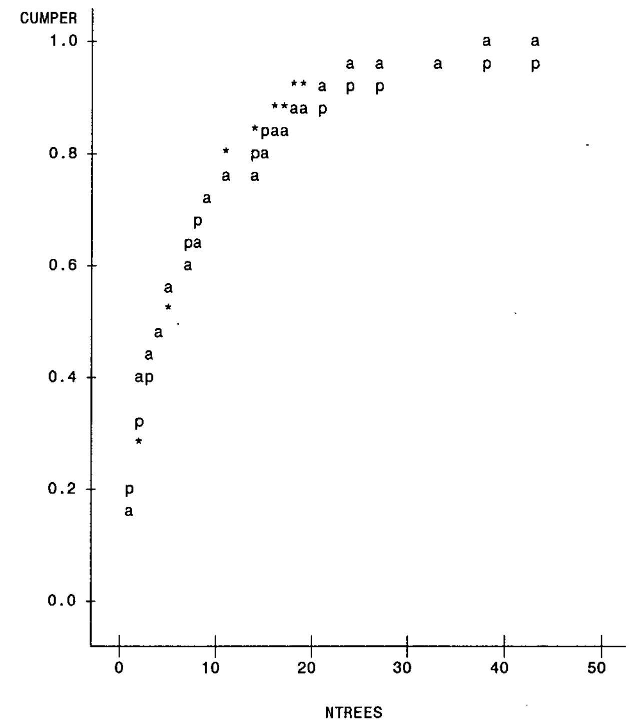
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 46 obs hidden.

Comparing different linear estimates of B and C
By insertion into the Weibull 14:01 Tuesday, July 20, 1999
Cat_15 Hw/Cw series, south, <7yrs

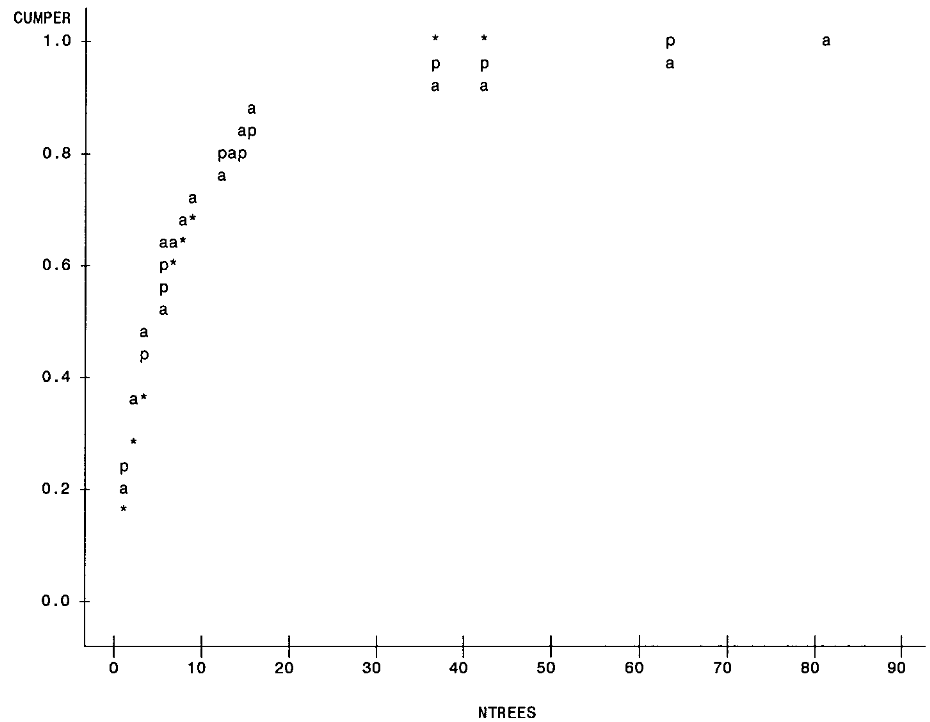
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 22 obs hidden.

Comparing different linear estimates of B and C 27
By insertion into the Weibull 14:01 Tuesday, July 20, 1999
Cat_16 Hw/Cw series, west, <7yrs

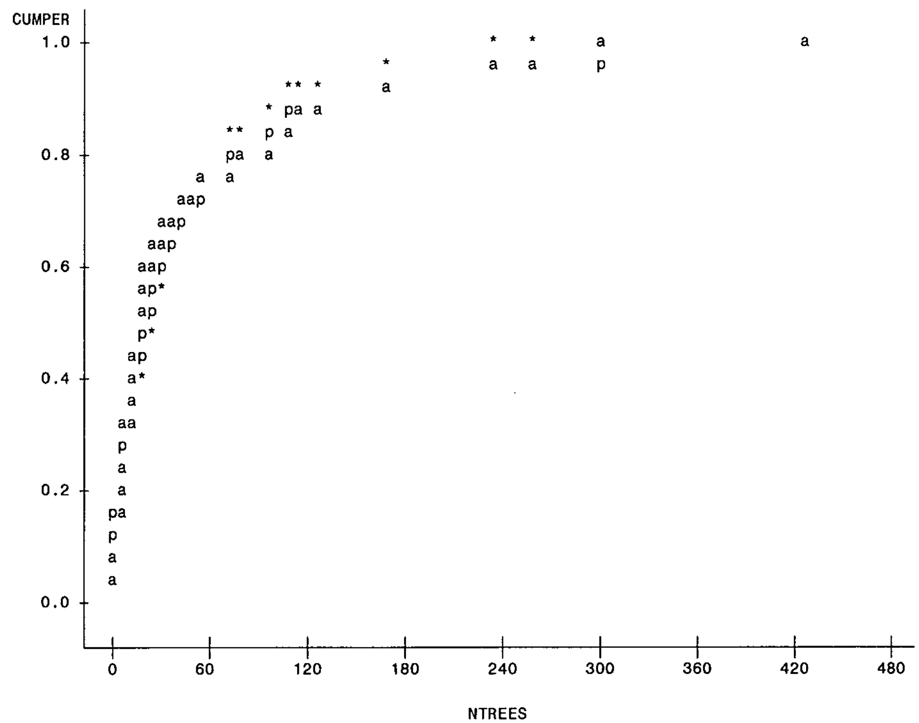
Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 14 obs hidden.

```
              Comparing different linear estimates of B and C                28
                      By insertion into the Weibull     14:01 Tuesday, July 20, 1999
                   Cat_17 Hw/Cw series, north, 8-12yrs

                Plot of CUMPER*NTREES.  Symbol used is 'a'.
                Plot of PRED*NTREES.    Symbol used is 'p'.
                Plot of SURCUM*NTREES.  Symbol used is '*'.

 CUMPER |
    1.0 +           p                      a                                             a
        |       a   a
        |      a
        |     a
        |     a
    0.8 +    aa
        |    a
        |   aa
        |   a
        |   a
    0.6 +   a
        |   a
        |  a*
        |  a
        |  a
    0.4 +  a
        |  a
        |  a
        |  p
        |  a
    0.2 + a*
        | a
        | p
        | a
        |
    0.0 +
        |
        --+---------+---------+---------+---------+---------+---------+---------+---------+--
          0        90       180       270       360       450       540       630       720

                                        NTREES

NOTE: 62 obs hidden.
```

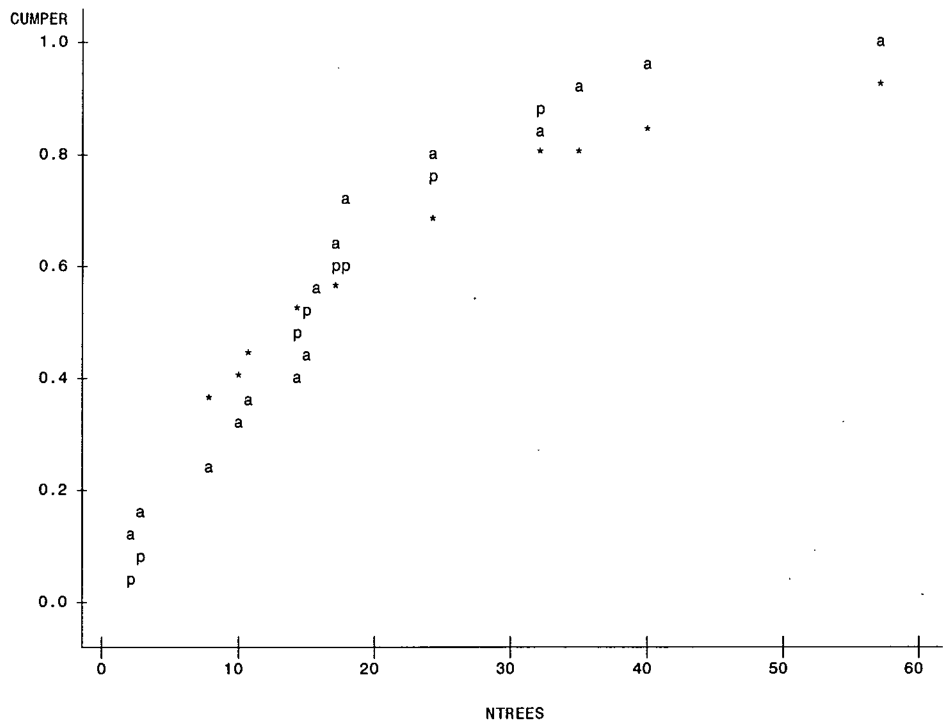
```
Comparing different linear estimates of B and C                    29
      By insertion into the Weibull      14:01 Tuesday, July 20, 1999
     Cat_18 Hw/Cw series, east, 8-12yrs

  Plot of CUMPER*NTREES.  Symbol used is 'a'.
  Plot of PRED*NTREES.    Symbol used is 'p'.
  Plot of SURCUM*NTREES.  Symbol used is '*'.
```



NOTE: 49 obs hidden.

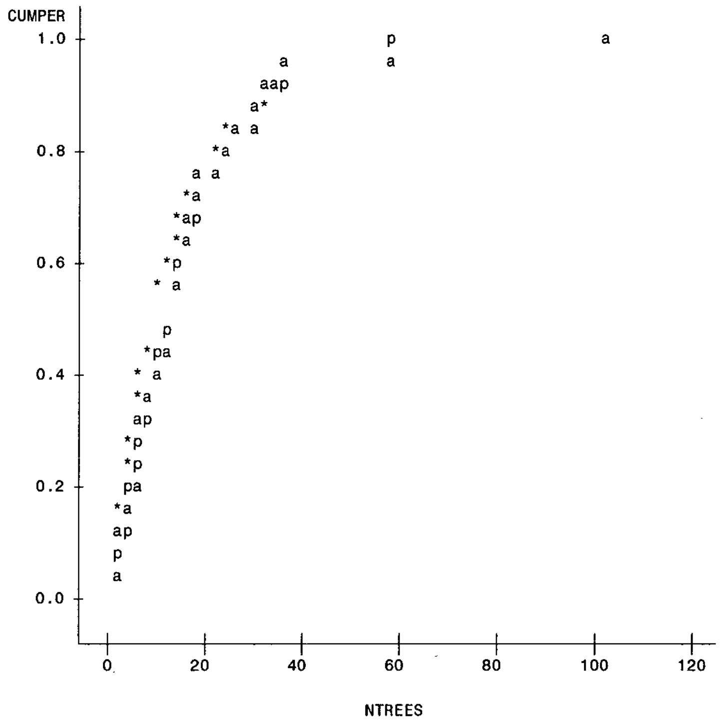
Comparing different linear estimates of B and C 30
By insertion into the Weibull 14:01 Tuesday, July 20, 1999
Cat_19 Hw/Cw series, south, 8-12yrs

Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 12 obs hidden.

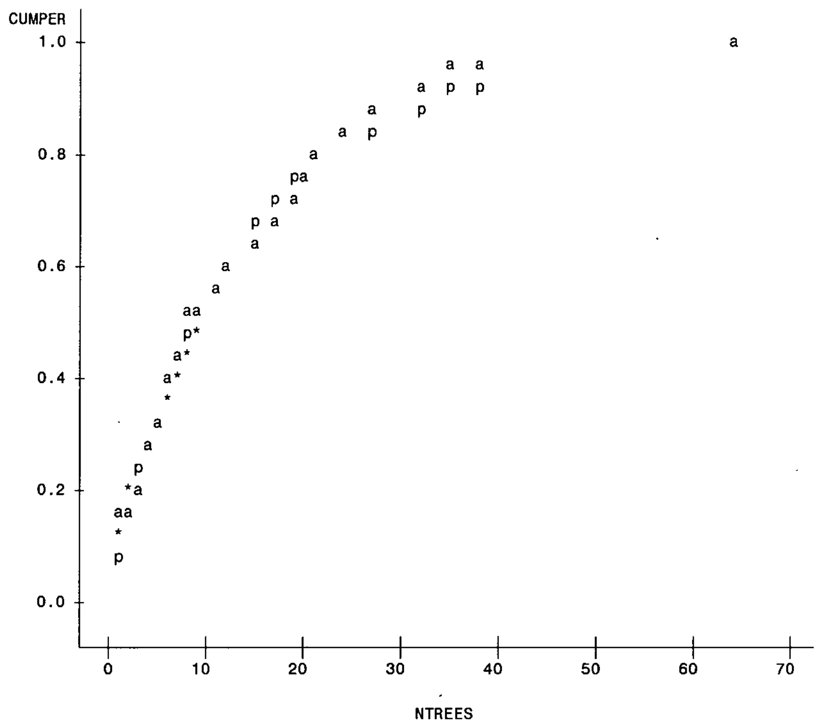
```
Comparing different linear estimates of B and C                     31
        By insertion into the Weibull      14:01 Tuesday, July 20, 1999
      Cat_20 Hw/Cw series, west, 8-12yrs

  Plot of CUMPER*NTREES.  Symbol used is 'a'.
  Plot of PRED*NTREES.    Symbol used is 'p'.
  Plot of SURCUM*NTREES.  Symbol used is '*'.
```



NOTE: 26 obs hidden.

Comparing different linear estimates of B and C 32
By insertion into the Weibull 14:01 Tuesday, July 20, 1999
Cat_21 Hw/Cw series, north, >12yrs

Plot of CUMPER*NTREES. Symbol used is 'a'.
Plot of PRED*NTREES. Symbol used is 'p'.
Plot of SURCUM*NTREES. Symbol used is '*'.



NOTE: 28 obs hidden.

APPENDIX 4: Probabilities of advance, subsequent and excess regeneration.

Re-fitted coefficients of the logit function in the logistic equation form used in Prognosis for probability predictions of advance subsequent and excess regeneration.

Coefficients of the logit functions for logistic equation resulting from a variable selection procedure for prediction of probabilities of advance subsequent and excess regeneration.

Re-fitted coefficients of the Prognosis model form for prediction of subsequent, advance and excess regeneration.

GRAND FIR (Bg) — Advance and subsequent regeneration

Data Set: X.RGNBG
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 13
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	934.0	259182	0.0000	0.9971	.	.
SLO	1	-44.7499	8750.4	0.0000	0.9959	-3.313606	0.000
DSITEP1	1	-118.7	26580.3	0.0000	0.9964	-16.365905	0.000
DSITEP2	1	-8.2239	2645.3	0.0000	0.9975	-2.170525	0.000
BAA	1	2.3687	2789.9	0.0000	0.9993	3.409445	10.683
BAA2	1	-0.5696	437.1	0.0000	0.9990	-6.998178	0.566
ELEV_FC	1	-49.3474	13575.6	0.0000	0.9971	-119.006325	0.000
ELEV_FC2	1	0.6518	178.7	0.0000	0.9971	107.620356	1.919
YRSINCE	1	0.1299	20.2612	0.0000	0.9949	0.441432	1.139
OVER	0	0	.	.	.	.	.
DHAB	1	-3.6398	816.2	0.0000	0.9964	-0.808937	0.026

GRAND FIR (Bg) — Excess regeneration

Data Set: X.RGNBG
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 13
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-5075.2	12894.9	0.1549	0.6939	.	.
X1	1	-240.0	614.5	0.1526	0.6961	-16.785734	.000
X2	1	205.6	541.8	0.1440	0.7043	16.32867	999.000
SLO	1	62.2290	389.7	0.0255	-0.8731	3.97932	999.000
DSITEP1	1	516.5	1346.0	0.1473	0.7012	100.85578	999.000
DSITEP2	1	106.2	326.5	0.1058	0.7449	22.08726	999.000
BAA	1	16.8154	66.4835	0.0640	0.8003	21.10494	999.000
LN_BAA	1	-1.0814	54.2042	0.0004	0.9841	-0.59131	0.339
ELEV_FC	1	270.2	683.9	0.1560	0.6928	798.98887	999.000
ELEV_FC2	1	-3.6745	9.3174	0.1555	0.6933	-716.490351	0.025
YRSINCE	1	3.2566	13.0605	0.0622	0.8031	11.626983	25.962
OVER	0	0	.	.	.	.	.

SUBALPINE FIR (Bl) — Advance and subsequent regeneration

Data Set: X.RGNBL
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 21
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-708.9	6545.7	0.0117	0.9138	.	.
X1	1	17.0975	802.6	0.0005	0.9830	1.27776	999.000
X2	1	-0.5719	126.3	0.0000	0.9964	-0.073189	0.564
SLO	1	-50.4742	333.4	0.0229	0.8797	-4.134083	0.000
DSITEP1	0	0	.	.	.	.	.
DSITEP2	1	-33.1322	250.5	0.0175	0.8948	-8.782330	0.000
BAA	1	-0.5769	21.0716	0.0007	0.9782	-0.829864	0.562
ELEV_FC	1	42.1298	385.8	0.0119	0.9130	83.48590	999.000
ELEV_FC2	1	-0.5609	5.3074	0.0112	0.9158	-83.620192	0.571
YRSINCE	1	-3.2324	14.6359	0.0488	0.8252	-11.455761	0.039
OVER	1	10.6289	101.0	0.0111	0.9162	1.32609	999.000
DHAB	1	-23.3584	88.4004	0.0698	0.7916	-5.918873	0.000

SUBALPINE FIR (Bl) — Excess regeneration

Data Set: X.RGNBL
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 21
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-0.6116	5.2819	0.0134	0.9078	.	.
X1	1	3.0918	3.9240	0.6208	0.4307	0.227647	22.018
X2	1	6.1035	2.8710	4.5195	0.0335	0.83507	447.404
SLO	1	-0.3817	3.7044	0.0106	0.9179	-0.036373	0.683
DSITEP1	0	0	.	.	.	.	.
DSITEP2	1	-0.00517	0.6822	0.0001	0.9939	-0.001233	0.995
ELEV_FC	1	-0.0412	0.1278	0.1040	0.7471	-0.062935	0.960
OVER	1	-1.4472	1.0981	1.7368	0.1875	-0.169958	0.235
DHAB	1	3.1818	0.9809	10.5223	0.0012	0.614337	24.091

WESTERN RED CEDAR (Cw) – Advance and subsequent regeneration

Data Set: X.RGNCW
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 94
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	0.0389	1.0135	0.0015	0.9694	.	.
X1	1	-0.0620	1.1586	0.0029	0.9573	-0.006643	0.940
X2	1	0.2428	0.9055	0.0719	0.7886	0.032850	1.275
SLO	1	-0.6016	1.4474	0.1728	0.6777	-0.054129	0.548
DSITEP1	1	-0.2529	0.9551	0.0701	0.7912	-0.038109	0.777
DSITEP2	1	-2.0802	0.5724	13.2060	0.0003	-0.400780	0.125
BAA	1	-0.9003	0.1896	22.5549	0.0001	-0.687640	0.406
ELEV_FC	1	0.1080	0.0318	11.5516	0.0007	0.409026	1.114
YRSINCE	1	-0.1074	0.0388	7.6544	0.0057	-0.357750	0.898
OVER	1	-0.2936	0.5217	0.3167	0.5736	-0.074011	0.746
DPOS1	1	-0.1032	0.8135	0.0161	0.8991	-0.014429	0.902
DHAB	1	-0.2365	0.4622	0.2619	0.6088	-0.059623	0.789

WESTEN RED CEDAR Cw) – Excess regeneration

Data Set: X.RGNCW
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 94
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	0.7942	0.4526	3.0787	0.0793	.	.
X1	1	-0.1807	0.5059	0.1275	0.7210	-0.020308	0.835
X2	1	-0.9494	0.4147	5.2416	0.0221	-0.122182	0.387
SLO	1	-0.6138	0.5508	1.2415	0.2652	-0.055139	0.541
DSITEP1	1	1.2990	0.4134	9.8721	0.0017	0.192379	3.666
DSITEP2	1	0.5033	0.2733	3.3924	0.0655	0.101203	1.654
ELEV_FC	1	-0.0343	0.0128	7.1910	0.0073	-0.134744	0.966
YRSINCE	1	0.0709	0.0153	21.5604	0.0001	0.252393	1.073
OVER	1	0.0296	0.2007	0.0217	0.8828	0.007455	1.030
DHAB	1	0.4720	0.2107	5.0173	0.0251	0.109213	1.603

DOUGLAS FIR (Fd) – Advance and subsequent regeneration

Data Set: X.RGNFD
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 111
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-3.7648	1.2345	9.3006	0.0023	.	.
X1	1	-0.8960	1.0946	0.6701	0.4130	-0.097355	0.408
X2	1	-0.6681	0.8279	0.6512	0.4197	-0.094562	0.513
SLO	1	0.8488	1.0395	0.6667	0.4142	0.089858	2.337
DSITEP1	1	1.2594	0.6021	4.3754	0.0365	0.233602	3.523
DSITEP2	1	-1.7071	0.5962	8.1974	0.0042	-0.402265	0.181
BAA	1	-0.3979	0.2316	2.9510	0.0858	-0.584442	0.672
BAA2	1	0.0157	0.0247	0.4029	0.5256	0.230142	1.016
ELEV_FC	1	0.0813	0.0319	6.5036	0.0108	0.314620	1.085
OVER	1	0.0526	0.4511	0.0136	0.9071	0.013436	1.054
DHAB	1	0.2966	0.4145	0.5120	0.4743	0.081514	1.345

DOUGLAS FIR (Fd) – Excess regeneration

Data Set: X.RGNFD
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 111
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	2.1354	0.6146	12.0734	0.0005	.	.
X1	1	0.8052	0.5759	1.9549	0.1621	0.088076	2.237
X2	1	-2.0077	0.5638	12.6823	0.0004	-0.268097	0.134
SLO	1	1.0242	0.6310	2.6345	0.1046	0.103259	2.785
DSITEP1	1	0.8851	0.3418	6.7052	0.0096	0.186624	2.423
DSITEP2	1	0.0527	0.2519	0.0438	0.8343	0.011935	1.054
ELEV_FC	1	-0.0475	0.0157	9.1468	0.0025	-0.185421	0.954
YRSINCE	1	-0.0431	0.0202	4.5574	0.0328	-0.121791	0.958
OVER	1	0.1806	0.2025	0.7955	0.3725	0.048487	1.198
DHAB	1	0.1938	0.2228	0.7566	0.3844	0.053114	1.214

WESTERN HEMLOCK (Hw) ╥ Advance and subsequent regeneration

Data Set: X.RGNHW
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 77
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	0.4390	0.3988	1.2119	0.2709	.	.
X1	1	-1.0001	1.1628	0.7397	0.3898	-0.089749	0.368
X2	1	1.1324	0.9650	1.3770	0.2406	0.140841	3.103
SLO	1	-3.6517	1.3623	7.1852	0.0074	-0.299044	0.026
DSITEP1	1	0.8135	0.8107	1.0068	0.3157	0.111557	2.256
DSITEP2	1	-0.3788	0.5390	0.4940	0.4822	-0.073729	0.685
OVER	1	0.5966	0.3517	2.8778	0.0898	0.164092	1.816

WESTERN HEMLOCK (Hw) ╥ Excess regeneration

Data Set: X.RGNHW
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 77
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	2.5963	2.1049	1.5214	0.2174	.	.
X1	1	0.0736	0.6697	0.0121	0.9124	0.006187	1.076
X2	1	2.4402	0.5318	21.0518	0.0001	0.277778	11.475
SLO	1	4.6810	0.8007	34.1756	0:0001	0.33637	07.879
DSITEP1	1	-1.9824	0.5937	11.1509	0.0008	-0.157179	0.138
DSITEP2	1	-0.1580	0.4211	0.1408	0.7075	-0.015604	0.854
ELEV_FC	1	-0.1706	0.1442	1.3997	0.2368	-0.673040	0.843
ELEV_FC2	1	0.00124	0.00241	0.2634	0.6078	0.275152	1.001
YRSINCE	1	0.0824	0.0247	11.1230	0.0009	0.208253	1.086
OVER	1	0.5872	0.2494	5.5460	0.0185	0.150150	1.799

WESTERN LARCH(Lw) ╥ Advance and subsequent regeneration

Data Set: X.RGNLW
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 29
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-2.7766	1.3738	4.0845	0.0433	.	.
X1	1	-5.7945	4.4736	1.6777	0.1952	-0.658310	0.003
X2	1	-1.4045	3.9126	0.1288	0.7196	-0.154647	0.246
SLO	1	-1.0661	5.5671	0.0367	0.8481	-0.081601	0.344
OVER	1	0.8501	1.4729	0.3331	0.5638	0.223614	2.340

WESTERN LARCH (Lw) ╥ Excess regeneration

Data Set: X.RGNLW
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 29
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-2.0797	8.1232	0.0655	0.7979	.	.
X1	1	-0.4236	1.8425	0.0529	0.8182	-0.050855	0.655
X2	1	-4.4471	1.6681	7.1076	0.0077	-0.408756	0.012
SLO	1	1.0217	2.6950	0.1437	0.7046	0.071691	2.778
DSITEP1	1	0.3888	1.1488	0.1146	0.7350	0.067714	1.475
DSITEP2	1	1.4392	0.7920	3.3019	0.0692	0.362949	4.217
ELEV_FC	1	0.1728	0.5254	0.1081	0.7423	0.596223	1.189
ELEV_FC2	1	-0.00381	0.00795	0.2299	0.6316	-0.870641	0.996
OVER	1	-0.5138	0.6271	0.6714	0.4126	-0.133170	0.598
DHAB	1	0.1679	0.6396	0.0689	0.7929	0.046335	1.183

LODGEPOLE PINE (Pl) – Advance and subsequent regeneration

Data Set: X.RGNPL
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 45
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-11.8828	5.5620	4.5644	0.0326	.	.
SLO	1	0.0109	3.7022	0.0000	0.9976	0.000973	1.011
LN_BAA	1	-0.2880	0.2642	1.1882	0.2757	-0.376112	0.750
ELEV_FC	1	0.2114	0.1188	3.1678	0.0751	0.858200	1.235
OVER	1	0.2813	1.2929	0.0473	0.8278	0.065460	1.325

LODGEPOLE PINE (Pl) – Excess regeneration

Data Set: X.RGNPL
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 45
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-22.1146	11.6162	3.6244	0.0569	.	.
X1	1	0.3987	2.4050	0.0275	0.8683	0.027764	1.490
X2	1	1.5320	1.3842	1.2250	0.2684	0.164802	4.627
SLO	1	-5.2697	1.8310	8.2835	0.0040	-0.443529	0.005
DSITEP1	1	3.9245	1.4209	7.6289	0.0057	1.013967	50.627
DSITEP2	1	-0.8698	0.6455	1.8158	0.1778	-0.209753	0.419
LN_BAA	1	0.3496	0.1193	8.5897	0.0034	0.426842	1.419
ELEV_FC	1	1.0472	0.6062	2.9840	0.0841	4.293691	2.850
ELEV_FC2	1	-0.0110	0.00789	1.9384	0.1638	-3.134247	0.989
OVER	1	0.3164	0.8372	0.1429	0.7054	0.084822	1.372
DPOS1	0	0	.	.	.	.	.
DHAB	1	0.4873	0.5775	0.7121	0.3988	0.120681	1.628

WHITE PINE (Pw) -Advance and subsequent regeneration

Data Set: X.RGNPW
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 54
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	4.4023	3.3912	1.6852	0.1942	.	.
X1	1	-4.9939	4.5056	1.2285	0.2677	-0.517698	0.007
X2	1	10.4625	9.8652	1.1248	0.2889	1.466014	9.000
SLO	1	-14.4451	10.9519	1.7396	0.1872	-1.427703	0.000
DSITEP1	1	2.7318	1.8116	2.2740	0.1316	0.410386	5.361
DSITEP2	1	-12.6929	212.6	0.0036	0.9524	-2.932694	0.000
BAA	1	-0.5207	0.8798	0.3502	0.5540	-0.767298	0.594
BAA2	1	-0.0468	0.1346	0.1209	0.7281	-0.576283	0.954
ELEV_FC	1	-0.0198	0.0866	0.0525	0.8188	-0.087980	0.980
YRSINCE	1	-0.4677	0.1986	5.5453	0.0185	-1.511460	0.626
OVER	1	-2.9601	2.6706	1.2286	0.2677	-0.517007	0.052
DHAB	1	2.5334	1.5865	2.5500	0.1103	0.655394	2.597

WHITE PINE (Pw) – Excess regeneration

Data Set: X.RGNPW
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 54
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	1.5240	0.4850	9.8750	0.0017	.	.
X1	1	2.0394	1.1627	3.0768	0.0794	0.175124	7.686
X2	1	-1.3685	0.8469	2.6109	0.1061	-0.195951	0.254
SLO	1	-2.3915	1.2416	3.7102	0.0541	-0.230560	0.091
BAA	1	-0.00257	0.1167	0.0005	0.9824	-0.003489	0.997
LN_BAA	1	0.3195	0.1162	7.5528	0.0060	0.411732	1.376
OVER	1	-2.1031	0.7687	7.4851	0.0062	-0.353989	0.122

Resulting models from a variable selection process for prediction of subsequent, advance and excess regeneration.

SPRUCE (Sx) ╥ Advance and subsequent regeneration

Data Set: X.RGNSX
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 20
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-165.7	541.3	0.0937	0.7595	.	.
DSITEP1	1	-7.6156	186.0	0.0017	0.9673	-0.916237	0.000
DSITEP2	1	-7.9892	49.1551	0.0264	0.8709	-1.922358	0.000
ELEV_FC	1	10.6001	34.6471	0.0936	0.7596	41.03978	999.000
ELEV_FC2	1	-0.1606	0.5328	0.0908	0.7631	-41.931317	0.852
YRSINCE	1	-0.6751	3.4918	0.0374	0.8467	-2.747617	0.509
OVER	1	-4.2757	84.1897	0.0026	0.9595	-0.948514	0.014

SPRUCE (Sx) ╥ Excess regeneration

Data Set: X.RGNSX
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 20
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-16.8282	14.2464	1.3953	0.2375	.	.
SLO	1	-3.1423	3.6409	0.7448	0.3881	-0.231891	0.043
DSITEP1	1	10.3051	747.5	0.0002	0.9890	0.87667	999.000
DSITEP2	1	0.2872	1.1241	0.0653	0.7983	0.065762	1.333
ELEV_FC	1	1.3153	0.9249	2.0227	0.1550	5.125508	3.726
ELEV_FC2	1	-0.0219	0.0139	2.4932	0.1143	-5.762330	0.978
YRSINCE	1	0.0312	0.0679	0.2112	0.6458	0.122610	1.032
OVER	1	-1.8315	1.4332	1.6330	0.2013	-0.357618	0.160
DHAB	1	-0.5600	1.0070	0.3093	0.5781	-0.155530	0.571

GRAND FIR (Bg) ╥ Advance and subsequent regeneration

Data Set: X.RGNBG
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 13
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-11.8107	259.5	0.0021	0.9637	.	.
OVER	1	-192E-14	449.5	0.0000	1.0000	-2.64054E-13	1.000
DHAB	1	9.3257	259.5	0.0013	0.9713	2.07262	999.000

GRAND FIR (Bg) ╥ Excess regeneration

Data Set: X.RGNBG
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 13
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	2.2256	1.3129	2.8739	0.0900	.	.
YRSINCE	1	0.0460	0.0772	0.3542	0.5517	0.164061	1.047
CCF	1	-0.0142	0.0115	1.5268	0.2166	-0.377212	0.986
DHAB	1	-0.1689	1.2585	0.0180	0.8933	-0.036999	0.845

SUBALPINE FIR (Bl) ╥ Advance and subsequent regeneration

Data Set: X.RGNBL
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 21
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	11.1861	5.4913	4.1496	0.0416	.	.
YRSINCE	1	-1.0918	0.5495	3.9482	0.0469	-3.869315	0.336
DHAB	1	-4.6652	3.0461	2.3456	0.1256	-1.182138	0.009

SUBALPINE FIR (Bl) ╥ Excess regeneration

Data Set: X.RGNBL
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 21
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-2.2401	0.7173	9.7518	0.0018	.	.
BAHA	1	0.1019	0.0232	19.3305	0.0001	0.775512	1.107
DHAB	1	1.8406	0.7353	6.2660	0.0123	0.355378	6.300

WESTERN RED CEDAR (Cw) ╥ Advance and subsequent regeneration

Data Set: X.RGNCW
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 94
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-0.2742	0.8631	0.1009	0.7508	.	.
DSITEP1	1	-0.1247	0.8339	0.0224	0.8811	-0.018796	0.883
DSITEP2	1	-1.8912	0.4672	16.3868	0.0001	-0.364359	0.151
ELEV	1	0.00333	0.000937	12.6048	0.0004	0.384915	1.003
BAHA	1	-0.1990	0.0413	23.2737	0.0001	-0.660402	0.820
YRSINCE	1	-0.1064	0.0357	8.8896	0.0029	-0.354221	0.899

WESTEN RED CEDAR (Cw) ╥ Excess regeneration

Data Set: X.RGNCW
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 94
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	0.9492	0.2628	13.0435	0.0003	.	.
X2	1	-1.8186	0.5120	12.6179	0.0004	-0.234035	0.162
DSITEP1	1	0.8541	0.3709	5.3024	0.0213	0.126492	2.349
DSITEP2	1	-0.3384	0.2715	1.5535	0.2126	-0.068039	0.713
ASP	1	-0.00288	0.00107	7.1965	0.0073	-0.171885	0.997
BAHA	1	0.0400	0.0138	8.4110	0.0037	0.162103	1.041
YRSINCE	1	0.0585	0.0157	13.8856	0.0002	0.208028	1.060
CCF	1	-0.00414	0.00111	13.8241	0.0002	-0.179953	0.996

DOUGLAS FIR (Fd) – Advance and subsequent regeneration

Data Set: X.RGNFD
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 111
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	3.3554	1.0277	10.6606	0.0011	.	.
X2	1	-3.3020	1.1243	8.6255	0.0033	-0.467349	0.037
DSITEP1	1	1.9426	0.8664	5.0273	0.0250	0.360320	6.977
DSITEP2	1	-2.0834	0.7539	7.6356	0.0057	-0.490940	0.125
BAHA	1	-0.1383	0.0351	15.4905	0.0001	-0.882301	0.871
YRSINCE	1	-0.3887	0.0792	24.0948	0.0001	-1.197687	0.678
DPOS1	1	-1.9148	1.5608	1.5051	0.2199	-0.180099	0.147
DPOS2	1	-2.2715	0.7254	9.8066	0.0017	-0.591832	0.103
DPOS3	1	-1.9223	1.1738	2.6820	0.1015	-0.303371	0.146
CCF	1	0.0201	0.00732	7.5648	0.0060	0.636765	1.020

DOUGLAS FIR (Fd) – Excess regeneration

Data Set: X.RGNFD
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 111
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	1.2417	0.6064	4.1922	0.0406	.	.
DSITEP1	1	1.0357	0.2807	13.6152	0.0002	0.218378	2.817
DSITEP2	1	0.6262	0.2510	6.2240	0.0126	0.141812	1.870
ELEV	1	-0.00118	0.00051	5.3580	0.0206	-0.141159	0.999
BAHA	1	0.0668	0.00935	51.0569	0.0001	0.514514	1.069
YRSINCE	1	-0.0398	0.0192	4.2943	0.0382	-0.112503	0.961

WESTERN HEMLOCK (Hw) – Advance and subsequent regeneration

Data Set: X.RGNHW
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 77
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	2.0208	0.6803	8.8240	0.0030	.	.
BAHA	1	-0.0517	0.0192	7.2216	0.0072	-0.337026	0.950
YRSINCE	1	-0.1619	0.0464	12.1521	0.0005	-0.502419	0.851
DPOS2	1	-0.9375	0.4840	3.7515	0.0528	-0.226492	0.392
CCF	1	0.00889	0.00296	9.0350	0.0026	0.395499	1.009
DHAB	1	-1.1581	0.4974	5.4204	0.0199	-0.254978	0.314

WESTERN HEMLOCK (Hw) – Excess regeneration

Data Set: X.RGNHW
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 77
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	1.5062	0.5246	8.2427	0.0041	.	.
X2	1	1.5993	0.4360	13.4551	0.0002	0.182057	4.950
ELEV	1	-0.00298	0.000436	46.7781	0.0001	-0.358505	0.997
BAHA	1	0.0657	0.00858	58.6466	0.0001	0.606434	1.068
DPOS1	1	1.4864	0.8217	3.2725	0.0704	0.103130	4.421
DPOS2	1	0.8173	0.2285	12.7876	0.0003	0.195532	2.264
DPOS3	0	0	.	.	.	.	.
DHAB	1	1.1287	0.2900	15.1486	0.0001	0.177679	3.092

WESTERN LARCH ╥ Excess regeneration

Data Set: X.RGNLW
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 29
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-2.5649	0.5991	18.3271	0.0001	.	.

WESTERN LARCH (Lw) ╥ Excess regeneration

Data Set: X.RGNLW
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 29
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-1.1275	0.5347	4.4456	0.0350	.	.
ASP	1	0.00597	0.00198	9.0490	0.0026	0.374532	1.006
DPOS1	1	1.6198	0.8112	3.9876	0.0458	0.303162	5.052

LODGEPOLE PINE (Pl) ╥ Advance and subsequent regeneration

Data Set: X.RGNPL
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 45
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-10.0338	4.3172	5.4015	0.0201	.	.
ELEV	1	0.00623	0.00335	3.4593	0.0629	0.775675	1.006

LODGEPOLE PINE (Pl) ╥ Excess regeneration

Data Set: X.RGNPL
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 45
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	0.8162	0.2612	9.7645	0.0018	.	.
SLOPE	1	-0.0412	0.0115	12.7236	0.0004	-0.346508	0.960

WHITE PINE (Pw) ╥ Advance and subsequent regeneration

Data Set: X.RGNPW
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 54
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	0.4425	0.5886	0.5653	0.4521	.	.
YRSINCE	1	-0.3030	0.0937	10.4605	0.0012	-0.979370	0.739

WHITE PINE (Pw) ╥ Excess regeneration

Data Set: X.RGNPW
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 54
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-0.4361	0.6383	0.4667	0.4945	.	.
SLOPE	1	-0.0388	0.0130	8.8967	0.0029	-0.373580	0.962
DSITEP1	1	0.0938	0.7794	0.0145	0.9042	0.015457	1.098
DSITEP2	1	1.1901	0.6171	3.7188	0.0538	0.264070	3.287
ASP	1	0.00322	0.00198	2.6282	0.1050	0.194443	1.003
BAHA	1	0.0595	0.0228	6.8475	0.0089	0.350848	1.061
YRSINCE	1	-0.0740	0.0334	4.9216	0.0265	-0.245907	0.929
DPOS1	1	0.4439	0.7522	0.3483	0.5551	0.073121	1.559
DPOS2	1	1.6742	0.6106	7.5195	0.0061	0.438313	5.335
DPOS3	1	1.2479	1.0966	1.2950	0.2551	0.125845	3.483

Spruce (Sx) ╥ Advance and subsequent regeneration

Data Set: X.RGNSX
Response Variable (Events): ADVSUM
Response Variable (Trials): SMADVSUB
Number of Observations: 20
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	-3.6261	1.5360	5.5727	0.0182	.	.
X2	1	8.9349	4.8684	3.3683	0.0665	0.98292	999.000

SPRUCE (Sx) ╥ Advance and subsequent regeneration

Data Set: X.RGNSX
Response Variable (Events): XSSUM
Response Variable (Trials): SCOUNT
Number of Observations: 20
Link Function: Logit

Analysis of Maximum Likelihood Estimates

Parameter Variable	DF	Standard Estimate	Wald Error	Pr > Chi-Square	Standardized Chi-Square	Odds Estimate	Ratio
INTERCPT	1	6.6556	2.2734	8.5711	0.0034	.	.
ELEV	1	-0.00579	0.00199	8.4714	0.0036	-0.672079	0.994

APPENDIX 5: Heights of advance and subsequent regeneration.

Germination-delay

Non-linear least square estimates of data-fitted Weibull parameters, for the prediction of delay to germination for species with above 20 observations.

THE FITTED WEIBULL ADVANCED CEDAR REGENERATION

Non-Linear Least Squares Iterative Phase   Dependent Variable CUMPER   Method: Marquardt

Iter	B	C	Sum of Squares
0	17.779380	1.337220	15.536050
1	132.310818	-6.906642	15.482371
2	150.271638	4.616827	7.239222
3	98.664248	1.123284	2.343633
4	113.874121	3.438470	0.537021
5	100.099159	4.806537	0.203751
6	104.458292	4.781845	0.054895
7	104.341674	4.941860	0.053327
8	104.365014	4.942432	0.053322
9	104.364574	4.942817	0.053322
10	104.364628	4.942809	0.053322

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	14.818396502	7.409198251
Residual	44	0.053322248	0.001211869
Uncorrected Total	46	14.871718750	
(Corrected Total)	45	3.755954484	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	104.3646277	0.39721963058	103.56408692	105.16516847
C	4.9428093	0.14411219802	4.65237126	5.23324734

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.180710309
C	-0.180710309	1

THE FITTED WEIBULL ADVANCED DOUGLAS FIR REGENERATION

Non-Linear Least Squares Iterative Phase   Dependent Variable CUMPER   Method: Gauss-Newton

Iter	B	C	Sum of Squares
0	13.121020	1.043250	6.289389
1	1.332449	0.321010	5.918753
2	102.455062	4.524335	0.385179
3	112.431293	5.162149	0.082985
4	111.036292	5.790836	0.071798
5	111.232032	5.796805	0.071639
6	111.228694	5.800910	0.071639
7	111.229101	5.800819	0.071639

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	6.1708172178	3.0854086089
Residual	17	0.0716385574	0.0042140328
Uncorrected Total	19	6.2424557752	
(Corrected Total)	18	1.5407196451	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	111.2291007	1.0289113312	109.05830031	113.39990103
C	5.8008190	0.4894933483	4.76808439	6.83355360

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.163045783
C	-0.163045783	1

THE FITTED WEIBULL ADVANCED HEMLOCK REGENERATION

Non-Linear Least Squares Iterative Phase — Dependent Variable CUMPER — Method: Marquardt

Iter	B	C	Sum of Squares
0	13.064590	1.267060	9.182919
1	31.513974	0.253772	3.285043
2	71.120132	0.274171	2.471488
3	168.995811	0.945996	1.459338
4	124.634298	0.983794	0.962763
5	107.410246	1.328381	0.597656
6	83.776885	2.460754	0.293263
7	94.459924	2.783968	0.044938
8	93.762371	2.966148	0.040339
9	93.853427	2.966311	0.040322
10	93.851972	2.966740	0.040322
11	93.852114	2.966727	0.040322

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics — Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	9.5424780487	4.7712390243
Residual	27	0.0403219513	0.0014934056
Uncorrected Total	29	9.5828000000	
(Corrected Total)	28	2.6492689655	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	93.85211359	0.86676504100	92.073672451	95.630554735
C	2.96672678	0.11254844797	2.735798238	3.197655329

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.143936956
C	-0.143936956	1

THE FITTED WEIBULL SUBSEQUENT SUBALPINE FIR REGENERATION

Non-Linear Least Squares Iterative Phase — Dependent Variable CUMPER — Method: Marquardt

Iter	B	C	Sum of Squares
0	21.962340	1.101270	1.295954
1	4.876421	0.787867	0.451579
2	9.550850	1.231264	0.053802
3	9.036172	1.376282	0.043633
4	9.083438	1.373238	0.043575
5	9.083595	1.373764	0.043575
6	9.083600	1.373713	0.043575
7	9.083599	1.373718	0.043575

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics — Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	6.5657997552	3.2828998776
Residual	11	0.0435752448	0.0039613859
Uncorrected Total	13	6.6093750000	
(Corrected Total)	12	0.8870192308	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	9.083599406	0.40664917032	8.1885671988	9.9786316137
C	1.373718262	0.14246486339	1.0601540143	1.6872825096

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.0830985309
C	0.0830985309	1

THE FITTED WEIBULL SUBSEQUENT CEDAR REGENERATION

Non-Linear Least Squares Iterative Phase — Dependent Variable CUMPER — Method: Marquardt

Iter	B	C	Sum of Squares
0	4.162840	2.038920	1.240149
1	6.328864	0.684920	0.365428
2	9.772351	1.136100	0.066047
3	8.923713	1.250207	0.043592
4	8.994615	1.253933	0.043444
5	8.994844	1.253629	0.043444
6	8.994850	1.253659	0.043444

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics — Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	10.660431788	5.330215894
Residual	19	0.043443956	0.002286524
Uncorrected Total	21	10.703875744	
(Corrected Total)	20	1.830592594	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	8.994850045	0.28192456446	8.4047793663	9.5849207235
C	1.253659283	0.07864966277	1.0890448233	1.4182737429

Asymptotic Correlation Matrix

Corr	B	C
B	1	- 0.0581834109
C	0.0581834109	1

THE FITTED WEIBULL SUBSEQUENT DOUGLAS FIR REGENERATION

Non-Linear Least Squares Iterative Phase — Dependent Variable CUMPER — Method: Marquardt

Iter	B	C	Sum of Squares
0	4.343760	2.331940	0.947354
1	5.980954	0.985559	0.243329
2	8.279052	1.244479	0.055201
3	8.183387	1.290332	0.054017
4	8.182820	1.284364	0.054006
5	8.183127	1.285300	0.054006
6	8.183079	1.285156	0.054006
7	8.183086	1.285178	0.054006

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics — Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	11.186198456	5.593099228
Residual	19	0.054005626	0.002842401
Uncorrected Total	21	11.240204082	
(Corrected Total)	20	1.811389699	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	8.183085896	0.28265226819	7.5914921267	8.7746796650
C	1.285178383	0.08928638577	1.0983011649	1.4720556006

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.1537872822
C	0.1537872822	1

THE FITTED WEIBULL SUBSEQUENT HEMLOCK REGENERATION

Non-Linear Least Squares Iterative Phase — Dependent Variable CUMPER — Method: Marquardt

Iter	B	C	Sum of Squares
0	4.330940	1.974080	1.107247
1	6.795112	0.417001	0.647959
2	10.842012	1.053653	0.175008
3	8.433057	1.316676	0.053695
4	8.996989	1.340373	0.043438
5	9.003777	1.351829	0.043403
6	9.004890	1.350911	0.043402
7	9.004793	1.351017	0.043402
8	9.004804	1.351005	0.043402

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics — Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	10.412276391	5.206138195
Residual	18	0.043402279	0.002411238
Uncorrected Total	20	10.455678670	
(Corrected Total)	19	1.764508310	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	9.004803785	0.27854665713	8.4196028402	9.5900047290
C	1.351005038	0.09149890670	1.1587742388	1.5432358379

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.1782503954
C	0.1782503954	1

THE FITTED WEIBULL SUBSEQUENT LARCH REGENERATION

Non-Linear Least Squares Iterative Phase — Dependent Variable CUMPER — Method: Marquardt

Iter	B	C	Sum of Squares
0	5.237920	3.115980	1.312463
1	6.916501	0.125906	1.061541
2	15.547033	0.591369	0.439591
3	11.655420	0.790739	0.242814
4	9.343494	1.345240	0.097483
5	10.366186	1.476575	0.064084
6	10.349911	1.516896	0.063767
7	10.359908	1.514485	0.063763
8	10.359100	1.514944	0.063763
9	10.359227	1.514891	0.063763
10	10.359212	1.514898	0.063763

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics — Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	5.7479651811	2.8739825905
Residual	13	0.0637632140	0.0049048626
Uncorrected Total	15	5.8117283951	
(Corrected Total)	14	1.1820987654	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	10.35921166	0.42430365739	9.4425598851	11.275863432
C	1.51489809	0.15674883045	1.1762630288	1.853533144

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.045821254
C	-0.045821254	1

THE FITTED WEIBULL SUBSEQUENT LODGEPOLE REGENERATION

Non-Linear Least Squares Iterative Phase   Dependent Variable CUMPER   Method: Marquardt

Iter	B	C	Sum of Squares
0	5.335750	4.169940	0.466326
1	6.016606	0.601014	0.450200
2	8.947777	1.357824	0.155403
3	7.229812	1.467307	0.045847
4	7.401772	1.577446	0.042625
5	7.375932	1.568125	0.042584
6	7.377185	1.569909	0.042583
7	7.376847	1.569751	0.042583
8	7.376871	1.569776	0.042583

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	10.403790341	5.201895170
Residual	16	0.042583116	0.002661445
Uncorrected Total	18	10.446373457	
(Corrected Total)	17	1.493655693	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	7.376871411	0.23211301090	6.8848162549	7.8689265680
C	1.569776048	0.11654334464	1.3227164221	1.8168356743

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.1108513828
C	0.1108513828	1

THE FITTED WEIBULL SUBSEQUENT WHITE PINE REGENERATION

Non-Linear Least Squares Iterative Phase   Dependent Variable CUMPER   Method: Marquardt

Iter	B	C	Sum of Squares
0	3.529460	1.716210	1.685449
1	6.170594	0.356598	0.683277
2	12.534240	0.997970	0.286897
3	8.240833	1.233174	0.102390
4	9.378425	1.220644	0.059968
5	9.426475	1.265914	0.059293
6	9.434544	1.262778	0.059288
7	9.433810	1.263314	0.059288
8	9.433933	1.263238	0.059288
9	9.433915	1.263249	0.059288

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	9.986290691	4.993145346
Residual	18	0.059287969	0.003293776
Uncorrected Total	20	10.045578660	
(Corrected Total)	19	1.557855493	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	9.433915302	0.34193683862	8.7155374080	10.152293196
C	1.263249229	0.10069142092	1.0517058017	1.474792657

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.1404601298
C	0.1404601298	1

THE FITTED WEIBULL SUBSEQUENT SPRUCE REGENERATION

Non-Linear Least Squares Iterative Phase   Dependent Variable CUMPER   Method: Marquardt

Iter	B	C	Sum of Squares
0	5.365660	2.897770	0.377529
1	5.622504	1.495358	0.249760
2	6.288989	0.617241	0.053579
3	7.931172	0.765613	0.027352
4	8.112638	0.812703	0.026480
5	8.119323	0.811209	0.026478
6	8.119110	0.811431	0.026478
7	8.119153	0.811406	0.026478
8	8.119148	0.811409	0.026478

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	6.4942321045	3.2471160523
Residual	9	0.0264779547	0.0029419950
Uncorrected Total	11	6.5207100592	
(Corrected Total)	10	0.3620225928	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	8.119148127	0.59036080109	6.7836478491	9.4546484050
C	0.811409084	0.08876057764	0.6106169990	1.0122011689

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.3762292937
C	0.3762292937	1

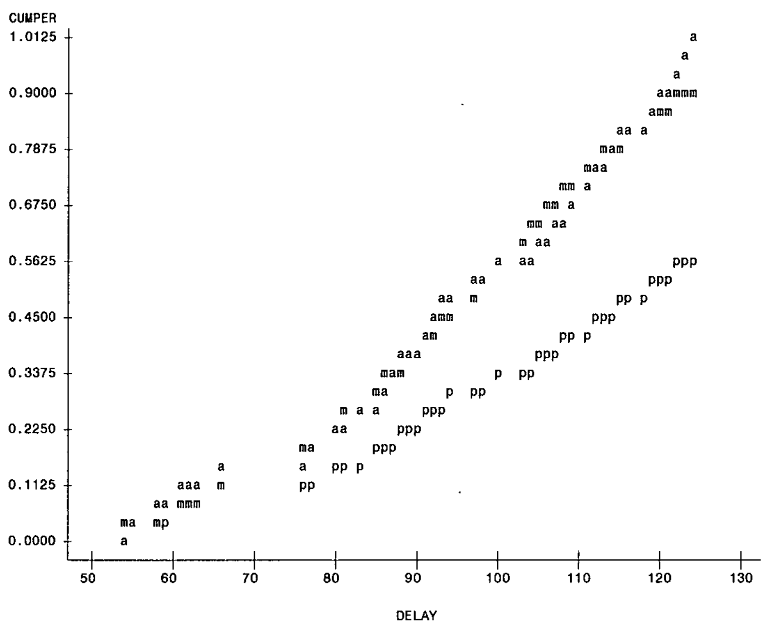
APPENDIX 6: Heights of advance and subsequent regeneration.

Germination-delay

Comparison of actual delay to germination cumulative density, cumulative density of delay to germination estimated using Prognosis models and cumulative density of delay to germination estimated with a data-fitted model

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF ADVANCED WESTERN RED CEDAR REGENERATION

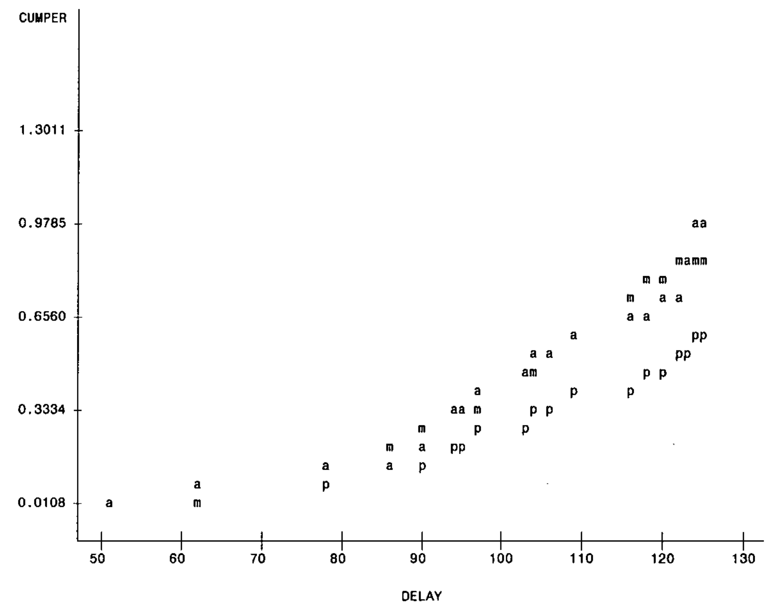
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 102 obs had missing values. 23 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF ADVANCED DOUGLAS FIR REGENERATION

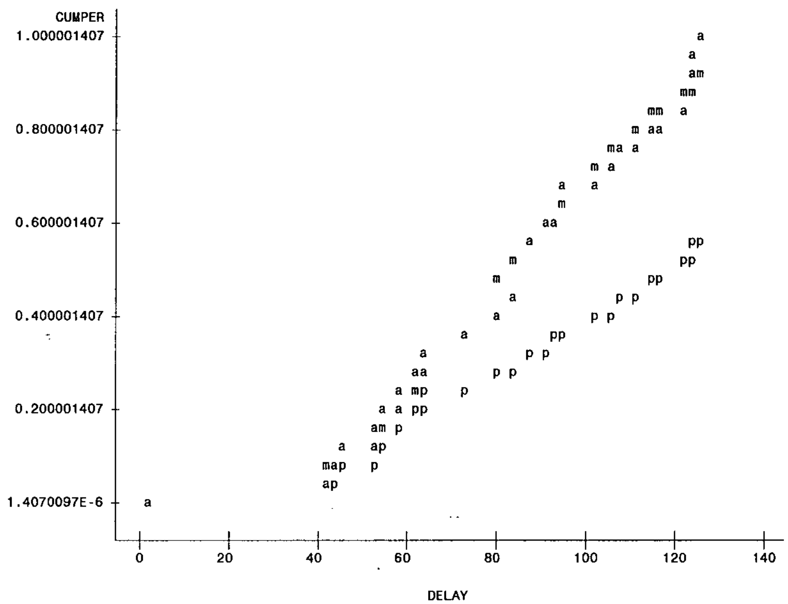
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 36 obs had missing values. 11 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF ADVANCED WESTERN HEMLOCK REGENERATION

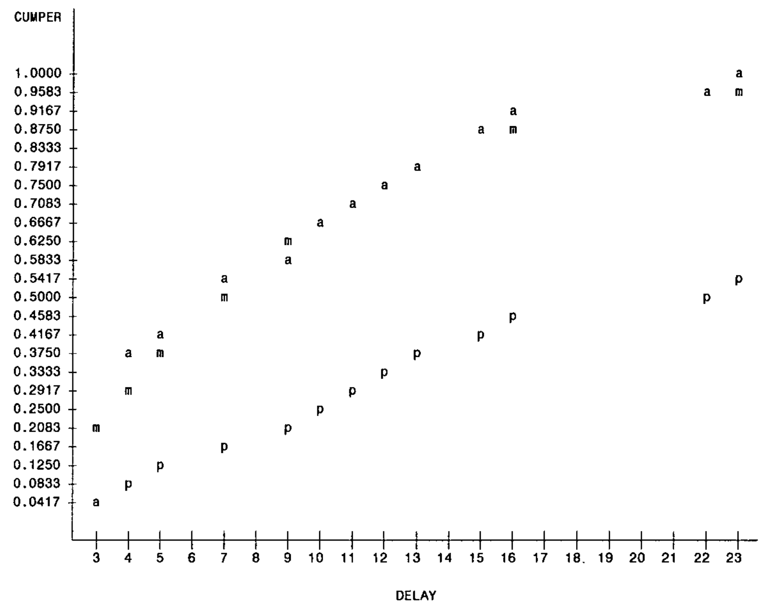
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 63 obs had missing values. 19 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF SUBSEQUENT SUBALPINE FIR REGENERATION

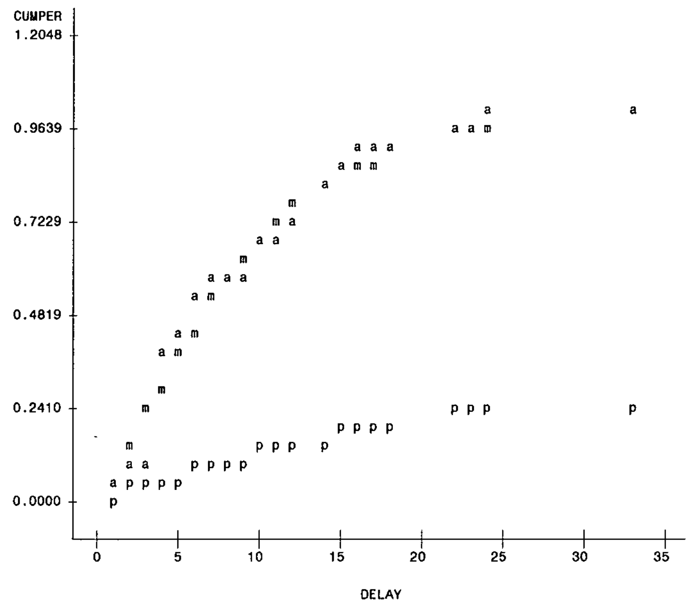
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 33 obs had missing values. 7 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF SUBSEQUENT WESTERN RED CEDAR REGENERATION

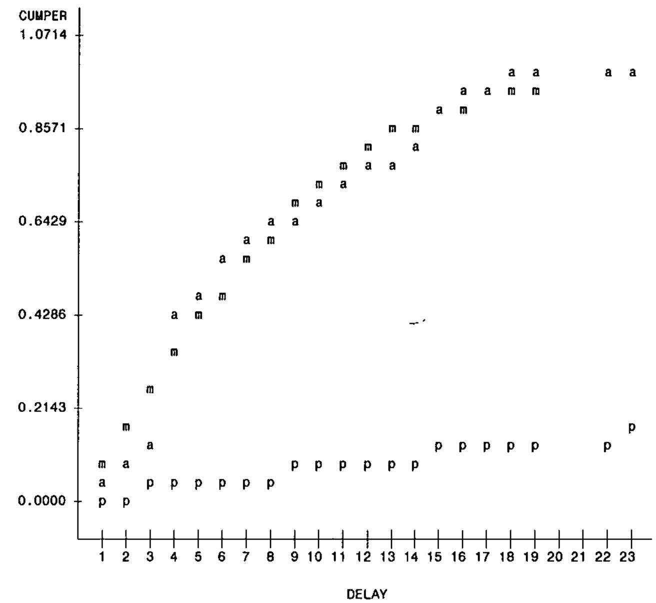
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 186 obs had missing values. 9 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF SUBSEQUENT DOUGLAS FIR REGENERATION

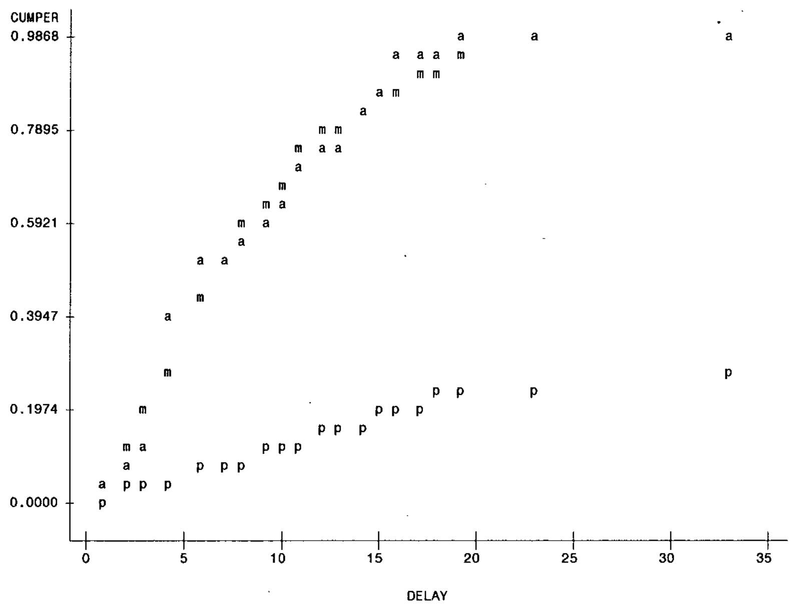
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 357 obs had missing values. 4 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF SUBSEQUENT WESTERN HEMLOCK REGENERATION

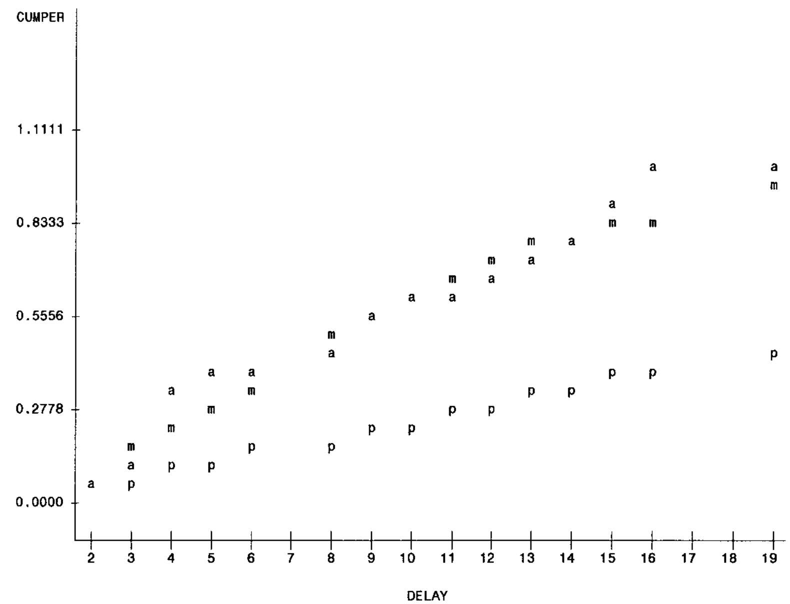
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 168 obs had missing values. 6 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF SUBSEQUENT WESTERN LARCH REGENERATION

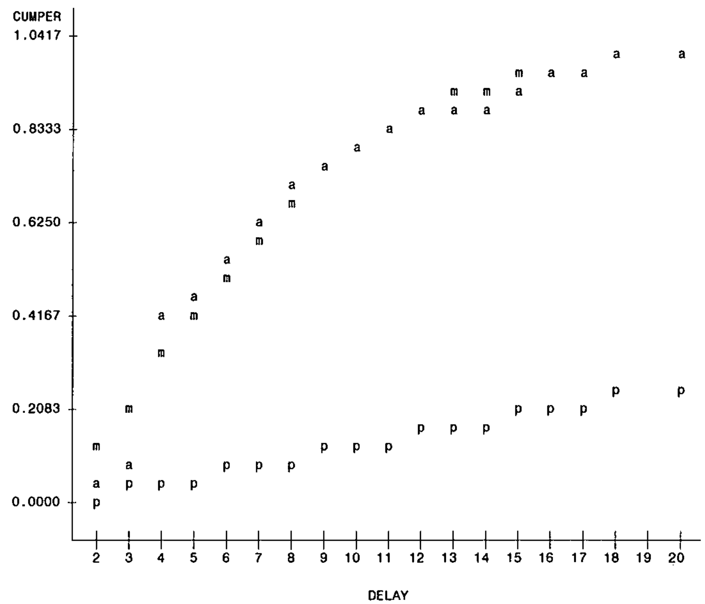
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 63 obs had missing values. 5 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF SUBSEQUENT LODGEPOLE PINE REGENERATION

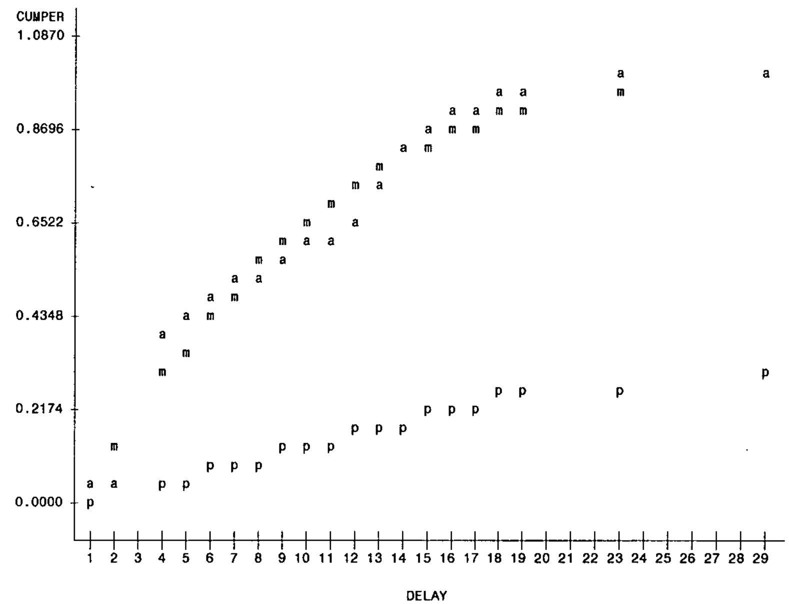
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 162 obs had missing values. 8 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF SUBSEQUENT WHITE PINE REGENERATION

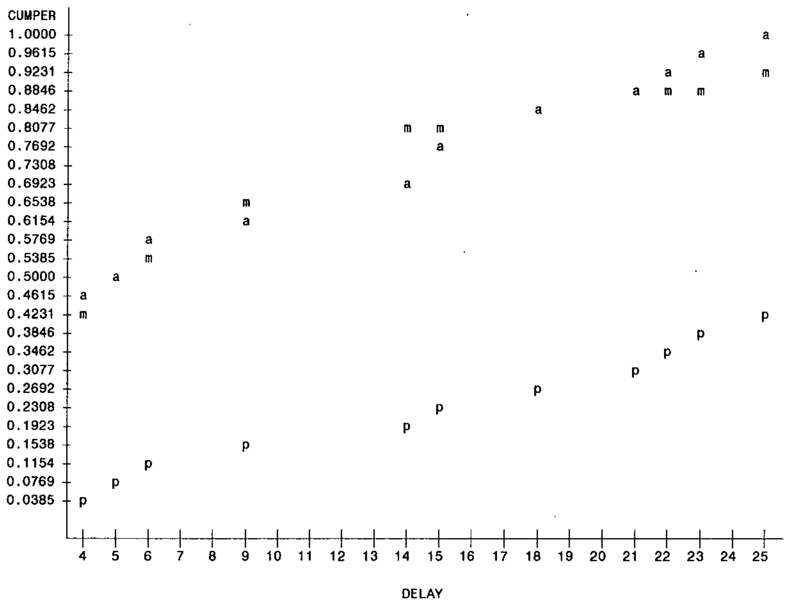
ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



NOTE: 147 obs had missing values. 4 obs hidden.

THE COMPARING FITTED-WEIBULL PREDICTIONS
PROGNOSIS MODEL PREDICTIONS AND ACTUAL CUMULATIVE DENSITIES FOR
DELAY OF SUBSEQUENT SPRUCE REGENERATION

ACTUAL CUMULATIVE DENSITY Plot of CUMPER*DELAY. Symbol used is 'a'.
ESTIMATED WEIBULL CUMULATIVE DENSITY Plot of PRED*DELAY. Symbol used is 'm'.
PROGNOSIS MODEL CUMULATIVE DENSITY Plot of CUMPROG*DELAY. Symbol used is 'p'.



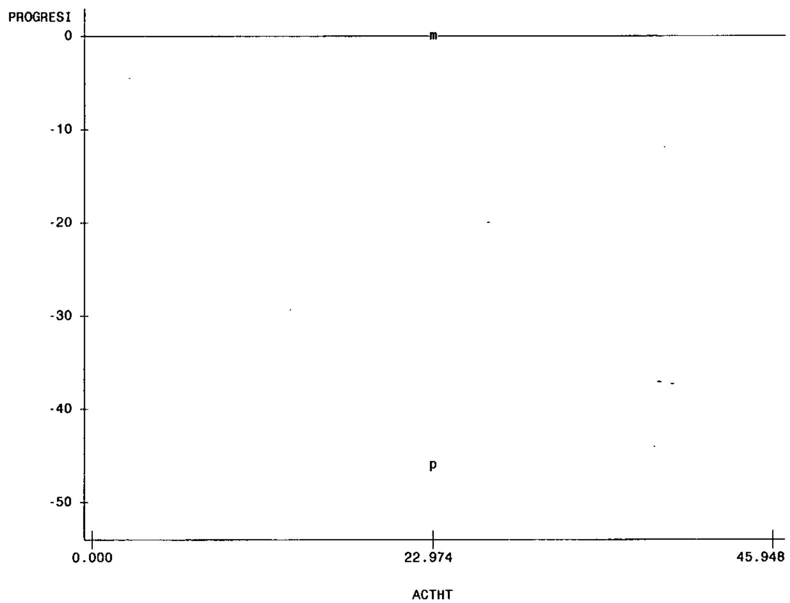
NOTE: 45 obs had missing values. 3 obs hidden.

APPENDIX 7: Heights of advance and subsequent regeneration.

Graphs comparing residuals from Prognosis models, re-fitted prognosis models and variable selection resulting model for height predictions of advance and subsequent regeneration, against actual heights.

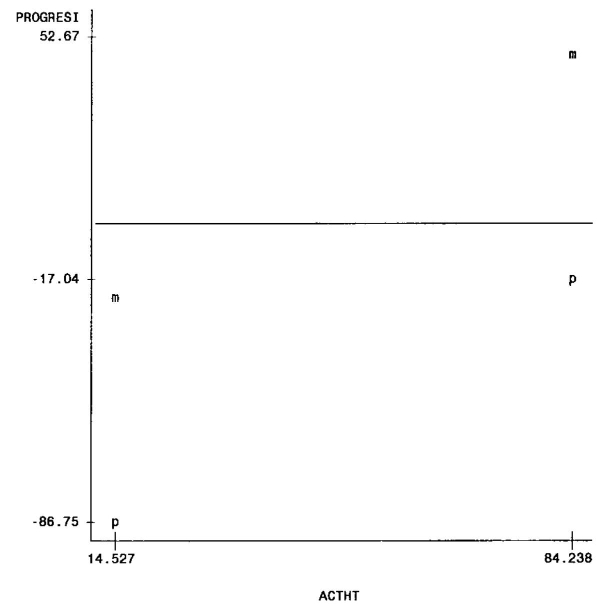
COMPARING PROGNOSIS MODEL RESIDUALS AND RE-FITTED PROGNOSIS MODEL RESIDUALS FOR HEIGHT OF ADVANCE GRAND FIR REGENERATION

Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.



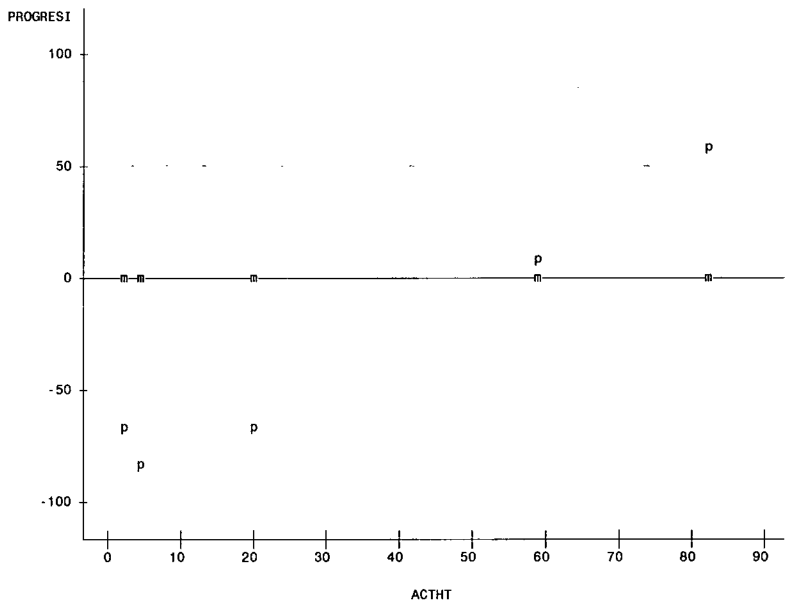
COMPARING PROGNOSIS MODEL RESIDUALS AND RE-FITTED PROGNOSIS MODEL RESIDUALS FOR HEIGHT OF ADVANCE LARCH REGENERATION

Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.



COMPARING PROGNOSIS MODEL RESIDUALS AND RE-FITTED PROGNOSIS MODEL
RESIDUALS FOR HEIGHT OF ADVANCE LODGEPOLE PINE REGENERATION

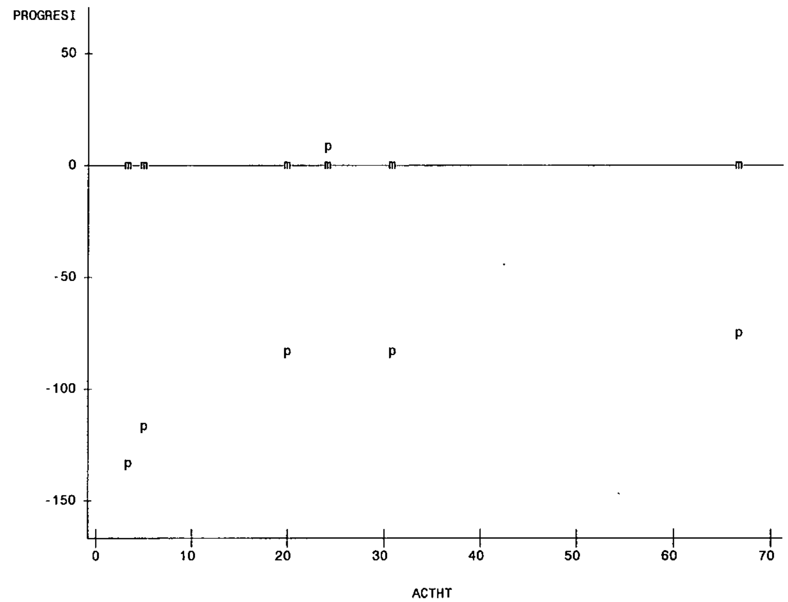
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.



NOTE: 2 obs hidden.

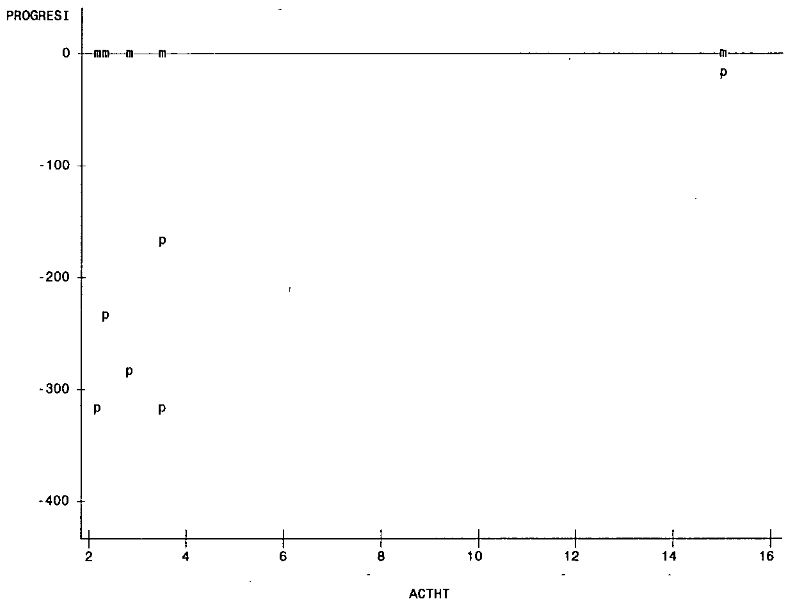
COMPARING PROGNOSIS MODEL RESIDUALS AND RE-FITTED PROGNOSIS MODEL
RESIDUALS FOR HEIGHT OF ADVANCE WHITE PINE REGENERATION

Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.



COMPARING PROGNOSIS MODEL RESIDUALS AND RE-FITTED PROGNOSIS MODEL RESIDUALS FOR HEIGHT OF ADVANCE SPRUCE REGENERATION

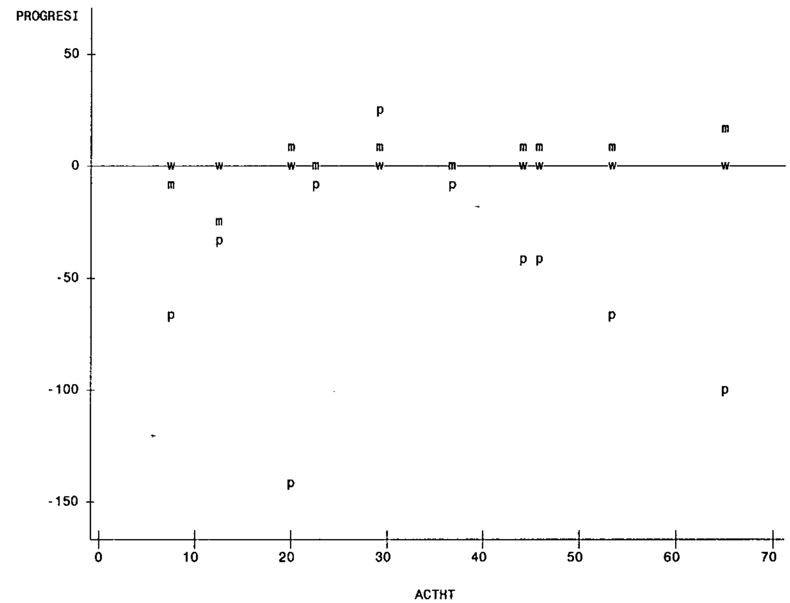
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.



NOTE: 1 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF ADVANCE SUBALPINE FIR REGENERATION

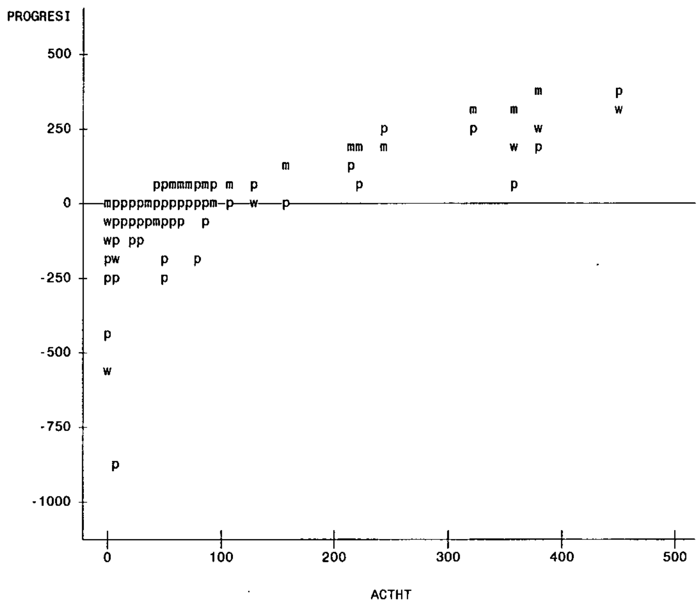
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 2 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND
VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF
ADVANCE WESTERN RED CEDAR REGENERATION

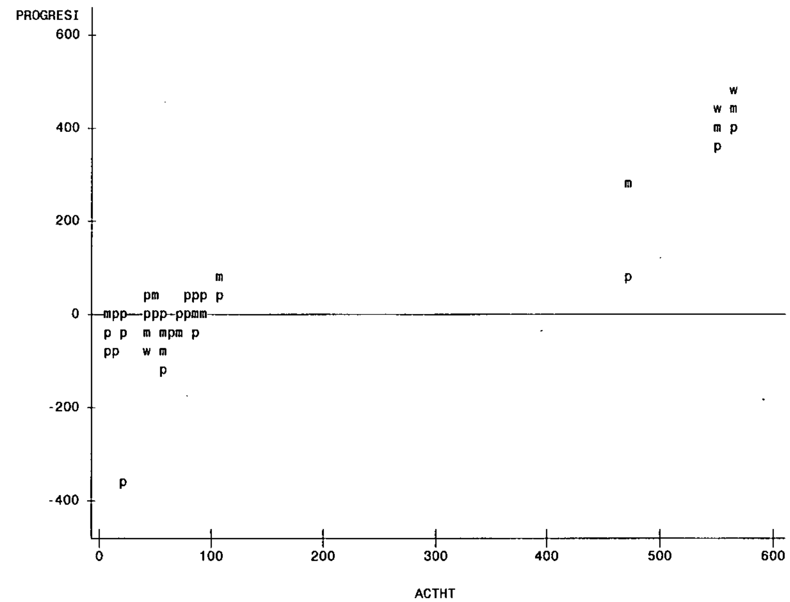
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 6 obs had missing values. 165 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND
VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF
ADVANCE DOUGLASFIR REGENERATION

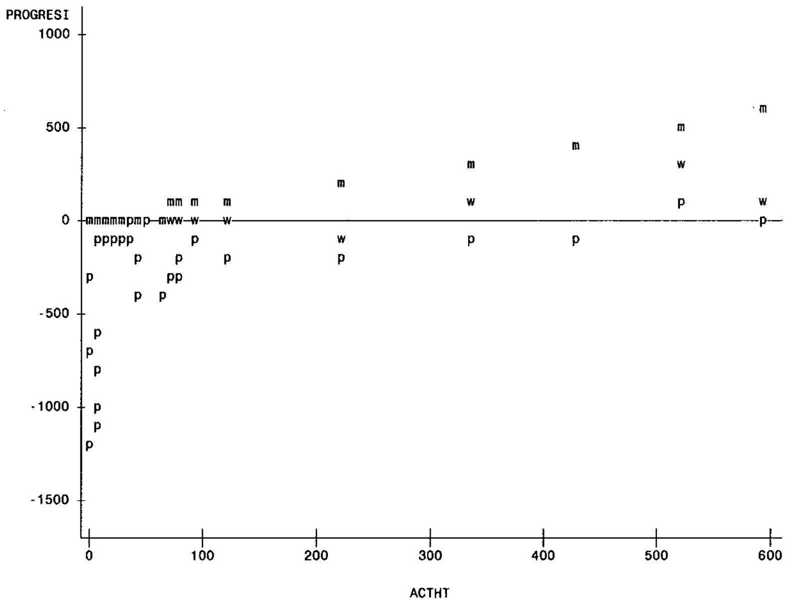
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 12 obs had missing values. 43 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF ADVANCE HEMLOCK REGENERATION

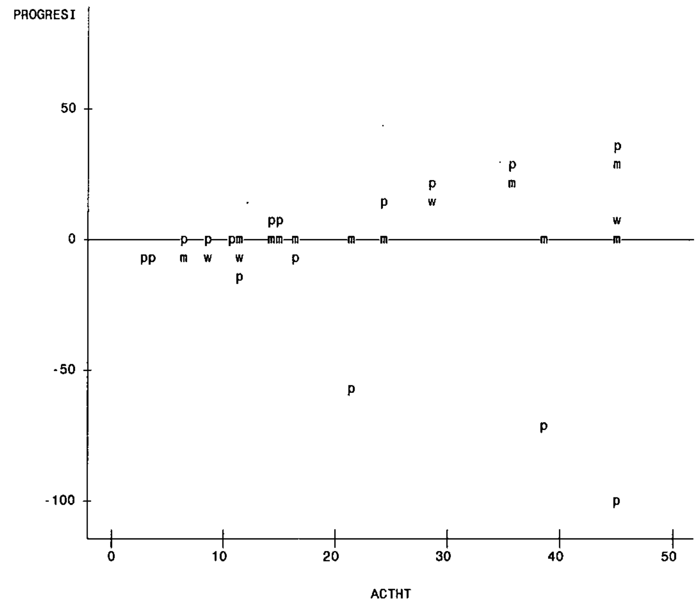
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 38 obs had missing values. 61 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF SUBSEQUENT GRAND FIR REGENERATION

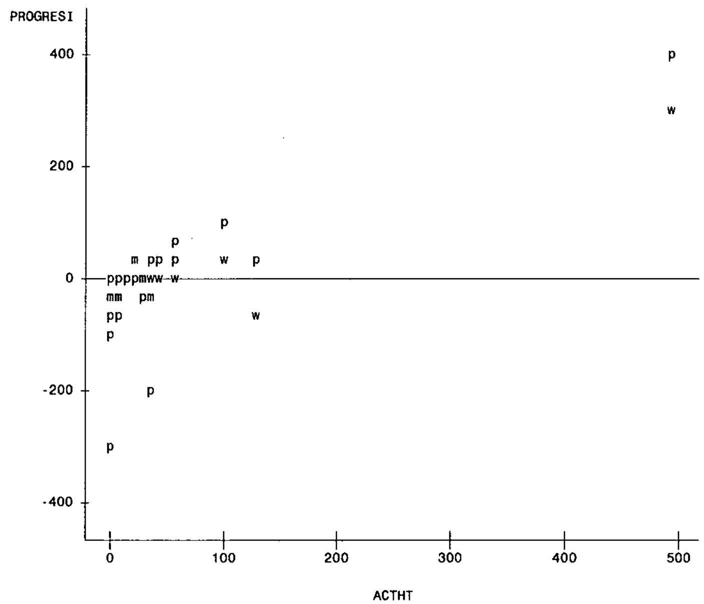
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 17 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND
VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF
SUBSEQUENT SUBALPINE FIR REGENERATION

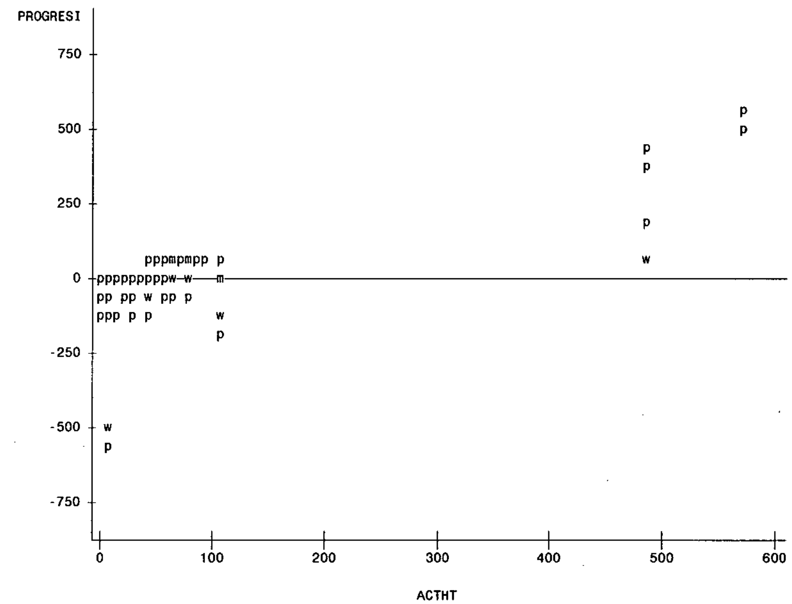
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 44 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND
VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF
SUBSEQUENT WESTERN RED CEDAR REGENERATION

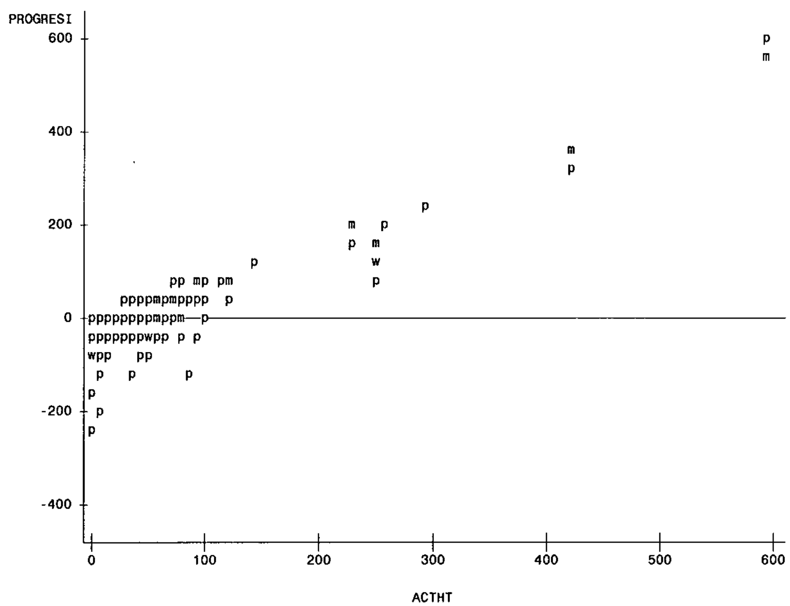
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 2 obs had missing values. 203 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF SUBSEQUENT DOUGLAS FIR REGENERATION

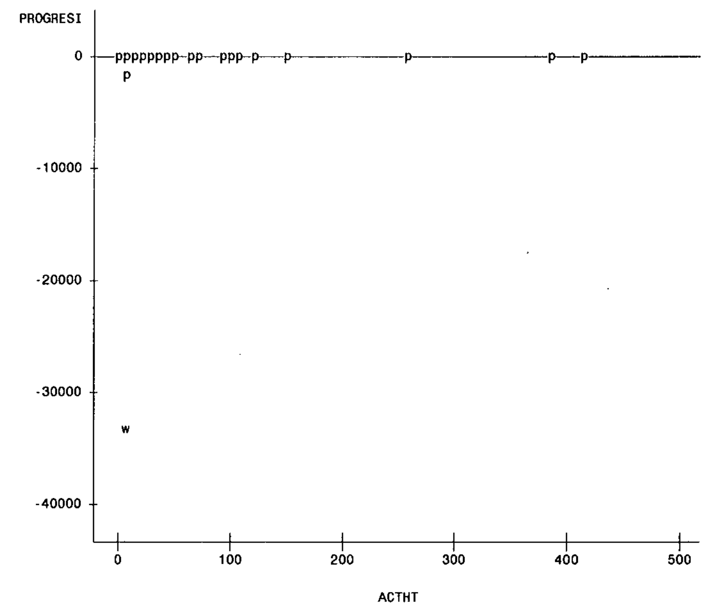
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 4 obs had missing values. 350 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF SUBSEQUENT HEMLOCK REGENERATION

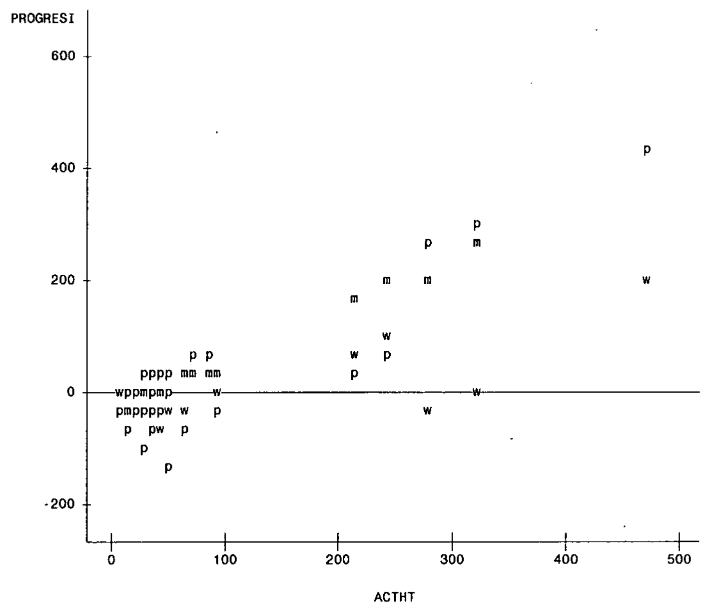
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 208 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF SUBSEQUENT LARCH REGENERATION

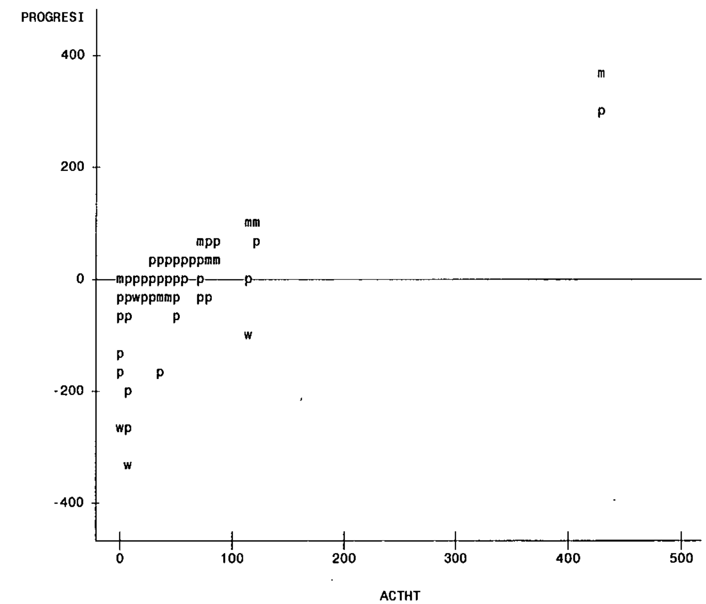
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 61 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF SUBSEQUENT LODGEPOLE PINE REGENERATION

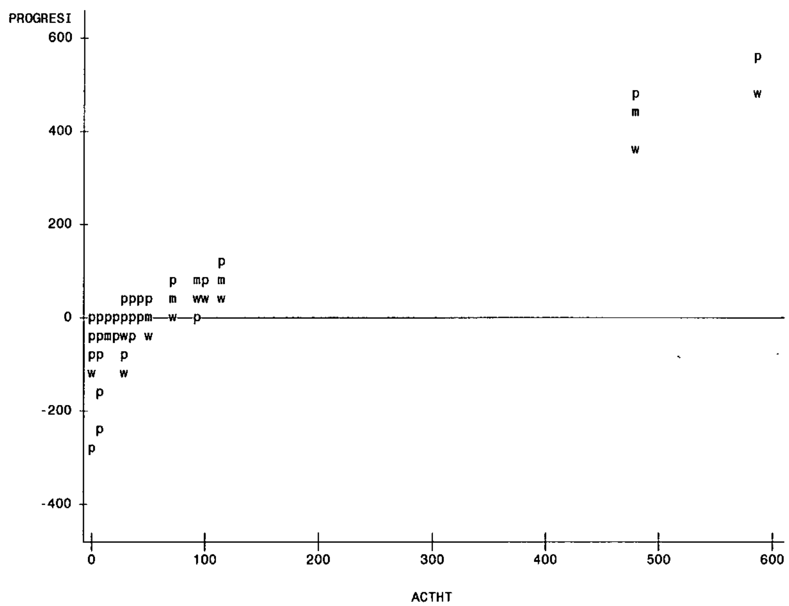
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 4 obs had missing values. 163 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF SUBSEQUENT WHITE PINE REGENERATION

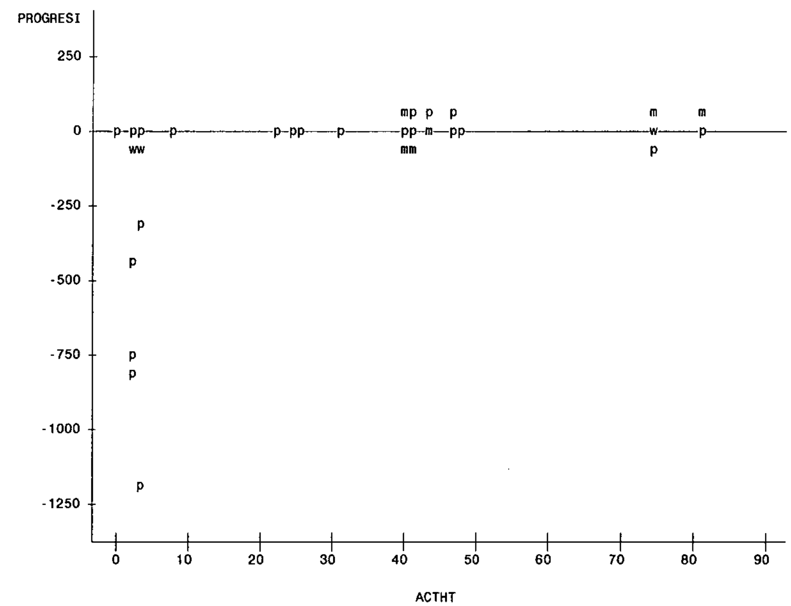
Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 164 obs hidden.

COMPARING PROGNOSIS MODEL RESIDUALS, RE-FITTED PROGNOSIS MODEL RESIDUALS AND VARIABLE SELECTION MODEL RESIDUALS FOR HEIGHT OF SUBSEQUENT SPRUCE REGENERATION

Plot of PROGRESI*ACTHT. Symbol used is 'p'.
Plot of NCFREST*ACTHT. Symbol used is 'm'.
Plot of BWRESI*ACTHT. Symbol used is 'w'.



NOTE: 47 obs hidden.

APPENDIX 8: Heights of advance and subsequent regeneration.

Coefficients and analysis of variance for the re-fitted Prognosis model form and the variable selection resulting model for height prediction of advance and subsequent regeneration.

Re-fitted Prognosis model form for the prediction of height of advance and subsequent regeneration

ADVANCE REGENERATION Lw
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Squares	Sum of Square	Mean F Value	Prob>F
Model	0	0.00000	.	.	.
Error	1	1.54464	1.54464		
C Total	1	1.54464			

Root MSE	1.24283	R-square	0.0000
Dep Mean	3.55483	Adj R-sq	0.0000
C.V.	34.96183		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.
LN_AGE = +2.4849 * INTERCEP

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	B	3.554832	0.87881657	4.045	0.1543
LN_AGE	0	0	.	.	.

ADVANCE REGENERATION Pl
PROGNOSIS RE-FITTED MODEL FORM
Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	4	11.16768	2.79192	.	.
Error	1	0	0		
C Total	5	11.16768			

Root MSE	0.00000	R-square	1.0000
Dep Mean	2.56377	Adj R-sq	1.0000
C.V.	0.00000		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	2.341715	0.00000000	.	.
LN_AGE	1	-2.640918	0.00000000	.	.
X1	1	12.955464	0.00000000	.	.
X2	1	-61.791298	0.00000000	.	.
SLO	1	55.484880	0.00000000	.	.

ADVANCE REGENERATION Sx
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	2	2.36869	1.18434	23.184	0.0150
Error	3	0.15325	0.05108		
C Total	5	2.52194			

Root MSE	0.22602	R-square	0.9392
Dep Mean	1.30933	Adj R-sq	0.8987
C.V.	17.26221		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	1.797519	1.84635112	0.974	0.4021
LN_AGE	1	-0.202199	0.47461727	-0.426	0.6988
BAA	1	0.590581	0.39468122	1.496	0.2315

ADVANCE REGENERATION Fd
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	8	19.07836	2.38480	3.419	0.0174
Error	16	11.15890	0.69743		
C Total	24	30.23726			

Root MSE	0.83512	R-square	0.6310
Dep Mean	4.00653	Adj R-sq	0.4464
C.V.	20.84407		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-0.654023	4.29901900	-0.152	0.8810
LN_AGE	1	0.370889	0.24234912	1.530	0.1454
ELEV_FC	1	0.233871	0.27541471	0.849	0.4083
ELEV_FC2	1	-0.004334	0.00401112	-1.080	0.2959
LN_TPSP	1	0.064276	0.16653948	0.386	0.7046
DPOS1	1	-1.431811	0.98519499	-1.453	0.1655
DPOS2	1	1.383321	0.71781641	1.927	0.0719
DPOS3	1	0.060468	0.82897982	0.073	0.9428
DHAB	1	-0.034860	0.37190389	-0.094	0.9265

ADVANCE REGENERATION Pw
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	6.42858	1.28572	.	.
Error	0	0.00000	.		
C Total	5	6.42858			

Root MSE	.	R-square	1.0000
Dep Mean	2.77302	Adj R-sq	.
C.V.	.		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.
BAA = +4.0905 * INTERCEP +0.9384 * LN_AGE -9.4279 * X1
+7.4705 * X2-9.3822 * SLO -0.1032 * ELEV_FC

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	B	4.859113	.	.	.
LN_AGE	B	-0.369793	.	.	.
X1	B	-7.147645	.	.	.
X2	B	3.355847	.	.	.
SLO	B	-2.288966	.	.	.
ELEV_FC	B	-0.034364	.	.	.
BAA	0	0	.	.	.

ADVANCE REGENERATION Bg
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	0	0.00000	.	.	.
Error	0	0.00000	.		
C Total	0	0			

MSE	.	R-square	.
Dep Mean	3.13437	Adj R-sq	.
C.V.	.		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combinationof other variables as shown.

LN_AGE = +2.3026 * INTERCEP
X1 = -0.0971 * INTERCEP
X2 = -0.0705 * INTERCEP
SLO = +0.1200 * INTERCEP
BAA = +2.2222 * INTERCEP
LN_TPSP = +3.0445 * INTERCEP
DHAB = +1.0000 * INTERCEP

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	B	3.134367	.	.	.
LN_AGE	0	0	.	.	.
X1	0	0	.	.	.
X2	0	0	.	.	.
SLO	0	0	.	.	.
BAA	0	0	.	.	.
LN_TPSP	0	0	.	.	.
DHAB	0	0	.	.	.

ADVANCE REGENERATION Hw
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	5	28.03406	5.60681	2.424	0.0530
Error	38	87.88020	2.31264		
C Total	43	115.91426			

Root MSE	1.52074	R-square	0.2419
Dep Mean	2.87150	Adj R-sq	0.1421
C.V.	52.95959		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	4.515234	1.02887253	4.389	0.0001
LN_AGE	1	-0.533771	0.22018445	-2.424	0.0202
BAA	1	0.092672	0.35828918	0.259	0.7973
LN_TPSP	1	-0.035473	0.22939368	-0.155	0.8779
DSITEP1	1	1.353953	0.80698947	1.678	0.1016
DSITEP2	1	-1.299202	0.82572648	-1.573	0.1239

ADVANCE REGENERATION Bl
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	4	1.99065	0.49766	1.064	0.4610
Error	5	2.33872	0.46774		
C Total	9	4.32937			

Root MSE	0.68392	R-square	0.4598
Dep Mean	3.33058	Adj R-sq	0.0276
C.V.	20.53451		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased.
The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.
DSITEP1 = 0

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	3.534530	0.90227285	3.917	0.0112
LN_AGE	1	0.165449	0.21623812	0.765	0.4787
SLO	1	1.250020	1.68465182	0.742	0.4914
LN_TPSP	1	-0.512397	0.28105007	-1.823	0.1279
DSITEP1	0	0	.	.	.
DSITEP2	1	0.265182	0.56541991	0.469	0.6588

ADVANCE REGENERATION Cw
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	7	24.17787	3.45398	2.071	0.0583
Error	69	115.06056	1.66754		
C Total	76	139.23843			

Root MSE	1.29133	R-square	0.1736
Dep Mean	3.29845	Adj R-sq	0.0898
C.V.	39.14972		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-3.269071	3.49097464	-0.936	0.3523
LN_AGE	1	-0.024196	0.11082451	-0.218	0.8278
X1	1	-1.329196	0.92404310	-1.438	0.1548
X2	1	-0.654195	0.64141925	-1.020	0.3113
SLO	1	1.609913	0.99464122	1.619	0.1101
ELEV_FC	1	0.368611	0.21819115	1.689	0.0957
ELEV_FC2	1	-0.005310	0.00335354	-1.583	0.1179
LN_TPSP	1	0.036912	0.13582777	0.272	0.7866

SUBSEQUENT REGENERATION Lw
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	4	5.20089	1.30022	1.425	0.2491
Error	31	28.29149	0.91263		
C Total	35	33.49238			

Root MSE	0.95532	R-square	0.1553
Dep Mean	3.72571	Adj R-sq	0.0463
C.V.	25.64116		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	3.362391	0.60557254	5.552	0.0001
LN_AGE	1	0.109879	0.19620405	0.560	0.5795
BAA	1	-0.156900	0.15468665	-1.014	0.3183
LN_TPSP	1	0.256302	0.19615361	1.307	0.2009
DHAB	1	-0.496535	0.33293288	-1.491	0.1460

SUBSEQUENT REGENERATION Pl
PROGNOSIS RE-FITTED MODEL FORM 15:41 Wednesday, August 25, 1999

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	13	66.01022	5.07771	4.571	0.0001
Error	56	62.20098	1.11073		
C Total	69	128.21119			

Root MSE	1.05391	R-square	0.5149
Dep Mean	2.83796	Adj R-sq	0.4022
C.V.	37.13629		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	-12.762506	2.97550296	-4.289	0.0001
LN_AGE	1	0.105051	0.26981886	0.389	0.6985
X1	1	1.729143	1.37165461	1.261	0.2127
X2	1	-0.740354	0.57960417	-1.277	0.2068
SLO	1	-1.374692	0.98149953	-1.401	0.1668
ELEV_FC	1	0.926677	0.19107407	4.850	0.0001
ELEV_FC2	1	-0.013541	0.00285676	-4.740	0.0001
BAA	1	-0.170799	0.12384537	-1.379	0.1733
LN_TPSP	1	-0.067498	0.17046478	-0.396	0.6936
DSITEP1	1	-0.477073	0.58613777	-0.814	0.4191
DSITEP2	1	0.116196	0.40968996	0.284	0.7777
DPOS2	1	1.542940	0.48490667	3.182	0.0024
DPOS3	1	1.856580	1.40306419	1.323	0.1911
DHAB	1	0.174142	0.33280561	0.523	0.6029

SUBSEQUENT REGENERATION Sx
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	6	21.52771	3.58795	2.408	0.0669
Error	19	28.31170	1.49009		
C Total	25	49.83940			

Root MSE	1.22069	R-square	0.4319
Dep Mean	2.70778	Adj R-sq	0.2526
C.V.	45.08096		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	1.651508	1.00249436	1.647	0.1159
LN_AGE	1	-0.102656	0.19997702	-0.513	0.6136
BAA	1	0.323647	0.10057284	3.218	0.0045
LN_TPSP	1	0.026535	0.24411344	0.109	0.9146
DSITEP1	1	1.285888	1.06029160	1.213	0.2401
DSITEP2	1	0.933134	0.64593033	1.445	0.1649
DHAB	1	0.025532	0.59325055	0.043	0.9661

SUBSEQUENT REGENERATION Fd
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Sum of	Mean				
Source	DF	Squares	Square	F Value	Prob>F
Model	12	22.08744	1.84062	1.391	0.1786
Error	125	165.38421	1.32307		
C Total	137	187.47165			

Root MSE	1.15025	R-square	0.1178
Dep Mean	3.32069	Adj R-sq	0.0331
C.V.	34.63882		

Parameter Estimates

Parameter		Standard	T for H0:		
Variable	DF	Estimate	Error	Parameter=0	Prob > |T|
INTERCEP	1	2.991356	0.41612918	7.189	0.0001
LN_AGE	1	0.099971	0.10803769	0.925	0.3566
X1	1	-1.257578	0.55503286	-2.266	0.0252
X2	1	0.916553	0.46457281	1.973	0.0507
SLO	1	0.101064	0.72542086	0.139	0.8894
BAA	1	-0.007454	0.03590312	-0.208	0.8359
LN_TPSP	1	-0.019464	0.09068537	-0.215	0.8304
DSITEP1	1	0.657560	0.48123209	1.366	0.1743
DSITEP2	1	0.289068	0.25560693	1.131	0.2603
DPOS1	1	0.043336	0.62896160	0.069	0.9452
DPOS2	1	0.167710	0.30041984	0.558	0.5777
DPOS3	1	0.136368	0.48196958	0.283	0.7777
DHAB	1	-0.090647	0.23803790	-0.381	0.7040

SUBSEQUENT REGENERATION Pw
PROGNOSIS RE-FITTED MODEL FORM 10:33 Monday, August 23, 1999

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

		Sum of	Mean		
Source	DF	Squares	Square	F Value	Prob>F
Model	2	15.98076	7.99038	4.946	0.0100
Error	66	106.62471	1.61553		
C Total	68	122.60547			

Root MSE	1.27103	R-square	0.1303
Dep Mean	2.88286	Adj R-sq	0.1040
C.V.	44.08936		

Parameter Estimates

		Parameter	Standard	T for H0:	
Variable	DF	Estimate	Error	Parameter=0	Prob > |T|
INTERCEP	1	3.614830	0.30357252	11.908	0.0001
LN_AGE	1	-0.514603	0.16519885	-3.115	0.0027
BAA	1	-0.072043	0.05741578	-1.255	0.2140

SUBSEQUENT REGENERATION Bg
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	11	3.26074	0.29643	0.172	0.9909
Error	4	6.91224	1.72806		
C Total	15	10.17297			

Root MSE	1.31456	R-square	0.3205
Dep Mean	2.74690	Adj R-sq	-1.5480
C.V.	47.85608		

NOTE: Model is not full rank. Least-squares solutions for the parameters are not unique. Some statistics will be misleading. A reported DF of 0 or B means that the estimate is biased. The following parameters have been set to 0, since the variables are a linear combination of other variables as shown.

DPOS2 = +10.8898 * INTERCEP -0.2911 * LN_AGE +6.0124 * X1 -3.3493 * X2 +4.3227 * SLO-0.5879 * ELEV_FC +0.009881 * ELEV_FC2 -0.1952 * BAA-0.6164 * LN_TPSP+1.5649 * DSITEP1 -1.9258 * DSITEP2 +1.7253 * DPOS1

DPOS3 = -54.8200 * INTERCEP +0.0696 * LN_AGE -3.4888 * X1+1.5588 * X2-1.0925 * SLO+3.0253 * ELEV_FC -0.0423 * ELEV_FC2 +0.2274 * BAA+0.1701 * LN_TPSP +4.2324 * DSITEP1 +1.1194 * DSITEP2 -1.4133 * DPOS1

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	B	-54.650762	155.79629869	-0.351	0.7434
LN_AGE	B	0.517970	0.62903490	0.823	0.4565
X1	B	-3.547766	10.80617702	-0.328	0.7591
X2	B	1.612528	5.55839291	0.290	0.7862
SLO	B	2.337774	8.32391450	0.281	0.7928
ELEV_FC	B	2.931806	8.30234955	0.353	0.7418
ELEV_FC2	B	-0.038823	0.11162094	-0.348	0.7455
BAA	B	0.279478	0.62297046	0.449	0.6769
LN_TPSP	B	0.135882	1.77162764	0.077	0.9425
DSITEP1	B	6.100135	19.12476092	0.319	0.7657
DSITEP2	B	0.670330	3.15864217	0.212	0.8423
DPOS1	B	0.011622	4.38053356	0.003	0.9980
DPOS2	0	0	.	.	.
DPOS3	0	0	.	.	.

SUBSEQUENT REGENERATION Hw
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	12.99689	4.33230	3.592	0.0176
Error	72	86.83230	1.20600		
C Total	75	99.82919			

Root MSE	1.09818	R-square	0.1302
Dep Mean	3.19590	Adj R-sq	0.0939
C.V.	34.36218		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	4.297433	0.38729237	11.096	0.0001
LN_AGE	1	-0.115330	0.12409251	-0.929	0.3558
BAA	1	-0.066740	0.04715806	-1.415	0.1613
LN_TPSP	1	-0.300731	0.12925477	-2.327	0.0228

SUBSEQUENT REGENERATION Bl
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	3	29.18923	9.72974	2.874	0.0618
Error	20	67.70953	3.38548		
C Total	23	96.89876			

Root MSE	1.83997	R-square	0.3012
Dep Mean	2.64652	Adj R-sq	0.1964
C.V.	69.52390		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	0.384052	1.49406867	0.257	0.7998
LN_AGE	1	-0.107315	0.29752425	-0.361	0.7221
BAA	1	-0.480085	0.18399948	-2.609	0.0168
LN_TPSP	1	1.248354	0.56491062	2.210	0.0389

SUBSEQUENT REGENERATION Cw
PROGNOSIS RE-FITTED MODEL FORM

Model: MODEL1
Dependent Variable: LN_ACTHT

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob>F
Model	9	19.83858	2.20429	1.304	0.2501
Error	72	121.71022	1.69042		
C Total	81	141.54881			

Root MSE	1.30016	R-square	0.1402
Dep Mean	3.27119	Adj R-sq	0.0327
C.V.	39.74588		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	T for H0: Parameter=0	Prob > |T|
INTERCEP	1	4.540887	0.90368460	5.025	0.0001
LN_AGE	1	0.207101	0.12563403	1.648	0.1036
X1	1	0.956177	0.83534594	1.145	0.2561
X2	1	0.567107	0.72126979	0.786	0.4343
SLO	1	-1.159073	1.04488148	-1.109	0.2710
ELEV_FC	1	-0.019380	0.02126120	-0.912	0.3651
BAA	1	0.033088	0.07064597	0.468	0.6409
LN_TPSP	1	-0.223337	0.16725508	-1.335	0.1860
DSITEP1	1	0.400053	0.59476799	0.673	0.5033
DSITEP2	1	-0.556564	0.38705458	-1.438	0.1548

Variable selection procedure resulting model for the prediction of height of advance and subsequent regeneration

ADVANCE REGENERATION Fd
VARIABLE SELECTION RESULTING MODEL

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step14 Group GROUP11 Removed R-square = 0.55131665 C(p) = -2.73103417

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	4	16.67030664	4.16757666	6.14	0.0022
Error	20	13.56695666	0.67834783		
Total	24	30.23726330			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	4.96956111	0.91706140	19.92010763	29.37	0.0001
--- Group GROUP5 ---			3.62662665	5.35	0.0315
ELEV	-0.00229992	0.00099469	3.62662665	5.35	0.0315
--- Group GROUP9 ---			16.66993657	8.19	0.0009
DPOS1	-1.11549040	0.95140284	0.93251372	1.37	0.2548
DPOS2	2.03460441	0.60806413	7.59475270	11.20	0.0032
DPOS3	0.45487761	0.73239342	0.26166925	0.39	0.5416

Bounds on condition number: 2.747115, 30.43578

All groups of variables left in the model are significant at the 0.1000 level.

ADVANCE REGENERATION Hw
VARIABLE SELECTION RESULTING MODEL

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step 2 Group GROUP10 Removed R-square = 0.90508670 C(p) = 12.45780842

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	13	26.27553497	2.02119500	7.34	0.0017
Error	10	2.75542410	0.27554241		
Total	23	29.03095907			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-3.98842870	3.35629468	0.38910960	1.41	0.2622
--- Group GROUP1 ---			3.19552737	11.60	0.0067
LN_AGE	4.21170704	1.23674770	3.19552737	11.60	0.0067
--- Group GROUP2 ---			1.45239963	5.27	0.0446
X1	-11.19118554	4.87446838	1.45239963	5.27	0.0446
--- Group GROUP3 ---			3.64633276	13.23	0.0046
X2	-40.11789202	11.02818852	3.64633276	13.23	0.0046
--- Group GROUP4 ---			4.36068429	15.83	0.0026
SLO	48.84563197	12.27842428	4.36068429	15.83	0.0026
--- Group GROUP5 ---			4.56220572	16.56	0.0023
ELEV	-0.01076985	0.00264677	4.56220572	16.56	0.0023
--- Group GROUP7 ---			3.03917665	11.03	0.0077
LN_TPSP	1.34503349	0.40499471	3.03917665	11.03	0.0077
--- Group GROUP8 ---			2.52206340	4.58	0.0388
DSITEP1	2.62976141	1.43784391	0.92171715	3.35	0.0973
DSITEP2	-13.88989373	4.61767747	2.49309660	9.05	0.0132
--- Group GROUP9 ---			1.36978236	4.97	0.0499
DPOS2	3.88104822	1.74067415	1.36978236	4.97	0.0499
--- Group GROUP11 ---			2.34237172	8.50	0.0154
COUNT	-0.06629809	0.02273879	2.34237172	8.50	0.0154
--- Group GROUP12 ---			2.46982217	8.96	0.0135
AGE	-0.33478253	0.11182121	2.46982217	8.96	0.0135
--- Group GROUP13 ---			1.55001099	5.63	0.0392
ASP	0.01227378	0.00517494	1.55001099	5.63	0.0392
--- Group GROUP15 ---			0.92103307	3.34	0.0974
CCF	0.01020861	0.00558372	0.92103307	3.34	0.0974

Bounds on condition number: 395.7488, 15890.02

All groups of variables left in the model are significant at the 0.1000 level.

```
ADVANCE REGENERATION Bl
VARIABLE SELECTION RESULTING MODEL

Step15   Group GROUP15  Removed     R-square = 0.99943740   C(p) = 10.06317583

DF          Sum of Squares      Mean Square          F   Prob>F
Regression         7            4.32693335       0.61813334      507.56    0.0020
Error              2            0.00243569       0.00121784
Total              9            4.32936903

                 Parameter          Standard          Type II
Variable          Estimate             Error    Sum of Squares          F     Prob>F
INTERCEP       -1.83569526        0.18264231        0.12302394     101.02     0.0098
--- Group GROUP1   ---                              0.05402412      44.36     0.0218
LN_AGE         -0.11465928        0.01721516        0.05402412      44.36     0.0218
--- Group GROUP2   ---                              0.73511239     603.62     0.0017
X1              3.75815455        0.15296547        0.73511239     603.62     0.0017
--- Group GROUP3   ---                              0.53210055     436.92     0.0023
X2             -2.63354417        0.12599096        0.53210055     436.92     0.0023
--- Group GROUP5   ---                              1.97408101    1620.97     0.0006
ELEV            0.00489265        0.00012152        1.97408101    1620.97     0.0006
--- Group GROUP6   ---                              0.24967508     205.01     0.0048
BAHA            0.03550575        0.00247974        0.24967508     205.01     0.0048
--- Group GROUP7   ---                              0.01103832       9.06     0.0949
LN_TPSP        -0.09364448        0.03110473        0.01103832       9.06     0.0949
--- Group GROUP8   ---                              0.27167125     223.08     0.0045
DSITEP2        -0.90172539        0.06037374        0.27167125     223.08     0.0045

Bounds on condition number:     6.369485,      204.109
-------------------------------------------------------------------------------------
All groups of variables left in the model are significant at the 0.1000 level.
```

```
ADVANCE REGENERATION Cw
VARIABLE SELECTION RESULTING MODEL

Step12   Group GROUP15  Removed     R-square = 0.40144342   C(p) =  0.88264174
DF          Sum of Squares      Mean Square          F   Prob>F
Regression         6           33.08066571       5.51344429       6.60    0.0001
Error             59           49.32363798       0.83599386
Total             65           82.40430370

Parameter         Standard           Type II
Variable          Estimate             Error    Sum of Squares         F     Prob>F
INTERCEP        2.63068118        0.43259235       30.91589776     36.98     0.0001
--- Group GROUP9   ---                              5.74805951      2.29     0.0874
DPOS1           1.68364836        0.71801386        4.59663707      5.50     0.0224
DPOS2           0.54990367        0.32627749        2.37466357      2.84     0.0972
DPOS3          -0.11501227        0.98036269        0.01150583      0.01     0.9070
--- Group GROUP10  ---                              5.75367781      6.88     0.0111
DHAB           -0.66475999        0.25339244        5.75367781      6.88     0.0111
--- Group GROUP12  ---                             14.26803826     17.07     0.0001
AGE             0.04175917        0.01010814       14.26803826     17.07     0.0001
--- Group GROUP13  ---                              3.57637467      4.28     0.0430
ASP             0.00246546        0.00119200        3.57637467      4.28     0.0430

Bounds on condition number:      1.329372,      41.29567
-------------------------------------------------------------------------------------
All groups of variables left in the model are significant at the 0.1000 level.
```

SUBSEQUENT REGENERATION Lw
VARIABLE SELECTION RESULTING MODEL

Step 3 Group GROUP11 Removed R-square = 0.83669980 C(p) = 13.55947633

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	14	28.02306741	2.00164767	7.69	0.0001
Error	21	5.46931224	0.26044344		
Total	35	33.49237965			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	7.79692549	0.77241741	26.53726036	101.89	0.0001
--- Group GROUP1 ---			1.85009310	7.10	0.0145
LN_AGE	-2.03145269	0.76219594	1.85009310	7.10	0.0145
--- Group GROUP2 ---			3.83037406	14.71	0.0010
X1	3.14677057	0.82054272	3.83037406	14.71	0.0010
--- Group GROUP3 ---			1.18258141	4.54	0.0451
X2	1.92017957	0.90112084	1.18258141	4.54	0.0451
--- Group GROUP4 ---			2.90570627	11.16	0.0031
SLO	-4.31856705	1.29291663	2.90570627	11.16	0.0031
--- Group GROUP6 ---			4.67097649	17.93	0.0004
BAHA	-0.13989116	0.03303263	4.67097649	17.93	0.0004
--- Group GROUP7 ---			2.58612244	9.93	0.0048
LN_TPSP	0.41713131	0.13237469	2.58612244	9.93	0.0048
--- Group GROUP8 ---			5.80043283	11.14	0.0005
DSITEP1	-2.46262441	0.53746385	5.46778303	20.99	0.0002
DSITEP2	-0.96250373	0.31665101	2.40633736	9.24	0.0062
--- Group GROUP9 ---			9.26355999	11.86	0.0001
DPOS1	0.02283442	0.47132571	0.00061130	0.00	0.9618
DPOS2	-0.43292900	0.30273318	0.53263136	2.05	0.1674
DPOS3	-3.95334261	0.67214008	9.00995752	34.59	0.0001
--- Group GROUP10 ---			15.38028923	59.05	0.0001
DHAB	-2.56118160	0.33328428	15.38028923	59.05	0.0001
--- Group GROUP12 ---			2.29411000	8.81	0.0073
AGE	0.53605862	0.18061835	2.29411000	8.81	0.0073
--- Group GROUP13 ---			4.38829432	16.85	0.0005
ASP	-0.00564312	0.00137476	4.38829432	16.85	0.0005

Bounds on condition number: 64.84315, 2206.333

All groups of variables left in the model are significant at the 0.1000 level.

SUBSEQUENT REGENERATION Pl
VARIABLE SELECTION RESULTING MODEL

Step13 Group GROUP14 Removed R-square = 0.22869350 C(p) = -1.98116288

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	3	12.59241025	4.19747008	5.04	0.0039
Error	51	42.46997754	0.83274466		
Total	54	55.06238779			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	3.45336418	0.27737479	129.08109941	155.01	0.0001
--- Group GROUP1 ---			3.01476073	3.62	0.0627
LN_AGE	-1.36046659	0.71501867	3.01476073	3.62	0.0627
--- Group GROUP2 ---			2.63368161	3.16	0.0813
X1	1.45745511	0.81953872	2.63368161	3.16	0.0813
--- Group GROUP12 ---			4.91559373	5.90	0.0187
AGE	0.42337045	0.17425630	4.91559373	5.90	0.0187

Bounds on condition number: 15.21938, 94.34773

All groups of variables left in the model are significant at the 0.1000 level.

SUBSEQUENT REGENERATION Sx
VARIABLE SELECTION RESULTING MODEL

Step17 Group GROUP11 Removed R-square = 0.61775757 C(p) = -2.74427757

DF	Sum of Squares	Mean Square	F	Prob>F	
Regression	2	19.91174644	9.95587322	14.55	0.0002
Error	18	12.32055238	0.68447513		
Total	20	32.23229882			

Parameter Variable	Standard Estimate	Type II Error	Sum of Squares	F	Prob>F
INTERCEP	-2.56716638	1.08278838	3.84749914	5.62	0.0291
--- Group GROUP2 ---			2.71279274	3.96	0.0619
X1	2.32722627	1.16898554	2.71279274	3.96	0.0619
--- Group GROUP5 ---			19.77106463	28.89	0.0001
ELEV	0.00517651	0.00096317	19.77106463	28.89	0.0001

Bounds on condition number: 1.2482, 4.992798

All groups of variables left in the model are significant at the 0.1000 level.

SUBSEQUENT REGENERATION Fd
VARIABLE SELECTION RESULTING MODEL

Step12 Group GROUP8 Removed R-square = 0.17714803 C(p) = -2.96839804

DF	Sum of Squares	Mean Square	F	Prob>F	
Regression	4	27.83764440	6.95941110	6.84	0.0001
Error	127	129.30575807	1.01815558		
Total	131	157.14340246			

Parameter Variable	Standard Estimate	Type II Error	Sum of Squares	F	Prob>F
INTERCEP	3.23013538	0.15059207	468.43721067	460.08	0.0001
--- Group GROUP2 ---			3.54450446	3.48	0.0644
X1	-0.85998422	0.46091389	3.54450446	3.48	0.0644
--- Group GROUP3 ---			4.33331418	4.26	0.0411
X2	0.79102461	0.38343078	4.33331418	4.26	0.0411
--- Group GROUP12 ---			14.67666112	14.41	0.0002
AGE	0.07750392	0.02041348	14.67666112	14.41	0.0002
--- Group GROUP15 ---			5.39650304	5.30	0.0229
CCF	-0.00337316	0.00146517	5.39650304	5.30	0.0229

Bounds on condition number: 1.069679, 16.64342

All groups of variables left in the model are significant at the 0.1000 level.

```
SUBSEQUENT REGENERATION Pw
VARIABLE SELECTION RESULTING MODEL

Step11   Group GROUP11  Removed     R-square = 0.33035496   C(p) =  4.43733926

                 DF          Sum of Squares      Mean Square          F   Prob>F
Regression        6          29.21302602         4.86883767        4.28   0.0014
Error            52          59.21617880         1.13877267
Total            58          88.42920482

                 Parameter        Standard           Type II
Variable         Estimate            Error     Sum of Squares          F   Prob>F

INTERCEP       2.29194988       0.56511581        18.73149130      16.45   0.0002
--- Group GROUP2   ---                             4.10845435       3.61   0.0631
X1             1.68327583       0.88620577         4.10845435       3.61   0.0631
--- Group GROUP3   ---                             6.83383692       6.00   0.0177
X2            -2.02501537       0.82663642         6.83383692       6.00   0.0177
--- Group GROUP5   ---                             4.03141660       3.54   0.0655
ELEV           0.00117417       0.00062405         4.03141660       3.54   0.0655
--- Group GROUP8   ---                            23.88219433      10.49   0.0001
DSITEP1        2.27870739       0.53863810        20.38074332      17.90   0.0001
DSITEP2        0.77002299       0.35901299         5.23870678       4.60   0.0367
--- Group GROUP13  ---                             4.98721950       4.38   0.0413
ASP           -0.00379093       0.00181149         4.98721950       4.38   0.0413

Bounds on condition number:     2.325024,     55.40759
---------------------------------------------------------------------------------
All groups of variables left in the model are significant at the 0.1000 level.
```

```
SUBSEQUENT REGENERATION Bg
VARIABLE SELECTION RESULTING MODEL

Step20   Group GROUP1   Removed     R-square = 0.22481738   C(p) = -7.43655018

DF          Sum of Squares      Mean Square            F   Prob>F
Regression        1            2.28706058        2.28706058        4.06   0.0635
Error            14            7.88590987        0.56327928
Total            15           10.17297045

Parameter        Standard           Type II
Variable         Estimate            Error   Sum of Squares          F   Prob>F

INTERCEP       2.53163921       0.21590933      77.44343184     137.49   0.0001
--- Group GROUP12  ---                           2.28706058       4.06   0.0635
AGE            0.07653553       0.03798273       2.28706058       4.06   0.0635

Bounds on condition number:           1,           1
---------------------------------------------------------------------------------
All groups of variables left in the model are significant at the 0.1000 level.
```

SUBSEQUENT REGENERATION Hw
VARIABLE SELECTION RESULTING MODEL

Bounds on condition number: 6.987583, 181.1625

Step 8 Group GROUP2 Removed R-square = 0.36572365 C(p) = 3.61044079

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	7	29.33038701	4.19005529	5.27	0.0001
Error	64	50.86783547	0.79480993		
Total	71	80.19822249			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	3.66364450	0.45071311	52.51574740	66.07	0.0001
--- Group GROUP1 ---			2.46761332	3.10	0.0828
LN_AGE	-0.51946245	0.29481342	2.46761332	3.10	0.0828
--- Group GROUP4 ---			4.95935041	6.24	0.0151
SLO	-2.05668683	0.82335554	4.95935041	6.24	0.0151
--- Group GROUP6 ---			4.31256929	5.43	0.0230
BAHA	-0.02160042	0.00927312	4.31256929	5.43	0.0230
--- Group GROUP7 ---			2.40227985	3.02	0.0869
LN_TPSP	-0.18998218	0.10927799	2.40227985	3.02	0.0869
--- Group GROUP9 ---			8.53304553	5.37	0.0070
DPOS1	0.98747192	0.45461122	3.75001064	4.72	0.0336
DPOS2	1.17606602	0.36382471	8.30505097	10.45	0.0019
--- Group GROUP12 ---			4.63425803	5.83	0.0186
AGE	0.13385108	0.05543237	4.63425803	5.83	0.0186

Bounds on condition number: 6.897224, 148.813

All groups of variables left in the model are significant at the 0.1000 level.

SUBSEQUENT REGENERATION Bl
VARIABLE SELECTION RESULTING MODEL

Step 8 Group GROUP11 Removed R-square = 0.93984305 C(p) = 8.54991749

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	9	74.52038461	8.28004273	17.36	0.0001
Error	10	4.76985885	0.47698588		
Total	19	79.29024346			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-4.02563635	1.30896013	4.51150843	9.46	0.0117
--- Group GROUP2 ---			2.50587390	5.25	0.0449
X1	-3.45344914	1.50669803	2.50587390	5.25	0.0449
--- Group GROUP3 ---			12.92316297	27.09	0.0004
X2	6.90391707	1.32636765	12.92316297	27.09	0.0004
--- Group GROUP4 ---			5.08075095	10.65	0.0085
SLO	4.91462935	1.50584260	5.08075095	10.65	0.0085
--- Group GROUP6 ---			16.88318817	35.40	0.0001
BAHA	-0.18252454	0.03067940	16.88318817	35.40	0.0001
--- Group GROUP9 ---			4.80209355	5.03	0.0307
DPOS1	2.68769770	0.89332737	4.31762667	9.05	0.0131
DPOS2	1.05127058	0.50527447	2.06480880	4.33	0.0641
--- Group GROUP10 ---			21.76960184	45.64	0.0001
DHAB	8.85183960	1.31027078	21.76960184	45.64	0.0001
--- Group GROUP12 ---			5.57270388	11.68	0.0066
AGE	0.08960998	0.02621659	5.57270388	11.68	0.0066
--- Group GROUP15 ---			21.14578463	44.33	0.0001
CCF	-0.03091374	0.00464293	21.14578463	44.33	0.0001

Bounds on condition number: 9.178184, 289.5341

All groups of variables left in the model are significant at the 0.1000 level.

SUBSEQUENT REGENERATION Cw
VARIABLE SELECTION RESULTING MODEL

Step10 Group GROUP10 Removed R-square = 0.30685452 C(p) = 3.69397919

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	6	42.31943260	7.05323877	5.46	0.0001
Error	74	95.59423786	1.29181403		
Total	80	137.91367046			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	2.74120649	0.36018491	74.82254351	57.92	0.0001
--- Group GROUP3 ---			5.06072842	3.92	0.0515
X2	1.14711469	0.57956256	5.06072842	3.92	0.0515
--- Group GROUP4 ---			6.17979836	4.78	0.0319
SLO	-2.09243106	0.95667407	6.17979836	4.78	0.0319
--- Group GROUP9 ---			24.77485107	6.39	0.0007
DPOS1	-0.13903346	0.54778436	0.08321841	0.06	0.8003
DPOS2	1.09342045	0.39902856	9.69988112	7.51	0.0077
DPOS3	-2.56487142	1.20356059	5.86671882	4.54	0.0364
--- Group GROUP12 ---			14.83303041	11.48	0.0011
AGE	0.05476009	0.01616029	14.83303041	11.48	0.0011

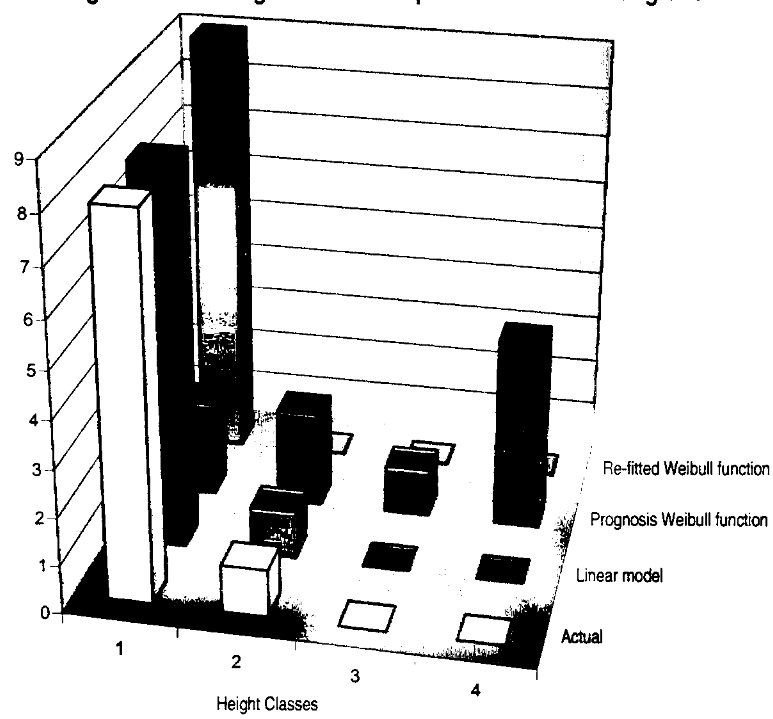
Bounds on condition number: 1.856448, 48.5314

All groups of variables left in the model are significant at the 0.1000 level.

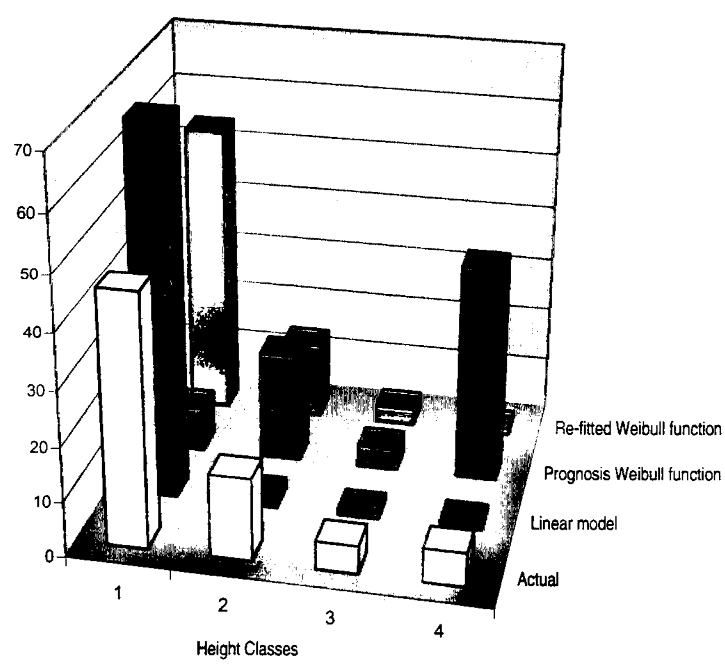
APPENDIX 9: Heights of advance and subsequent.

Graph comparing the number of trees per height class in the Nelson data set to linearly predicted heights, heights predicted with the Prognosis model and height predicted with data-fitted Weibull function.

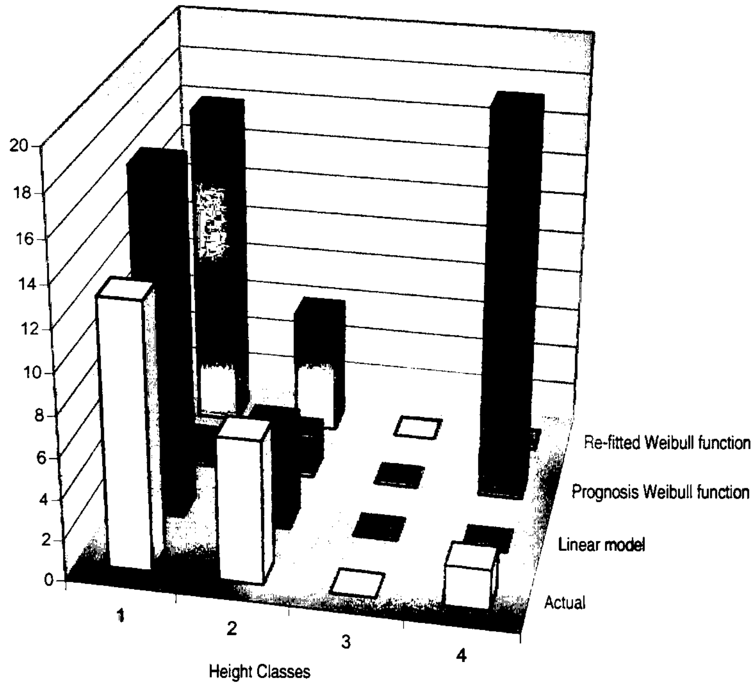
Height of excess regeneration comparison of models for grand fir



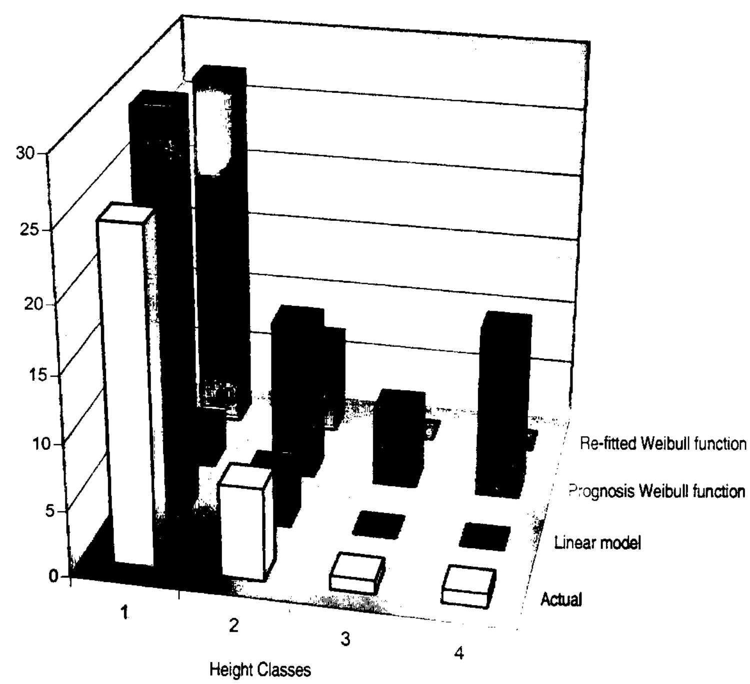
Height of excess regeneration comparison of models for Douglas fir



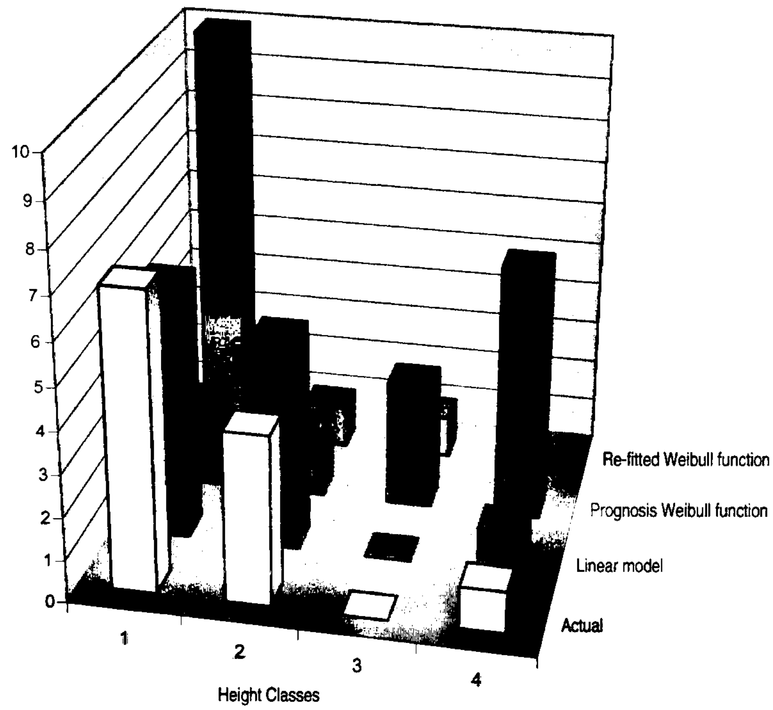
Height of excess regeneration comparison of models for western larch



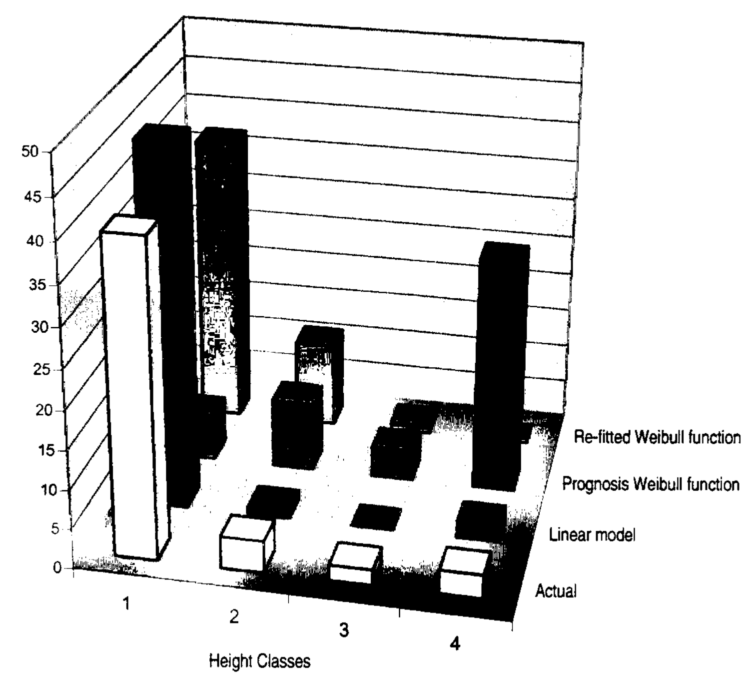
Height of excess regeneration comparison of models for white pine



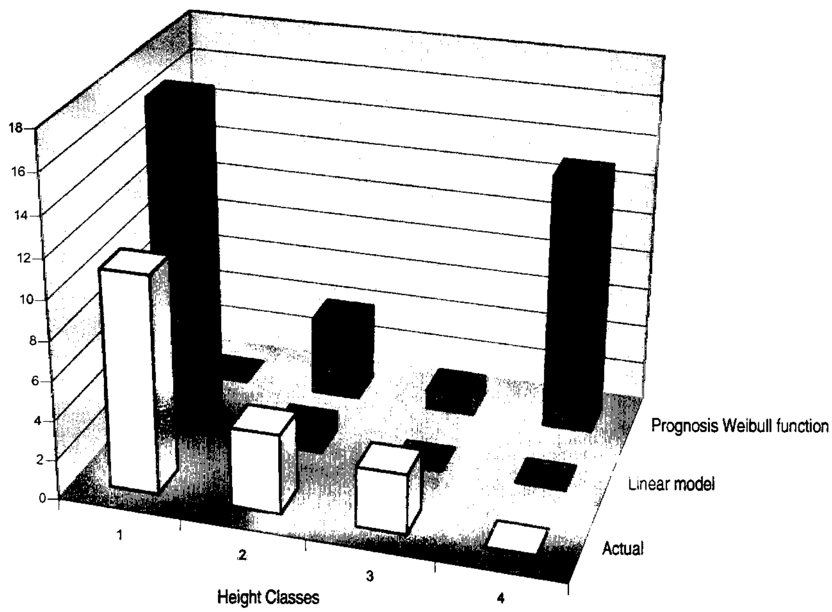
Height of excess regeneration comparison of models for subalpine fir



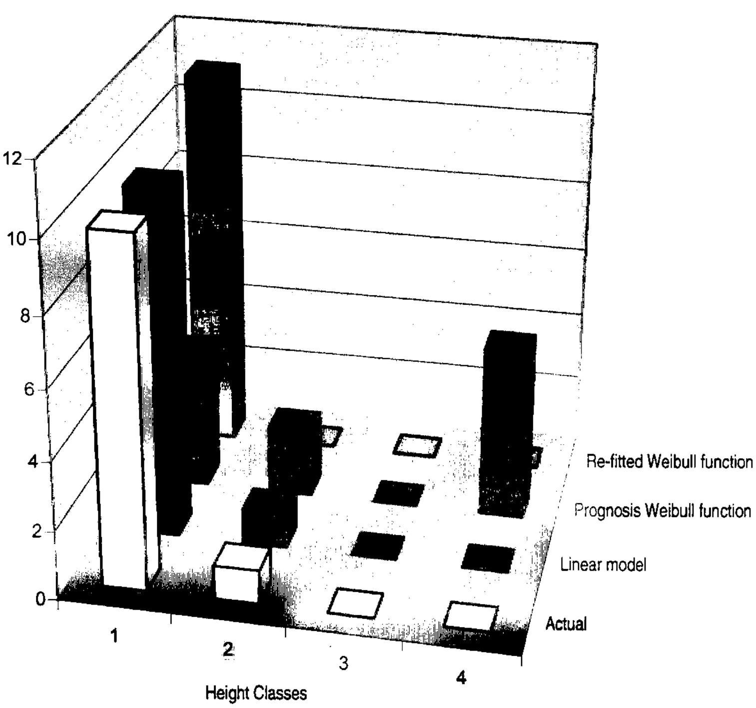
Height of excess regeneration comparison of models for hemlock



Height of excess regeneration comparison of models for lodgepole pine



Height of excess regeneration comparison of models for spruce



APPENDIX 10: Height of excess regeneration.

Coefficients and model forms used for linear predictions of height of excess regeneration, heights predictions using Prognosis models, and height predictions with data-fitted Weibull functions by species.

Coefficients and analysis of variance for prediction of height of excess regeneration.

EXCESS REGENERATION Lw
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step13 Group GROUP10 Removed R-square = 0.40719931 C(p) = -1.73090080

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	3	11.09021710	3.69673903	4.12	0.0217
Error	18	16.14513638	0.89695202		
Total	21	27.23535348			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	3.41111491	0.46568436	48.12587168	53.65	0.0001
--- Group GROUP5 ---			5.87414855	6.55	0.0197
BAHA	-0.09962548	0.03892984	5.87414855	6.55	0.0197
--- Group GROUP7 ---			5.71606046	3.19	0.0654
DSITEP1	-0.14888807	0.64088601	0.04840915	0.05	0.8189
DSITEP2	0.96403745	0.47602299	3.67875755	4.10	0.0579

Bounds on condition number: 1.498657, 11.94166

All groups of variables left in the model are significant at the 0.1000 level.

EXCESS REGENERATION Pl
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Forward Selection Procedure for Dependent Variable LN_ACTHT

Step 2 Group GROUP9 Entered R-square = 0.12906977 C(p) = -9.68702911

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	2	4.00788715	2.00394358	1.11	0.3547
Error	15	27.04421124	1.80294742		
Total	17	31.05209840			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	2.35750799	0.57952570	29.83623408	16.55	0.0010
--- Group GROUP9 ---			1.98943811	1.10	0.3101
DHAB	0.77173859	0.73467714	1.98943811	1.10	0.3101
--- Group GROUP14 ---			3.50097260	1.94	0.1838
CCF	0.02424626	0.01739970	3.50097260	1.94	0.1838

Bounds on condition number: 1.197485, 4.789939

No other group of variables met the 0.5000 significance level for entry into the model.

EXCESS REGENERATION Sx
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Forward Selection Procedure for Dependent Variable LN_ACTHT

Step 9 Group GROUP4 Entered R-square = 0.99996294 C(p) = .

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	9	9.93291008	1.10365668	2998.18	0.0142
Error	1	0.00036811	0.00036811		
Total	10	9.93327819			

Parameter Variable	Standard Estimate	Type II Error	Sum of Squares	F	Prob>F
INTERCEP	2.54069307	0.06657072	0.53618376	1456.59	0.0167
--- Group GROUP1 ---			0.20049990	544.68	0.0273
X1	1.23922188	0.05309821	0.20049990	544.68	0.0273
--- Group GROUP2 ---			2.87610625	7813.20	0.0072
X2	6.15496102	0.06963230	2.87610625	7813.20	0.0072
--- Group GROUP4 ---			0.05230356	142.09	0.0533
ELEV	0.00072978	0.00006122	0.05230356	142.09	0.0533
--- Group GROUP5 ---			0.64294924	1746.63	0.0152
BAHA	0.09711361	0.00232370	0.64294924	1746.63	0.0152
--- Group GROUP8 ---			0.19894419	540.45	0.0274
DPOS2	0.47490138	0.02042799	0.19894419	540.45	0.0274
--- Group GROUP9 ---			2.58359647	7018.57	0.0076
DHAB	-1.95640593	0.02335256	2.58359647	7018.57	0.0076
--- Group GROUP10 ---			1.65846719	4505.38	0.0095
COUNT	-0.43902160	0.00654064	1.65846719	4505.38	0.0095
--- Group GROUP11 ---			0.54929422	1492.21	0.0165
AGE	-0.12875891	0.00333321	0.54929422	1492.21	0.0165
--- Group GROUP14 ---			0.03050786	82.88	0.0697
CCF	0.00484458	0.00053216	0.03050786	82.88	0.0697

Bounds on condition number: 10.70776, 418.4308

No other group of variables met the 0.5000 significance level for entry into the model.

EXCESS REGENERATION Fd
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step14 Group GROUP8 Removed R-square = 0.09425336 C(p) = -1.38825062

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	1	13.35129323	13.35129323	7.28	0.0087
Error	70	128.30194522	1.83288493		
Total	71	141.65323844			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	3.05332706	0.18830743	481.88891484	262.91	0.0001
--- Group GROUP11 ---			13.35129323	7.28	0.0087
AGE	0.05061270	0.01875277	13.35129323	7.28	0.0087

Bounds on condition number: 1, 1

All groups of variables left in the model are significant at the 0.1000 level.

EXCESS REGENERATION Pw
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step10 Group GROUP9 Removed R-square = 0.34715408 C(p) = -0.24604538

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	5	15.82178767	3.16435753	2.98	0.0280
Error	28	29.75390462	1.06263945		
Total	33	45.57569228			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	1.98538616	0.76958496	7.07233411	6.66	0.0154
--- Group GROUP3 ---			10.54037805	9.92	0.0039
SLO	-4.36995916	1.38752959	10.54037805	9.92	0.0039
--- Group GROUP4 ---			6.45525382	6.07	0.0201
ELEV	0.00212849	0.00086359	6.45525382	6.07	0.0201
--- Group GROUP8 ---			10.57248207	3.32	0.0342
DPOS1	-0.52844474	0.93914154	0.33645190	0.32	0.5781
DPOS2	0.48125157	0.53967906	0.84500468	0.80	0.3801
DPOS3	-1.80093683	0.83991434	4.88554372	4.60	0.0408

Bounds on condition number: 1.934717, 41.22886

All groups of variables left in the model are significant at the 0.1000 level.

EXCESS REGENERATION Bg
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step19 Group GROUP10 Removed R-square = 0.81472787 C(p) = .

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	2	10.27614049	5.13807024	13.19	0.0064
Error	6	2.33683238	0.38947206		
Total	8	12.61297287			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	3.82592074	0.37490985	40.55968302	104.14	0.0001
--- Group GROUP11 ---			6.69572861	17.19	0.0060
AGE	0.36900578	0.08899639	6.69572861	17.19	0.0060
--- Group GROUP13 ---			7.35574430	18.89	0.0048
SLOPE	-0.06465058	0.01487638	7.35574430	18.89	0.0048

Bounds on condition number: 1.1569, 4.627601

All groups of variables left in the model are significant at the 0.1000 level.

EXCESS REGENERATION Hw
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step11 Group GROUP8 Removed R-square = 0.43474502 C(p) = 1.44444227

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	5	21.53604215	4.30720843	6.61	0.0001
Error	43	28.00113720	0.65118924		
Total	48	49.53717935			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	2.54680064	0.23731957	74.99460219	115.17	0.0001
--- Group GROUP1 ---			1.86631085	2.87	0.0977
X1	-1.06820407	0.63098037	1.86631085	2.87	0.0977
--- Group GROUP7 ---			3.29522756	2.53	0.0914
DSITEP1	1.13978725	0.50833697	3.27379448	5.03	0.0302
DSITEP2	0.07946497	0.31144277	0.04239379	0.07	0.7998
--- Group GROUP11 ---			12.62527437	19.39	0.0001
AGE	0.11089836	0.02518595	12.62527437	19.39	0.0001
--- Group GROUP12 ---			2.86012147	4.39	0.0420
ASP	0.00239536	0.00114297	2.86012147	4.39	0.0420

Bounds on condition number: 1.17156, 27.44403

All groups of variables left in the model are significant at the 0.1000 level.

EXCESS REGENERATION Bl
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step13 Group GROUP13 Removed R-square = 0.96439166 C(p) = .

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	6	25.85232400	4.30872067	22.57	0.0018
Error	5	0.95454831	0.19090966		
Total	11	26.80687232			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	7.55240146	0.47874123	47.51124167	248.87	0.0001
--- Group GROUP6 ---			9.75736155	51.11	0.0008
NTREES	0.07203116	0.01007554	9.75736155	51.11	0.0008
--- Group GROUP7 ---			4.77247384	25.00	0.0041
DSITEP2	-2.12317370	0.42464665	4.77247384	25.00	0.0041
--- Group GROUP8 ---			3.90257928	10.22	0.0171
DPOS1	2.21034152	0.56977859	2.87299203	15.05	0.0117
DPOS2	-0.34324520	0.29162801	0.26447119	1.39	0.2922
--- Group GROUP12 ---			11.13883400	58.35	0.0006
ASP	-0.01394841	0.00182608	11.13883400	58.35	0.0006
--- Group GROUP14 ---			21.46426040	112.43	0.0001
CCF	-0.03508600	0.00330895	21.46426040	112.43	0.0001

Bounds on condition number: 2.12525, 64.60899

All groups of variables left in the model are significant at the 0.1000 level.

EXCESS REGENERATION Cw
VARIABLE SELECTION RESULTING MODEL FOR PREDICTING HEIGHT OF EXCESS REGENERATION

Backward Elimination Procedure for Dependent Variable LN_ACTHT

Step14 Group GROUP12 Removed R-square = 0.28618629 C(p) = -3.96622360

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	1	24.12032461	24.12032461	27.26	0.0001
Error	68	60.16157553	0.88472905		
Total	69	84.28190014			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	3.00739507	0.13870856	415.89598826	470.08	0.0001
--- Group GROUP11 ---			24.12032461	27.26	0.0001
AGE	0.05571405	0.01067034	24.12032461	27.26	0.0001

Bounds on condition number: 1, 1

All groups of variables left in the model are significant at the 0.1000 level.

Data-fitted Weibull parameters for prediction height of excess regeneration.

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WESTERN RED CEDAR REGENERATION
< 7 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: DUD

Iter	B	C	Sum of Squares
18	42.930793	1.446426	0.048211
19	42.928942	1.446633	0.048211
20	42.929181	1.446658	0.048211
21	42.928648	1.446719	0.048211
22	42.928354	1.446743	0.048211

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	10.248931882	5.124465941
Residual	27	0.048210975	0.001785592
Uncorrected Total	29	10.297142857	
(Corrected Total)	28	2.360168895	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	42.92835379	0.92143022947	41.037749815	44.818957760
C	1.44674337	0.08225992506	1.277961258	1.615525484

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.386299015
C	-0.386299015	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WESTERN RED CEDAR REGENERATION
between 7-12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Gauss-Newton

Iter	B	C	Sum of Squares
0	4.506400	0.813540	7.044731
1	9.635827	0.043501	2.971542
2	243.870692	0.608111	2.216974
3	118.669633	0.632313	0.962456
4	39.967834	0.785928	0.305835
5	46.821149	1.166580	0.037973
6	44.272366	1.303179	0.025238
7	44.428129	1.322750	0.024932
8	44.415828	1.324355	0.024930
9	44.414946	1.324481	0.024930
10	44.414876	1.324491	0.024930

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	9.7101715501	4.8550857751
Residual	27	0.0249304907	0.0009233515
Uncorrected Total	29	9.7351020408	
(Corrected Total)	28	2.5847572132	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	44.41487572	0.77578934812	42.823099828	46.006651607
C	1.32449081	0.04756039871	1.226905695	1.422075933

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.371538451
C	-0.371538451	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WESTERN RED CEDAR REGENERATION
> 12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Marquardt

Iter	B	C	Sum of Squares
0	8.940540	0.943490	2.230365
1	15.871617	-0.274729	1.481388
2	2.377234	0.118274	1.410586
3	23.757633	0.299826	0.748724
4	70.114825	0:987586	0.243958
5	35.555811	1.141684	0.091894
6	43.615578	1.278876	0.013128
7	43.576589	1.331299	0.012456
8	43.555158	1.334912	0.012453
9	43.553498	1.335114	0.012453
10	43.553400	1.335125	0.012453

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	3.7910159023	1.8955079512
Residual	10	0.0124534854	0.0012453485
Uncorrected Total	12	3.8034693878	
(Corrected Total)	11	0.8744727891	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	43.55339959	1.2074620800	40.862989498	46.243809686
C	1.33512545	0.0774638982	1.162524040	1.507726854

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.225327693
C	-0.225327693	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS GRAND FIR REGENERATION
< 7 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Gauss-Newton

Iter	B	C	Sum of Squares
0	3.169510	0.640550	0.253997
1	5.747994	0.326428	0.150794
2	18.884191	0.543640	0.012092
3	24.179977	0.693667	0.000528
4	24.097115	0.745976	0.000103
5	24.146242	0.749927	0.000101
6	24.147270	0.750033	0.000101
7	24.147298	0.750035	0.000101

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	1.0616272376	0.5308136188
Residual	1	0.0001011575	0.0001011575
Uncorrected Total	3	1.0617283951	
(Corrected Total)	2	0.2551440329	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	24.14729769	0.66350234133	15.716836940	32.577758438
C	0.75003516	0.03011877350	0.367346026	1.132724298

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.2769023272
C	0.2769023272	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS GRAND FIR REGENERATION
between 7-12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Gauss-Newton

Iter	B	C	Sum of Squares
0	4.506400	0.813540	0.356862
1	7.509762	0.253451	0.198962
2	31.339359	0.851964	0.056245
3	16.153562	0.962206	0.012298
4	19.786472	1.007848	0.000910
5	19.918108	1.042936	0.000742
6	19.939093	1.042737	0.000742
7	19.938439	1.042837	0.000742
8	19.938533	1.042830	0.000742
9	19.938525	1.042830	0.000742

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	2.1474062600	1.0737031300
Residual	2	0.0007418881	0.0003709441
Uncorrected Total	4	2.1481481481	
(Corrected Total)	3	0.3703703704	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	19.93852524	0.76549973467	16.644809530	23.232240946
C	1.04283044	0.05748250972	0.795500442	1.290160431

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.099664387
C	-0.099664387	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS GRAND FIR REGENERATION
> 12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Marquardt

Iter	B	C	Sum of Squares
0	8.940540	0.943490	0.156641
1	15.884531	0.408597	0.059753
2	32.084341	0.543023	0.001070
3	32.035809	0.607206	0.0000006049
4	31.914227	0.610618	6.0545843E-11
5	31.914929	0.610623	2.7250026E-20
6	31.914929	0.610623	1.5290744E-27

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	0.30864197531	0.15432098765
Residual	0	0.00000000000	0.00000000000
Uncorrected Total	2	0.30864197531	
(Corrected Total)	1	0.00617283951	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	31.91492917	0	31.914929173	31.914929173
C	0.61062268	0	0.610622677	0.610622677

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.966083184
C	-0.966083184	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS SUBALPINE FIR REGENERATION
between 7-12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Gauss-Newton

Iter	B	C	Sum of Squares
0	4.506400	0.813540	0.745062
1	1.301226	0.372942	0.673428
2	10.747634	0.026172	0.225841
3	88.165893	0.148060	0.191320
4	43.537639	0.255818	0.133244
5	62.096579	1.014715	0.034506
6	46.628428	1.082141	0.002956
7	48.949259	1.096336	0.001697
8	48.973380	1.100182	0.001695
9	48.975499	1.100164	0.001695
10	48.975480	1.100167	0.001695

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	2.4566386336	1.2283193168
Residual	3	0.0016946998	0.0005648999
Uncorrected Total	5	2.4583333333	
(Corrected Total)	4	0.2361111111	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	48.97548047	1.5864474783	43.926611372	54.024349571
C	1.10016680	0.0656452144	0.891250906	1.309082696

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.136443054
C	0.136443054	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS SUBALPINE FIR REGENERATION
> 12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Marquardt

Iter	B	C	Sum of Squares
0	8.940540	0.943490	0.425863
1	22.147625	0.263534	0.224280
2	63.254513	0.530799	0.018539
3	53.958617	0.715146	0.003466
4	52.960265	0.803876	0.001918
5	52.513654	0.825242	0.001866
6	52.476930	0.827775	0.001865
7	52.471698	0.828042	0.001865
8	52.471210	0.828068	0.001865
9	52.471161	0.828070	0.001865

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	1.4078572408	0.7039286204
Residual	2	0.0018649814	0.0009324907
Uncorrected Total	4	1.4097222222	
(Corrected Total)	3	0.4913194444	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	52.47116091	5.7479398397	27.739500166	77.202821663
C	0.82807029	0.1052302577	0.375296064	1.280844523

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.630965922
C	-0.630965922	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WESTERN HEMLOCK REGENERATION
< 7 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Gauss-Newton

Iter	B	C	Sum of Squares
0	3.169510	0.640550	2.726731
1	3.971549	0.096239	1.196005
2	67.129504	0.642696	0.377291
3	35.481708	0.821542	0.103440
4	34.414171	1.237567	0.023390
5	34.708485	1.376509	0.018534
6	34.719852	1.393378	0.018478
7	34.723959	1.394409	0.018478
8	34.724172	1.394476	0.018478
9	34.724187	1.394480	0.018478

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	6.9111348177	3.4555674089
Residual	13	0.0184778437	0.0014213726
Uncorrected Total	15	6.9296126614	
(Corrected Total)	14	1.3568235457	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	34.72418663	0.91661991865	32.743950875	36.704422388
C	1.39448018	0.08932845890	1.201497897	1.587462472

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.07116026
C	-0.07116026	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WESTERN HEMLOCK REGENERATION
> 12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Marquardt

Iter	B	C	Sum of Squares
0	8.940540	0.943490	1.459393
1	22.099426	0.467900	0.530451
2	51.849205	0.831097	0.013398
3	45.991678	0.987208	0.006209
4	40.759683	1.107371	0.003906
5	37.554974	1.210544	0.002548
6	31.607812	1.425201	0.002050
7	31.936222	1.476461	0.001223
8	31.950778	1.476287	0.001223
9	31.950713	1.476292	0.001223

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	0.39902703225	0.19951351613
Residual	4	0.00122286362	0.00030571591
Uncorrected Total	6	0.40024989588	
(Corrected Total)	5	0.06976259892	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	31.95071308	2.2933547263	25.583425729	38.318000430
C	1.47629233	0.1388811241	1.090701730	1.861882929

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.948838373
C	-0.948838373	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WESTERN LARCH REGENERATION
> 12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Marquardt

Iter	B	C	Sum of Squares
0	8.940540	0.943490	0.570925
1	15.682695	0.237290	0.378203
2	58.269113	0.891129	0.100880
3	23.693328	1.247561	0.076484
4	35.327500	1.157107	0.012148
5	36.114653	1.391404	0.004529
6	36.301070	1.441452	0.004293
7	36.341837	1.446872	0.004290
8	36.345610	1.447428	0.004290
9	36.346012	1.447482	0.004290
10	36.346050	1.447487	0.004290

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics   Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	1.5060406518	0.7530203259
Residual	2	0.0042899267	0.0021449633
Uncorrected Total	4	1.5103305785	
(Corrected Total)	3	0.4643595041	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval	
Lower	Upper			
B	36.34604991	2.5266604587	25.474587955	47.217511867
C	1.44748703	0.1714517418	0.709781617	2.185192436

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.022852928
C	-0.022852928	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WHITE PINE REGENERATION
< 7 yrsince disturbance   12:53 Friday, August 27, 1999

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Gauss-Newton

Iter	B	C	Sum of Squares
0	3.169510	0.640550	1.093512
1	4.453608	0.057243	0.501676
2	68.516563	0.449989	0.291807
3	40.203819	0.600480	0.109407
4	27.599669	1.094103	0.041712
5	34.380594	1.232782	0.003460
6	34.344616	1.280495	0.003226
7	34.346267	1.279428	0.003226
8	34.346312	1.279477	0.003226
9	34.346310	1.279475	0.003226

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	3.7952170241	1.8976085121
Residual	6	0.0032258824	0.0005376471
Uncorrected Total	8	3.7984429066	
(Corrected Total)	7	0.5621756055	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	34.34631040	0.77426719878	32.451745446	36.240875351
C	1.27947462	0.07937597223	1.085248477	1.473700772

Asymptotic Correlation Matrix

Corr	B	C
B	1	0.3104030887
C	0.3104030887	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WHITE PINE REGENERATION
between 7-12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: DUD

Iter	B	C	Sum of Squares
0	4.957040	0.813540	4.002456
1	13.909256	-0.359182	3.168975
2	20.145732	0.257263	1.085805
3	37.974343	0.413495	0.433177
4	57.025406	0.764461	0.232907
5	57.361403	0.740359	0.231713
6	34.562042	0.964523	0.018424
7	33.385462	1.047447	0.016667
8	37.022957	1.061734	0.015566
9	35.306615	1.054666	0.011065
10	35.242605	1.053936	0.011063
11	35.248642	1.055397	0.011062
12	35.260400	1.054814	0.011062
13	35.260402	1.054814	0.011062

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	5.8228482595	2.9114241297
Residual	18	0.0110617751	0.0006145431
Uncorrected Total	20	5.8339100346	
(Corrected Total)	19	1.3493079585	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	35.26040171	0.71593842696	33.756280826	36.764522590
C	1.05481425	0.03440854166	0.982525068	1.127103440

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.390711999
C	-0.390711999	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS WHITE PINE REGENERATION
> 12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Marquardt

Iter	B	C	Sum of Squares
0	8.940540	0.943490	0.549733
1	20.668454	0.314847	0.369680
2	50.010544	0.726521	0.032259
3	27.279749	0.979766	0.017289
4	33.704725	1.005463	0.001177
5	34.254977	1.024464	0.000954
6	34.258953	1.024326	0.000954
7	34.258994	1.024327	0.000954

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	2.2049284061	1.1024642031
Residual	4	0.0009539468	0.0002384867
Uncorrected Total	6	2.2058823529	
(Corrected Total)	5	0.7641291811	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	34.25899429	1.1849436691	30.969107752	37.548880823
C	1.02432694	0.0367309119	0.922346963	1.126306924

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.46870147
C	-0.46870147	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS SPRUCE REGENERATION
> 12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: Marquardt

Iter	B	C	Sum of Squares
0	8.940540	0.943490	0.251174
1	17.639690	0.790984	0.051921
2	21.386105	1.120184	0.003275
3	20.757570	1.221069	0.001852
4	20.841513	1.224585	0.001842
5	20.840271	1.224964	0.001842
6	20.840637	1.224946	0.001842
7	20.840604	1.224948	0.001842

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	2.1138601746	1.0569300873
Residual	3	0.0018423047	0.0006141016
Uncorrected Total	5	2.1157024793	
(Corrected Total)	4	0.6280991736	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	20.84060422	0.95945958799	17.787124082	23.894084359
C	1.22494828	0.07662019431	0.981104516	1.468792053

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.363893708
C	-0.363893708	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS DOUGLAS FIR REGENERATION
< 7 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: DUD

Iter	B	C	Sum of Squares
18	41.317214	1.268034	0.025854
19	41.310399	1.268774	0.025854
20	41.310219	1.268771	0.025854

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	9.5769626516	4.7884813258
Residual	24	0.0258537064	0.0010772378
Uncorrected Total	26	9.6028163580	
(Corrected Total)	25	2.0793046652	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	41.31021899	0.79764622137	39.663971359	42.956466622
C	1.26877103	0.05443416758	1.156425337	1.381116728

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.291256682
C	-0.291256682	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS DOUGLAS FIR REGENERATION
between 7-12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: DUD

Iter	B	C	Sum of Squares
18	42.102585	1.222377	0.045402
19	42.102018	1.222478	0.045402
20	42.100078	1.222543	0.045402
21	42.100796	1.222540	0.045402
22	42.100867	1.222554	0.045402

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	12.612776932	6.306388466
Residual	33	0.045402080	0.001375821
Uncorrected Total	35	12.658179012	
(Corrected Total)	34	3.286397707	

Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	42.10086669	0.92195037835	40.225156670	43.976576712
C	1.22255372	0.05122013810	1.118346243	1.326761205

Asymptotic Correlation Matrix

Corr	B	C
B	1	-0.38630673
C	-0.38630673	1

THE FITTED WEIBULL FOR HEIGHT OF EXCESS DOUGLAS FIR REGENERATION
> 12 yrsince disturbance

Non-Linear Least Squares Iterative Phase
Dependent Variable CUMPER
Method: DUD

Iter	B	C	Sum of Squares
18	43.474946	1.162770	0.004981
19	43.474745	1.162775	0.004981

NOTE: Convergence criterion met.

Non-Linear Least Squares Summary Statistics
Dependent Variable CUMPER

Source	DF	Sum of Squares	Mean Square
Regression	2	2.2363388769	1.1181694385
Residual	9	0.0049805675	0.0005533964
Uncorrected Total	11	2.2413194444	
(Corrected Total)	10	0.4790965208	

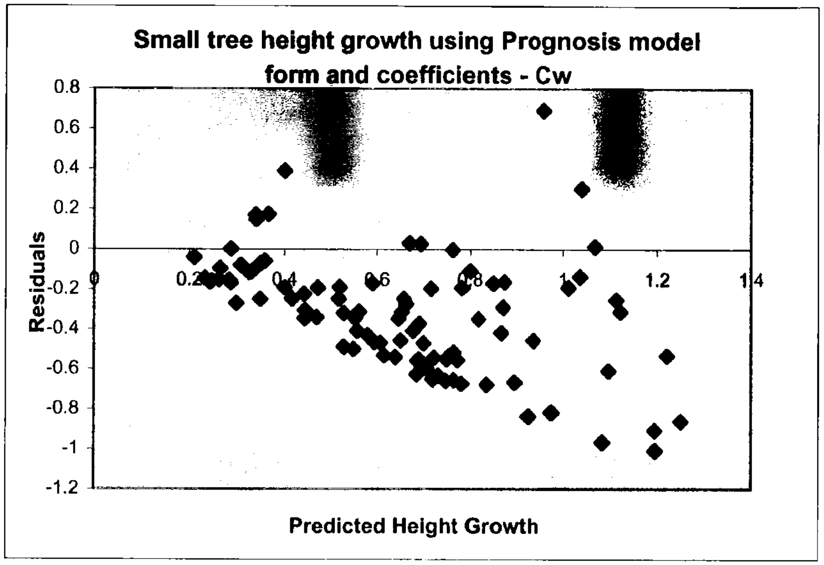
Parameter	Estimate	Asymptotic Std. Error	Asymptotic 95 % Confidence Interval Lower	Upper
B	43.47474542	1.1439103974	40.887018306	46.062472539
C	1.16277508	0.0679519973	1.009055675	1.316494486

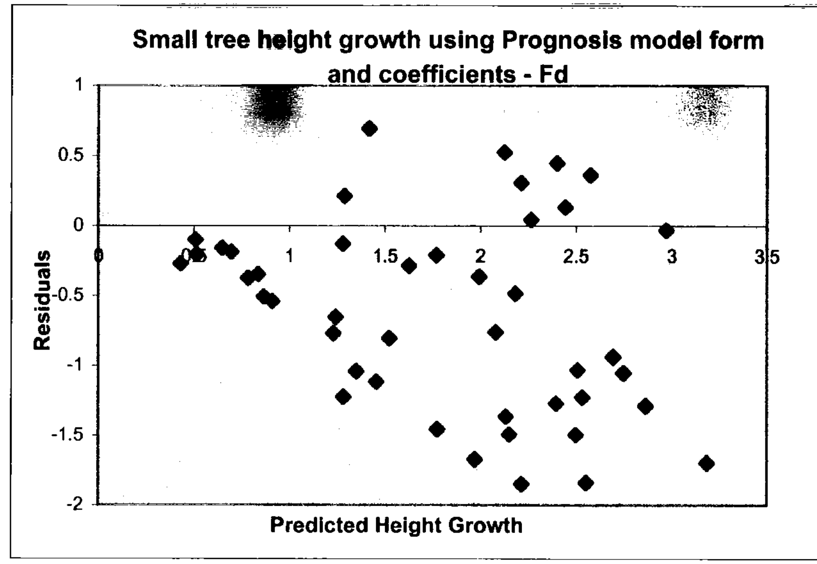
Asymptotic Correlation Matrix

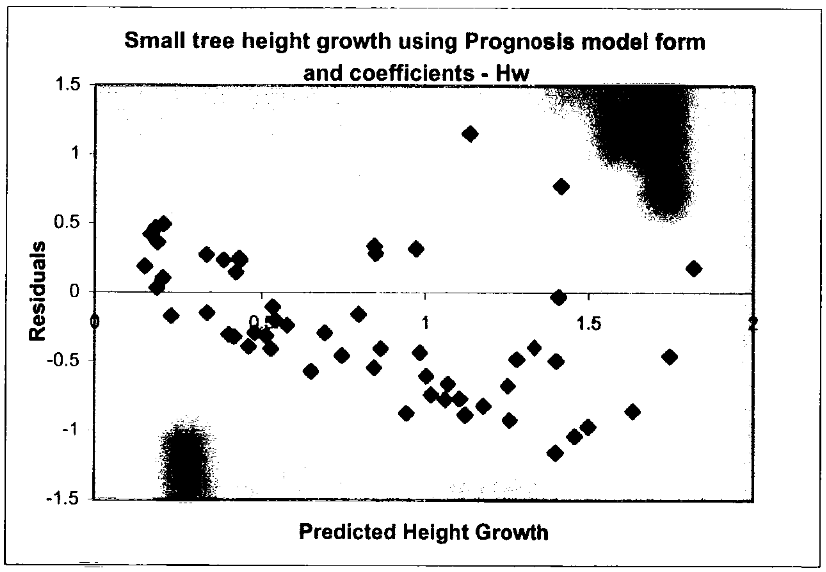
Corr	B	C
B	1	-0.613699694
C	-0.613699694	1

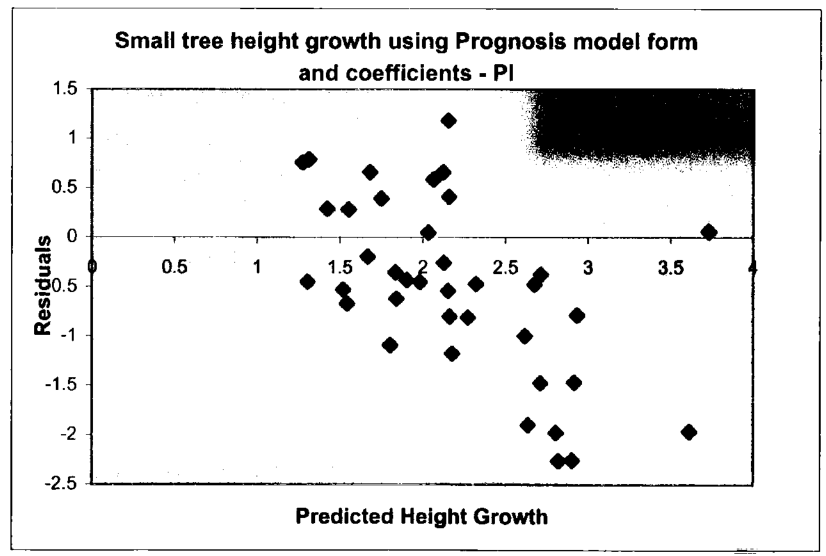
APPENDIX 11: Small tree height growth.

Plotted residuals of small tree height growth predictions with Prognosis models and re-fitted Prognosis for Cw, Fd, Hw, Pl, tolerant, intermediate tolerance and intolerant species.

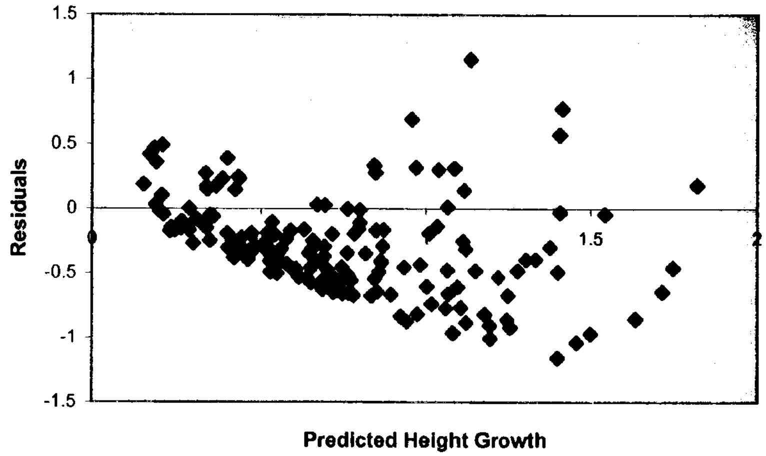

Small tree height growth using Prognosis model form and coefficients - Cw
Residuals
Predicted Height Growth


Small tree height growth using Prognosis model form and coefficients - Fd
Residuals
Predicted Height Growth

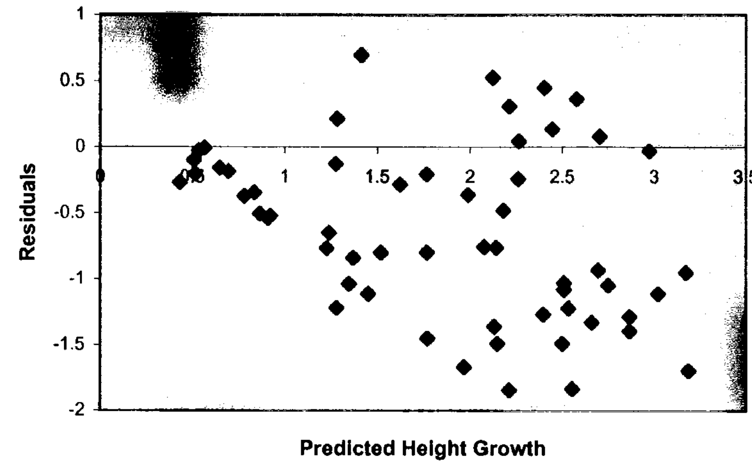

Small tree height growth using Prognosis model form and coefficients - Hw
Residuals
Predicted Height Growth


Small tree height growth using Prognosis model form and coefficients - Pl
Residuals
Predicted Height Growth

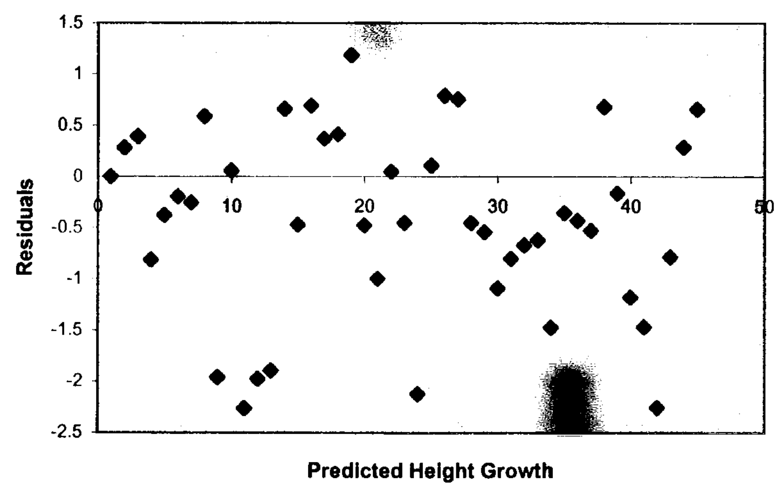
Small tree height growth using Prognosis model form and coefficients - Tolerant species

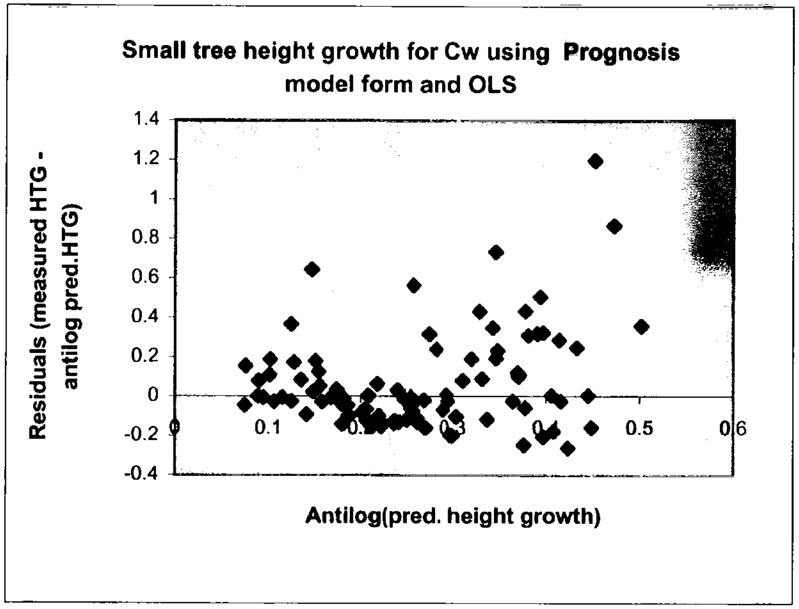


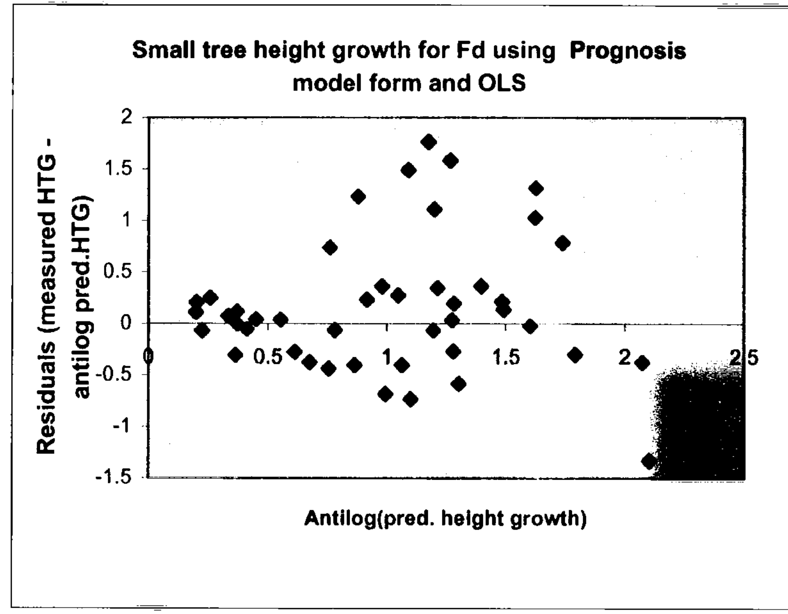
Small tree height growth using Prognosis model form and coefficients - Intermediate tolerance species

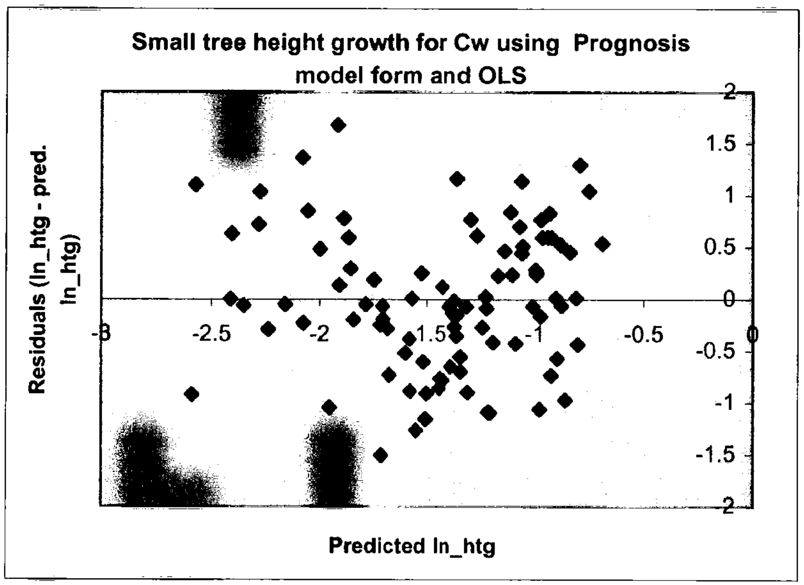


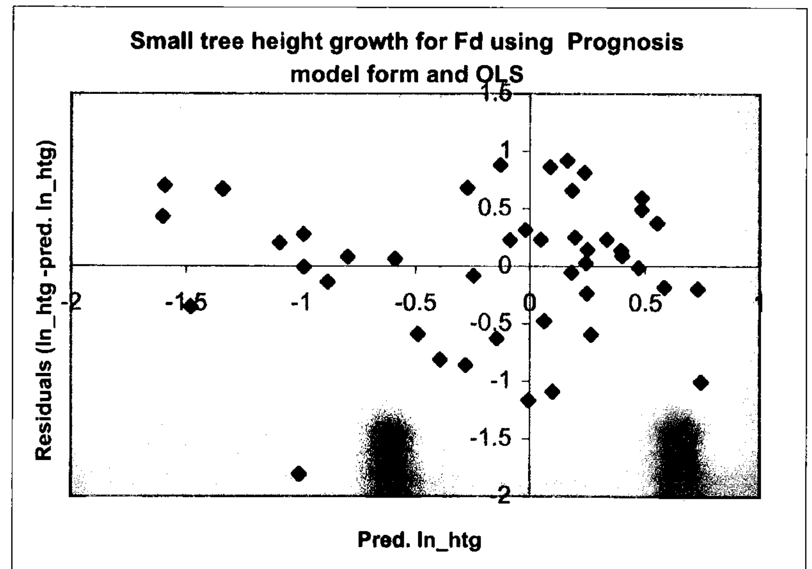
Small tree height growth using Prognosis model form and coefficients - Intolerant species

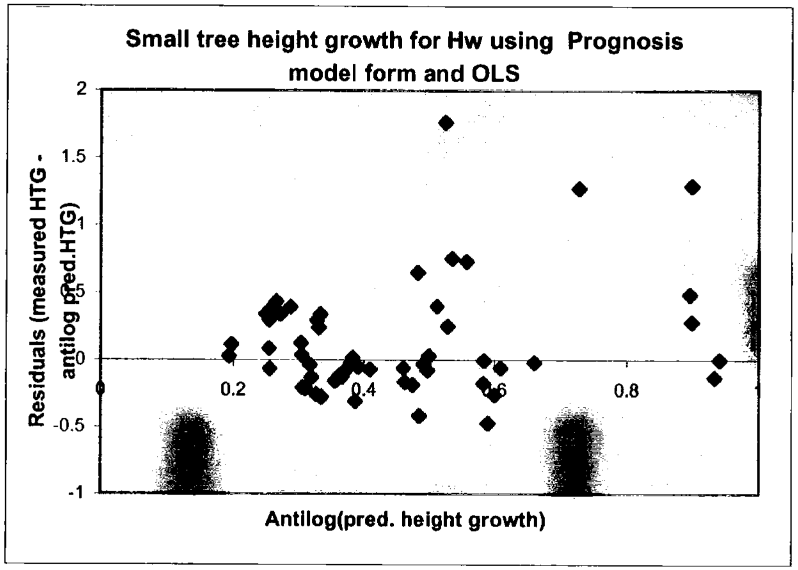


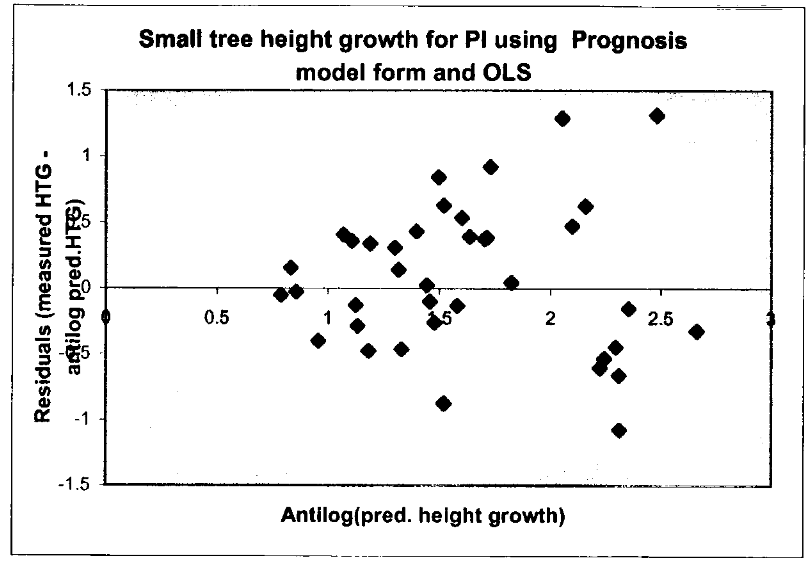

Small tree height growth for Cw using Prognosis model form and OLS
Residuals (measured HTG - antilog pred.HTG)
Antilog(pred. height growth)

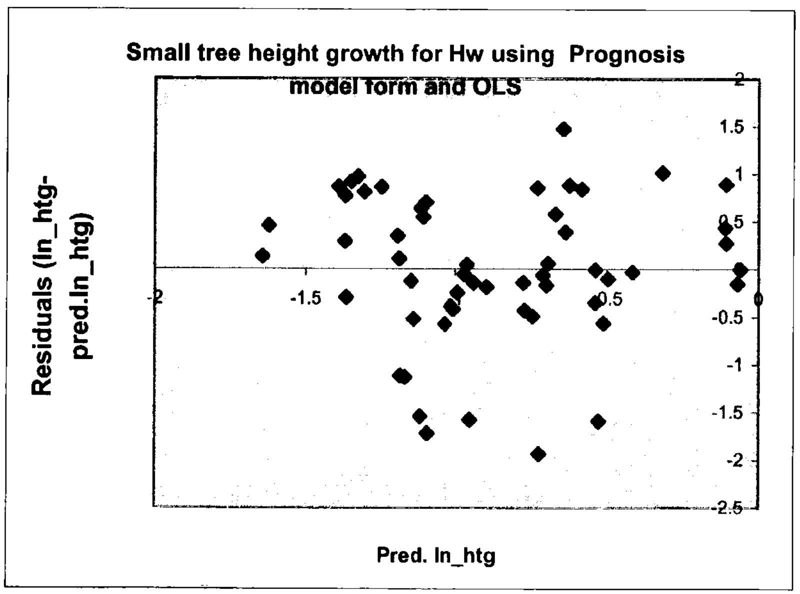

Small tree height growth for Fd using Prognosis model form and OLS
Residuals (measured HTG - antilog pred.HTG)
Antilog(pred. height growth)

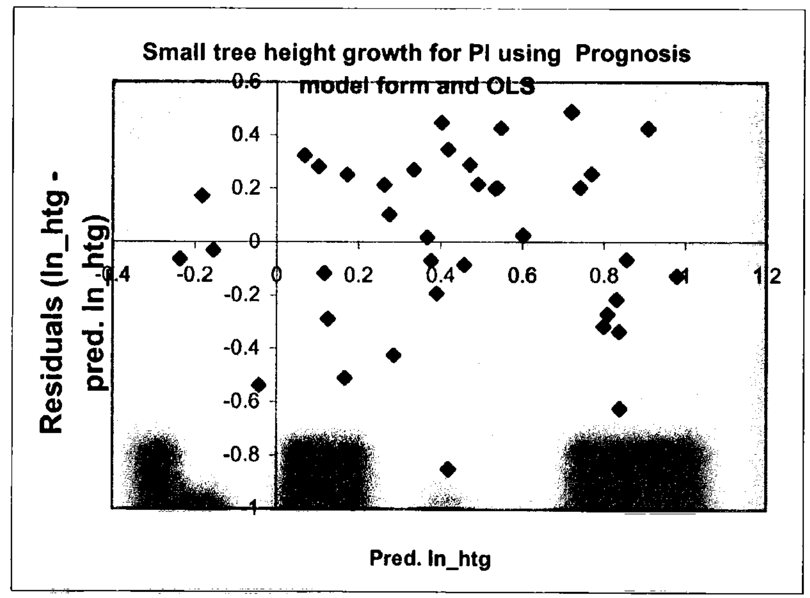

Small tree height growth for Cw using Prognosis model form and OLS
Residuals (ln_htg - pred. ln_htg)
Predicted ln_htg

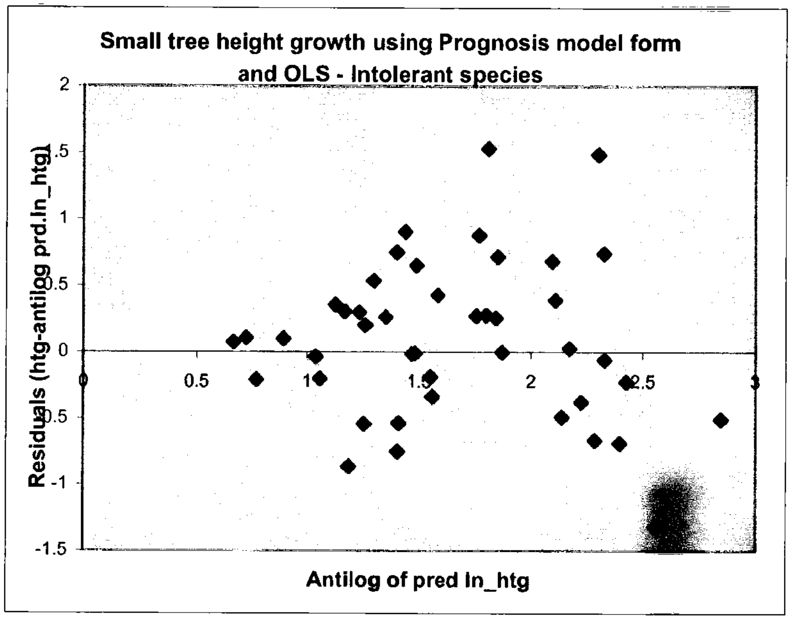

Small tree height growth for Fd using Prognosis model form and OLS
Residuals (ln_htg -pred. ln_htg)
Pred. ln_htg

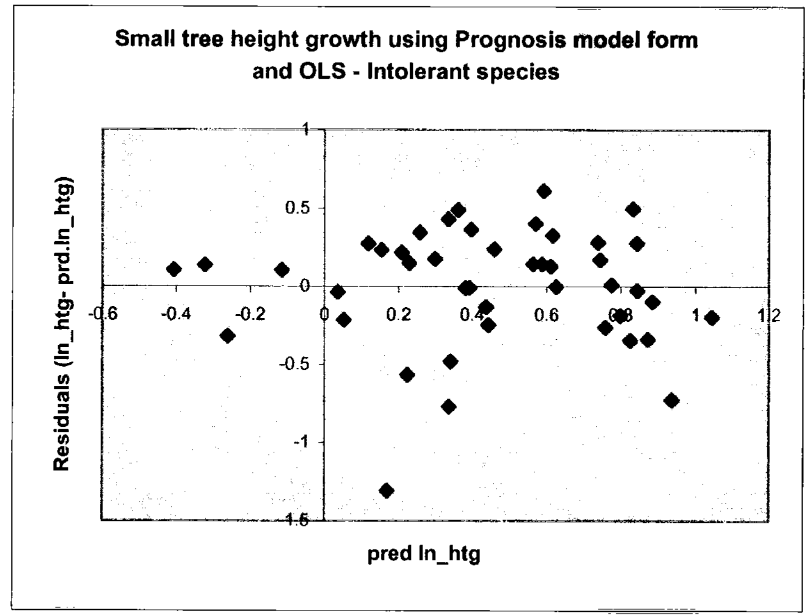

Small tree height growth for Hw using Prognosis model form and OLS
Residuals (measured HTG - antilog pred.HTG)
Antilog(pred. height growth)


Small tree height growth for Pl using Prognosis model form and OLS
Residuals (measured HTG - antilog pred.HTG)
Antilog(pred. height growth)


Small tree height growth for Hw using Prognosis model form and OLS
Residuals (ln_htg-pred.ln_htg)
Pred. ln_htg

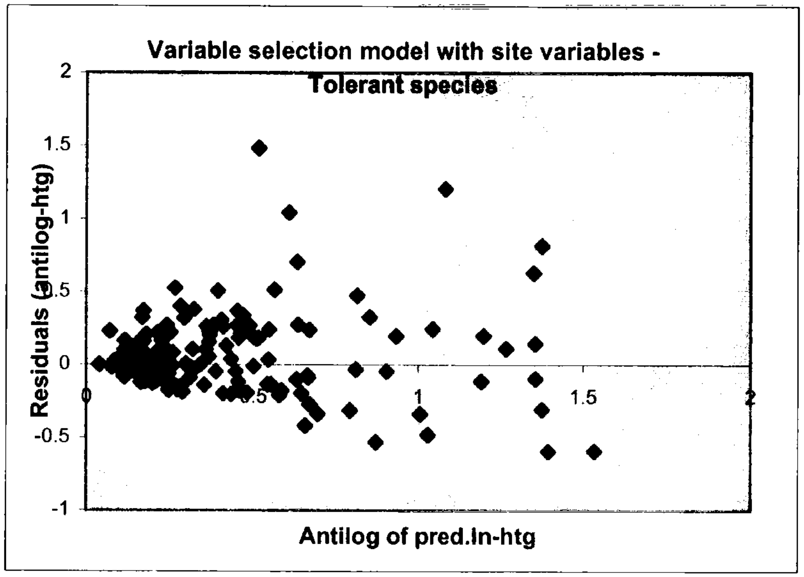

Small tree height growth for Pl using Prognosis model form and OLS
Residuals (ln_htg - pred. ln_htg)
Pred. ln_htg

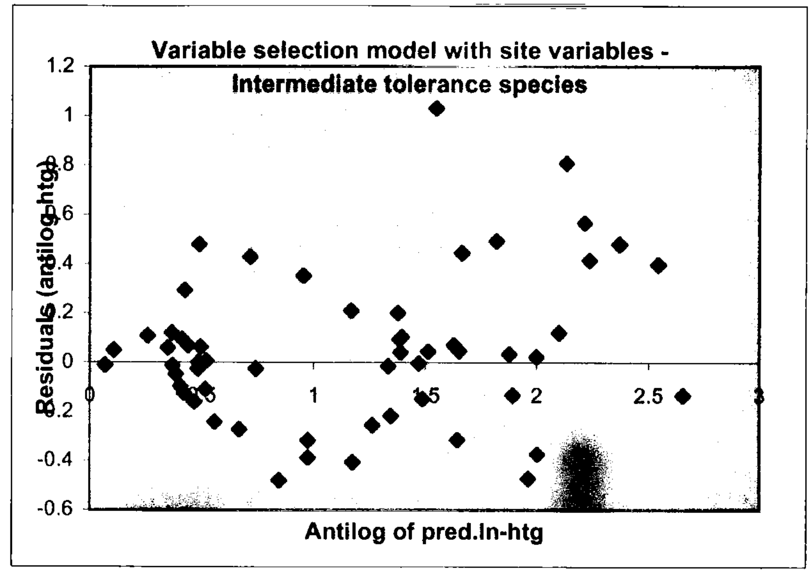

Small tree height growth using Prognosis model form
and OLS - Intolerant species
Residuals (htg-antilog prd.ln_htg)
Antilog of pred ln_htg
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
0.5
1
1.5
2
2.5
3

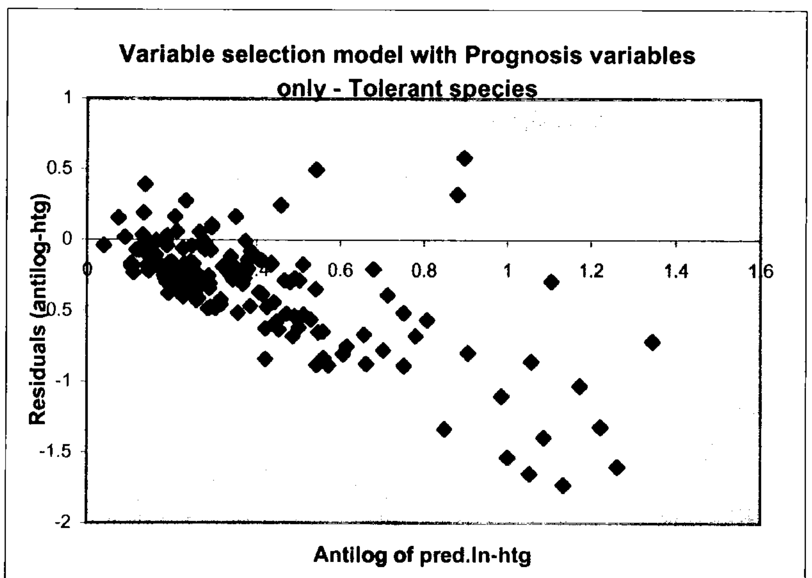

Small tree height growth using Prognosis model form
and OLS - Intolerant species
Residuals (ln_htg- prd.ln_htg)
pred ln_htg
1
0.5
0
-0.5
-1
-1.5
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2

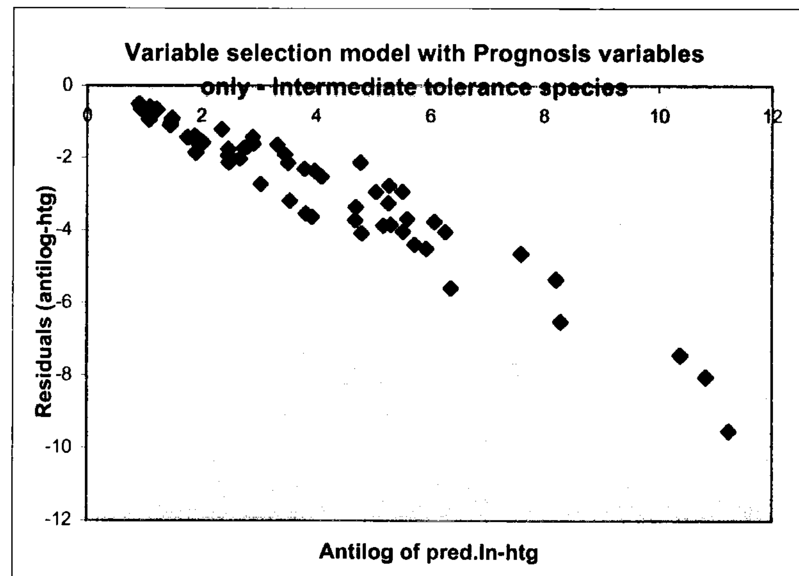
APPENDIX12: Small tree height growth.

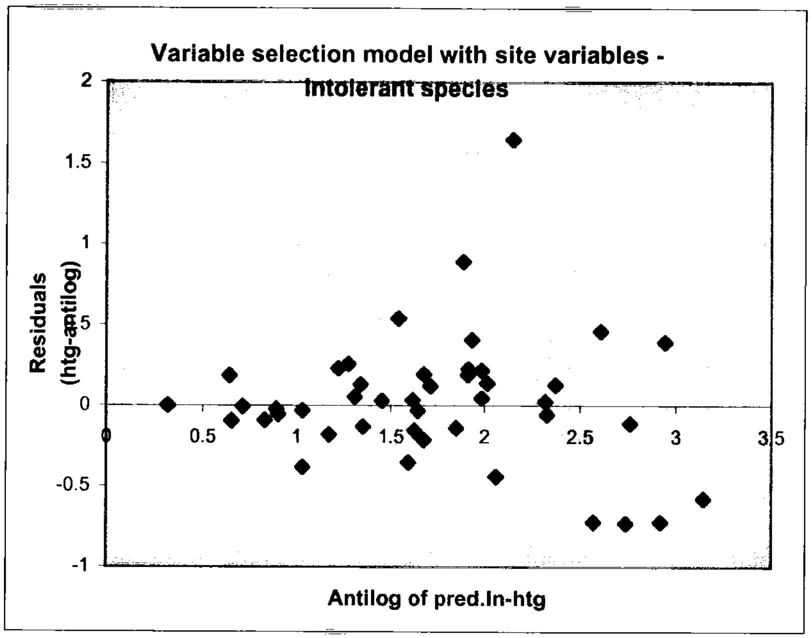
Plotted residuals of small tree height growth predictions with variable selection model with Prognosis variables and a variable selection model with all site variables for tolerant, intermediate tolerance and intolerant species.

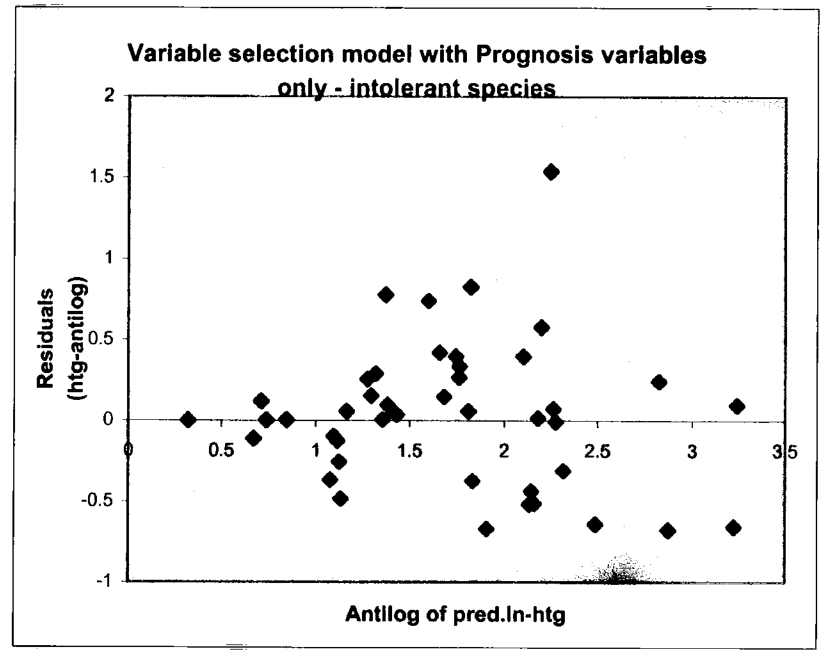

Variable selection model with site variables - Tolerant species
Residuals (antilog-htg)
Antilog of pred.ln-htg


Variable selection model with site variables - Intermediate tolerance species
Residuals (antilog-htg)
Antilog of pred.ln-htg


Variable selection model with Prognosis variables only - Tolerant species
Residuals (antilog-htg)
Antilog of pred.ln-htg


Variable selection model with Prognosis variables only - Intermediate tolerance species
Residuals (antilog-htg)
Antilog of pred.ln-htg


Variable selection model with site variables - intolerant species
Residuals (htg-antilog)
2
1.5
1
0.5
0
-0.5
-1
0
0.5
1
1.5
2
2.5
3
3.5
Antilog of pred.ln-htg


Variable selection model with Prognosis variables only - intolerant species
Residuals (htg-antilog)
2
1.5
1
0.5
0
-0.5
-1
0
0.5
1
1.5
2
2.5
3
3.5
Antilog of pred.ln-htg

APPENDIX13: Small tree height growth.

Variable selection model coefficients - Prognosis variables and
variable selection model - all site variables
for tolerant, intermediate tolerance and intolerant species.

Variable selection model with all site variables - Tolerant species
Modeling HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	15	18.60068924	1.24004595	15.80	0.0001
Error	149	11.69744197	0.07850632		
Total	164	30.29813121			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.44317286	0.15726266	0.62344722	7.94	0.0055
--- Group species ---			2.54266336	8.10	0.0001
DSPP1	-0.23583109	0.05060999	1.70464619	21.71	0.0001
DSPP2	-0.36180086	0.28845568	0.12350531	1.57	0.2117
DSPP3	0.14466014	0.10730530	0.14267899	1.82	0.1797
DSPP4	-0.14823176	0.12555825	0.10941998	1.39	0.2397

1 Backward Stepwise for Tolerant Species 14

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
--- Group habitat ---			0.30872017	3.93	0.0492
HT	-0.22474372	0.11333326	0.30872017	3.93	0.0492
--- Group GROUP4 ---			0.51073224	6.51	0.0118
LN_HT	1.01112226	0.39642346	0.51073224	6.51	0.0118
--- Group GROUP5 ---			2.77119062	35.30	0.0001
AGE	-0.00713129	0.00120029	2.77119062	35.30	0.0001
--- Group GROUP6 ---			1.15532136	14.72	0.0002
TIME	0.01797960	0.00468685	1.15532136	14.72	0.0002
--- Group GROUP7 ---			1.13803866	3.62	0.0075
DSS1	0.19343954	0.07490207	0.52360947	6.67	0.0108
DSS2	0.04322140	0.06646103	0.03320230	0.42	0.5165
DSS3	0.22638630	0.07895598	0.64540882	8.22	0.0047
DSS4	0.17493912	0.14729011	0.11074684	1.41	0.2368
--- Group GROUP10 ---			0.22805713	2.90	0.0904
SLOPE	-0.00247728	0.00145347	0.22805713	2.90	0.0904
--- Group GROUP11 ---			0.41953938	5.34	0.0222
CCF	-0.00082212	0.00035563	0.41953938	5.34	0.0222
--- Group GROUP13 ---			0.24995585	3.18	0.0764
COS_ASP	-0.06433110	0.03605302	0.24995585	3.18	0.0764

Bounds on condition number: 34.11123, 1312.197

Variable selection model with all site variables - Tolerant species
Modeling LN_HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	13	83.71682036	6.43975541	19.10	0.0001
Error	151	50.90591004	0.33712523		
Total	164	134.62273040			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-0.87978530	0.33167005	2.37209536	7.04	0.0088
--- Group species ---			11.42628782	8.47	0.0001
DSPP1	-0.50563599	0.10556448	7.73448895	22.94	0.0001
DSPP2	-1.75518262	0.59325103	2.95092982	8.75	0.0036
DSPP3	0.08144774	0.22294099	0.04499554	0.13	0.7154
DSPP4	-0.22975183	0.26059109	0.26205359	0.78	0.3794
--- Group GROUP4 ---			4.03807023	11.98	0.0007
LN_HT	0.55194065	0.15947811	4.03807023	11.98	0.0007
--- Group GROUP5 ---			19.71768292	58.49	0.0001
AGE	-0.01893099	0.00247538	19.71768292	58.49	0.0001
--- Group GROUP7 ---			2.93151804	2.17	0.0746
DSS1	0.26973139	0.14869182	1.10937933	3.29	0.0717
DSS2	-0.04798240	0.13293651	0.04392044	0.13	0.7186
DSS3	0.17810079	0.16825065	0.37775430	1.12	0.2915
DSS4	0.31079860	0.30586136	0.34809687	1.03	0.3112
--- Group GROUP9 ---			2.56840665	7.62	0.0065
ELEV	0.00063021	0.00022832	2.56840665	7.62	0.0065
--- Group GROUP10 ---			1.17381274	3.48	0.0640
SLOPE	-0.00558708	0.00299420	1.17381274	3.48	0.0640
--- Group GROUP11 ---			4.78496249	14.19	0.0002
CCF	-0.00259448	0.00068866	4.78496249	14.19	0.0002

Bounds on condition number: 2.116104, 248.2139

Variable selection model with all site variables - Intermediate tolerance species
Modeling HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	8	31.25666022	3.90708253	27.53	0.0001
Error	48	6.81211171	0.14191899		
Total	56	38.06877193			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.98695554	0.34727490	1.14627521	8.08	0.0066
--- Group SS	---		5.09174076	35.88	0.0001
DBH	0.25042464	0.04180846	5.09174076	35.88	0.0001
--- Group GROUP4	---		5.27019589	37.14	0.0001
AGE	-0.02551579	0.00418713	5.27019589	37.14	0.0001
--- Group GROUP5	---		1.86678185	13.15	0.0007
TIME	0.04017022	0.01107587	1.86678185	13.15	0.0007
--- Group GROUP7	---		0.82778392	5.83	0.0196
ASPECT	0.00172422	0.00071393	0.82778392	5.83	0.0196
--- Group GROUP8	---		0.52915161	3.73	0.0594
ELEV	-0.00061782	0.00031996	0.52915161	3.73	0.0594
--- Group GROUP10	---		1.09453891	7.71	0.0078
CCF	-0.00373666	0.00134551	1.09453891	7.71	0.0078
--- Group GROUP12	---		0.74751000	5.27	0.0261
COS_ASP	-0.21442623	0.09343072	0.74751000	5.27	0.0261
--- Group GROUP13	---		2.22696871	15.69	0.0002
SIN_ASP	0.43962869	0.11098115	2.22696871	15.69	0.0002

Bounds on condition number: 2.654024, 125.9203

Variable selection model with all site variables - Intermediate tolerance species
Modeling LN_HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	4	34.83643889	8.70910972	94.97	0.0001
Error	52	4.76874034	0.09170655		
Total	56	39.60517923			

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Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-0.13123160	0.17989405	0.04880267	0.53	0.4690
--- Group SS	---		2.96908792	32.38	0.0001
DBH	0.18776255	0.03299876	2.96908792	32.38	0.0001
--- Group GROUP4	---		10.38624157	113.26	0.0001
AGE	-0.03505818	0.00329428	10.38624157	113.26	0.0001
--- Group GROUP5	---		1.21731331	13.27	0.0006
TIME	0.02797917	0.00767952	1.21731331	13.27	0.0006
--- Group GROUP10	---		0.63439567	6.92	0.0112
CCF	-0.00246065	0.00093556	0.63439567	6.92	0.0112

Bounds on condition number: 1.985681, 26.3926

All groups of variables left in the model are significant at the 0.1000 level.

Variable selection model with all site variables - Intolerant species
Modeling HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	9	19.35824567	2.15091619	12.59	0.0001
Error	34	5.80832706	0.17083315		
Total	43	25.16657273			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.38089954	0.57502769	0.07495758	0.44	0.5122
--- Group SS	---		1.00392500	5.88	0.0208
DBH	0.33873165	0.13973050	1.00392500	5.88	0.0208
--- Group GROUP4	---		4.55668902	26.67	0.0001
AGE	-0.21017828	0.04069576	4.55668902	26.67	0.0001
--- Group GROUP6	---		2.53345413	4.94	0.0059
DSS1	1.38320486	0.50012321	1.30674591	7.65	0.0091
DSS2	0.38448324	0.51349010	0.09577735	0.56	0.4591
DSS3	1.73300022	0.52328164	1.87369280	10.97	0.0022
--- Group GROUP12	---		1.35768820	7.95	0.0080
COS_ASP	0.52003491	0.18446694	1.35768820	7.95	0.0080
--- Group GROUP13	---		1.64404380	9.62	0.0039
SIN_ASP	-0.86216444	0.27791980	1.64404380	9.62	0.0039
--- Group GROUP15	---		0.58645348	3.43	0.0726
LN_HT	0.92824856	0.50099521	0.58645348	3.43	0.0726
--- Group GROUP18	---		1.77237557	10.37	0.0028
X2	3.06539897	0.95168934	1.77237557	10.37	0.0028

Bounds on condition number: 14.90758, 668.9444

Variable selection model with all site variables - Intolerant species
Modeling LN_HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	8	9.77437367	1.22179671	26.43	0.0001
Error	35	1.61804663	0.04622990		
Total	43	11.39242030			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-0.90183165	0.29634964	0.42811962	9.26	0.0044
--- Group SS	---		4.15996521	89.98	0.0001
DBH	0.37623725	0.03966235	4.15996521	89.98	0.0001
--- Group GROUP4	---		2.07666337	44.92	0.0001
AGE	-0.14145291	0.02110524	2.07666337	44.92	0.0001
--- Group GROUP6	---		3.81217034	27.49	0.0001
DSS1	1.56306314	0.25808768	1.69567063	36.68	0.0001
DSS2	0.60739253	0.25011979	0.27262506	5.90	0.0204
DSS3	1.82103700	0.26504719	2.18229840	47.21	0.0001
--- Group GROUP12	---		1.49277715	32.29	0.0001
COS_ASP	0.42212749	0.07428611	1.49277715	32.29	0.0001
--- Group GROUP13	---		1.11799444	24.18	0.0001
SIN_ASP	-0.62980452	0.12807001	1.11799444	24.18	0.0001
--- Group GROUP18	---		1.00624924	21.77	0.0001
X2	2.20144225	0.47186309	1.00624924	21.77	0.0001

Bounds on condition number: 14.67023, 433.2799

Variable selection model with Prognosis variables - Tolerant species
Modeling HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	14	15.21247124	1.08660509	10.80	0.0001
Error	150	15.08565997	0.10057107		
Total	164	30.29813121			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.48931299	0.18998840	0.66710220	6.63	0.0110
--- Group GROUP1 ---			4.20051617	10.44	0.0001
DSPP1	-0.29161705	0.05714829	2.61873986	26.04	0.0001
DSPP2	-0.21574697	0.32468687	0.04440512	0.44	0.5074
DSPP3	0.20101460	0.12192923	0.27334590	2.72	0.1013
DSPP4	-0.23190879	0.14197537	0.26833754	2.67	0.1045
--- Group GROUP2 ---			0.42137032	4.19	0.0424
DBH	-0.06213966	0.03035802	0.42137032	4.19	0.0424
--- Group GROUP4 ---			0.51715427	5.14	0.0248
LN_HT	0.33757114	0.14886472	0.51715427	5.14	0.0248
--- Group GROUP5 ---			1.09409169	2.72	0.0318
DSS1	0.11763950	0.08362759	0.19901243	1.98	0.1616
DSS2	-0.08151644	0.07342050	0.12397348	1.23	0.2687
DSS3	0.04474881	0.09653874	0.02160891	0.21	0.6437
DSS4	0.19070253	0.16733219	0.13062520	1.30	0.2562
--- Group GROUP6 ---			0.43274135	4.30	0.0398
ASPECT	-0.00081223	0.00039156	0.43274135	4.30	0.0398
--- Group GROUP7 ---			0.70953869	7.06	0.0088
ELEV	0.00033765	0.00012712	0.70953869	7.06	0.0088
--- Group GROUP9 ---			2.71829932	27.03	0.0001
CCF	-0.00182153	0.00035037	2.71829932	27.03	0.0001
--- Group GROUP12 ---			0.98135537	9.76	0.0021
SIN_ASP	-0.17236977	0.05518035	0.98135537	9.76	0.0021

Small Tree Height, backwards selection: Tolerant 117
Variables have no references to age or time since dist.
Bounds on condition number: 3.754861, 390.1864

Variable selection model with Prognosis site variables - Tolerant species
Modeling LN_HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	13	66.08447746	5.08342134	11.20	0.0001
Error	151	68.53825294	0.45389571		
Total	164	134.62273040			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-1.31978771	0.38900350	5.22465020	11.51	0.0009
--- Group GROUP1 ---			16.59734109	9.14	0.0001
DSPP1	-0.60995136	0.12149354	11.44037123	25.20	0.0001
DSPP2	-1.84504796	0.68871313	3.25757695	7.18	0.0082
DSPP3	0.14909354	0.25857165	0.15090787	0.33	0.5651
DSPP4	-0.36777761	0.30199096	0.67319171	1.48	0.2252
--- Group GROUP2 ---			2.08534002	4.59	0.0337
DBH	-0.13674998	0.06379944	2.08534002	4.59	0.0337
--- Group GROUP4 ---			2.38543345	5.26	0.0233
LN_HT	0.71745617	0.31296067	2.38543345	5.26	0.0233
--- Group GROUP5 ---			4.65099777	2.56	0.0408
DSS1	0.31604633	0.17340564	1.50775630	3.32	0.0703
DSS2	-0.10002795	0.15518600	0.18857917	0.42	0.5202
DSS3	0.09646725	0.19597878	0.10997595	0.24	0.6233
DSS4	0.36633856	0.35552335	0.48193126	1.06	0.3045
--- Group GROUP7 ---			4.94456251	10.89	0.0012
ELEV	0.00086801	0.00026299	4.94456251	10.89	0.0012
--- Group GROUP8 ---			2.12471801	4.68	0.0321
SLOPE	-0.00750462	0.00346862	2.12471801	4.68	0.0321

Small Tree Height, backwards selection: Tolerant 28
Variables have no references to age or time since dist.
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--- Group GROUP9 ---			15.87653508	34.98	0.0001
CCF	-0.00442613	0.00074838	15.87653508	34.98	0.0001

Bounds on condition number: 3.677111, 301.0468

---All groups of variables left in the model are significant at the 0.1000 level.

Variable selection model with Prognosis variables - Intolerant species
Modeling HGT

Step 5 Group GROUP6 Removed R-square = 0.70434851 C(p) = 8.16091000

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	11	17.72603810	1.61145801	6.93	0.0001
Error	32	7.44053463	0.23251671		
Total	43	25.16657273			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.03015539	0.62865700	0.00053500	0.00	0.9620
--- Group GROUP2 ---			1.66817894	7.17	0.0116
DBH	0.18856264	0.07039818	1.66817894	7.17	0.0116
--- Group GROUP4 ---			3.22897482	4.63	0.0085
DSS1	1.52054405	0.63604997	1.32883087	5.71	0.0229
DSS2	0.33070177	0.54849129	0.08452550	0.36	0.5508
DSS3	1.87097320	0.67341472	1.79483315	7.72	0.0091
--- Group GROUP5 ---			1.39263880	5.99	0.0201
ASPECT	0.00299450	0.00122358	1.39263880	5.99	0.0201
--- Group GROUP7 ---			2.95700108	12.72	0.0012
SLOPE	-0.03243013	0.00909390	2.95700108	12.72	0.0012
--- Group GROUP8 ---			0.71361366	3.07	0.0894
CCF	-0.01828354	0.01043652	0.71361366	3.07	0.0894
--- Group GROUP10 ---			2.07259965	8.91	0.0054
COS_ASP	0.61104093	0.20466316	2.07259965	8.91	0.0054
--- Group GROUP11 ---			1.23030349	5.29	0.0281
SIN_ASP	-0.69323667	0.30137171	1.23030349	5.29	0.0281
--- Group GROUP14 ---			0.87645977	3.77	0.0610
BALM_100	0.39927960	0.20565450	0.87645977	3.77	0.0610

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
--- Group GROUP16 ---			2.06117154	8.86	0.0055
X2	3.57720679	1.20147312	2.06117154	8.86	0.0055

Bounds on condition number: 17.71551, 923.1904

Variable selection model with Prognosis variables - Intolerant species
Modeling LN_HGT

Step 5 Group GROUP3 Removed R-square = 0.78962540 C(p) = 11.00702246

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	11	8.99574447	0.81779495	10.92	0.0001
Error	32	2.39667584	0.07489612		
Total	43	11.39242030			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	-1.38801455	0.35679301	1.13348216	15.13	0.0005
--- Group GROUP2 ---			1.05941355	14.15	0.0007
DBH	0.15026821	0.03995434	1.05941355	14.15	0.0007
--- Group GROUP4 ---			2.26112753	10.06	0.0001
DSS1	1.75671712	0.36098887	1.77368038	23.68	0.0001
DSS2	0.87223468	0.31129512	0.58800550	7.85	0.0086
DSS3	1.91847220	0.38219516	1.88712198	25.20	0.0001
--- Group GROUP5 ---			0.30695507	4.10	0.0513
ASPECT	0.00140586	0.00069444	0.30695507	4.10	0.0513
--- Group GROUP7 ---			1.22509174	16.36	0.0003
SLOPE	-0.02087407	0.00516122	1.22509174	16.36	0.0003
--- Group GROUP8 ---			0.49164161	6.56	0.0153
CCF	-0.01517585	0.00592323	0.49164161	6.56	0.0153
--- Group GROUP10 ---			0.88669116	11.84	0.0016
COS_ASP	0.39966745	0.11615616	0.88669116	11.84	0.0016
--- Group GROUP11 ---			0.45288213	6.05	0.0195
SIN_ASP	-0.42059876	0.17104290	0.45288213	6.05	0.0195
--- Group GROUP14 ---			0.62305744	8.32	0.0070
BALM_100	0.33664733	0.11671879	0.62305744	8.32	0.0070

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
--- Group GROUP16 ---			0.75431119	10.07	0.0033
X2	2.16402490	0.68189364	0.75431119	10.07	0.0033

Bounds on condition number: 17.71551, 923.1904

All groups of variables left in the model are significant at the 0.1000 level.

Variable selection model with Prognosis variables - Intermediate tolerance species
Modeling HGT

Step12 Group GROUP9 Removed R-square = 0.60062676 C(p) = 3.27690355

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	6	22.86512328	3.81085388	12.53	0.0001
Error	50	15.20364865	0.30407297		
Total	56	38.06877193			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	1.02015973	0.30233375	3.46211032	11.39	0.0014
--- Group GROUP1 ---			0.98653489	3.24	0.0777
DSPP1	-0.31739339	0.17621001	0.98653489	3.24	0.0777
--- Group GROUP2 ---			2.70492058	8.90	0.0044
DBH	0.18789299	0.06299734	2.70492058	8.90	0.0044
--- Group GROUP5 ---			2.88017091	9.47	0.0034
ASPECT	0.00268758	0.00087325	2.88017091	9.47	0.0034
--- Group GROUP8 ---			14.30966626	47.06	0.0001

Small Tree Height, backwards selection: Intermediate 93
Variables have no references to age or time since dist.
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Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
CCF	-0.01057233	0.00154115	14.30966626	47.06	0.0001
--- Group GROUP11 ---			2.12742383	7.00	0.0109
SIN_ASP	0.80665037	0.30496306	2.12742383	7.00	0.0109
--- Group GROUP16 ---			1.00674301	3.31	0.0748
X2	-1.24460864	0.68400994	1.00674301	3.31	0.0748

Bounds on condition number: 6.508663, 111.4099

All groups of variables left in the model are significant at the 0.1000 level.

Variable selection model with Prognosis variables - Intermediate tolerance species
Modeling LN_HGT

	DF	Sum of Squares	Mean Square	F	Prob>F
Regression	12	27.82041167	2.31836764	8.66	0.0001
Error	44	11.78476755	0.26783563		
Total	56	39.60517923			

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
INTERCEP	0.25460486	0.34378475	0.14690227	0.55	0.4629
--- Group GROUP1 ---			1.05646330	3.94	0.0533
DSPP1	-0.36275047	0.18264801	1.05646330	3.94	0.0533
--- Group GROUP2 ---			1.87901400	7.02	0.0112
DBH	0.17876088	0.06749034	1.87901400	7.02	0.0112
--- Group GROUP4 ---			2.83652843	3.53	0.0223
DSS1	0.12714051	0.29062920	0.05125754	0.19	0.6639

LN(Small Tree Height), backwards selection: Intermediate 102
Variables have no references to age or time since dist.
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Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	Prob>F
DSS2	-0.01788959	0.25604555	0.00130748	0.00	0.9446
DSS3	-0.84562969	0.37689490	1.34830535	5.03	0.0299
--- Group GROUP5 ---			1.22218214	4.56	0.0383
ASPECT	0.00187267	0.00087665	1.22218214	4.56	0.0383
--- Group GROUP7 ---			1.12780277	4.21	0.0461
SLOPE	-0.01308234	0.00637534	1.12780277	4.21	0.0461
--- Group GROUP8 ---			7.10282648	26.52	0.0001
CCF	-0.00869862	0.00168915	7.10282648	26.52	0.0001
--- Group GROUP10 ---			0.87335605	3.26	0.0778
COS_ASP	-0.34118884	0.18894410	0.87335605	3.26	0.0778
--- Group GROUP11 ---			2.67810295	10.00	0.0028
SIN_ASP	1.05691710	0.33424234	2.67810295	10.00	0.0028
--- Group GROUP15 ---			1.40948029	5.26	0.0266
X1	1.69003518	0.73671653	1.40948029	5.26	0.0266
--- Group GROUP16 ---			1.60025919	5.97	0.0186
X2	-2.01303785	0.82355185	1.60025919	5.97	0.0186

Bounds on condition number: 10.57997, 597.0228

All groups of variables left in the model are significant at the 0.1000 level.