Development of Regeneration Imputation

Models for the ICHmw2 in the Vicinity of Nelson

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Executive Summary

Forests are dynamic systems and are seldom in equilibrium. This is due, in part, to anthropogenic disturbances such as harvesting. Understanding the dynamics of complex stands has become a management priority and is the subject of a number of studies in northwestern North America. Understanding regeneration patterns in these stands is crucial, since future stands are determined by the way the regeneration is managed. The objective of this work is to explore and test the applicability of using imputation techniques rather than more traditional regression techniques for predicting regeneration in the complex mixed-species stands prevalent in the ICHmw2 subzone variant in the vicinity of of Nelson, BC (Interior Cedar-Hemlock moist warm variant 2). Two approaches were used: tabular imputation and Most Similar Neighbour (MSN) imputation.

This report describes the sampling regime employed to collect regeneration and small tree data in the ICHmw2. The regeneration data collected during the 2000 field season and that collected during the 1998 field season are summarized. A series of tabular imputation and MSN imputation approaches are developed and their performances in predicting the regeneration are compared. The tabular approach depicted average regeneration by five site groups, two residual density classes, five years-since-disturbance classes, species, and height class. The MSN approach made use of regeneration data of some plots (called reference plots) and a complete coverage of selected easy-to measure attributes for the entire data set (called reference and target plots) for its development. MSN imputation provided regeneration for the assumed missing regeneration data (target plots) by choosing a most similar plot from the reference plots to act as its surrogate. The most similar plot selection was based on a similarity measure that took into consideration the multivariate relationships between the two different sets of data.

The full MSN imputation model (four height classes) was the best predictor for regeneration. Stand density indicators (basal area (BA), number of residual trees per hectare (TPH), and crown coefficient factor (CCF)) were the driving variables in the most similar neighbour selection process. When the number of match categories and the root mean square error (RMSE) were used as comparison criteria, about 97.5% of the target plots imputations were classified as being moderate to good. Perfect matches with high precision corresponded to those plots that had high number of cells with no regeneration (zero). However, the use of the number of matched categories and the ratio of the RMSE to the observed regeneration of target plots provided better results by decreasing the number of unsatisfactory predictions from 2.4% to 0.3%. The mismatch of BA, TPH, CCF, and seemingly, the presence/absence of advance regeneration were considered as a major cause of poor predictions.

A sensitivity analysis showed that Prognosis^{BC} was mostly insensitive to regeneration predictions from both imputation models during the first 50 years of the projection. However, regeneration estimates were generally quite good. Also, with longer periods of simulation, it is likely that the model would be more sensitive, particularly to tabular predictions.

As Prognosis^{BC} grows stands based on the interaction among trees, the user can provide data either by randomly selecting a single plot from those having the same variables, or by using the means from the table that has the desired characteristics. As more data become available, these tables can be easily updated and the reliability of tables based on small sample size can be improved. There were not a lot of obvious trends apparent in the tabulated data. This may be due to the dominance of advance regeneration among the regeneration present. Advance regeneration would be more affected by the conditions that existed prior to the most recent disturbance than the conditions that exist today. Designing a sampling that separates advance from subsequent regeneration will without doubt improve the results.

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1. Introduction

Forests are dynamic systems and are seldom in equilibrium (Mitchell 1980). This is due to natural disturbances, anthropogenic disturbances, or a combination of these disturbance types. The current stand structure and species composition are the direct result of such disturbances and continue to be strongly influenced by them. Young vegetation is extremely dynamic (Ek *et al*. 1997); however, future stand is determined by the way the regeneration is managed.

Smith and others (1996) stressed the importance of regeneration by the following statement: "physicians can bury their worst mistakes, but those of foresters can occupy the landscape in public view for decades". By mistakes, they refer to failures of silvicultural treatments applied during stand establishment. Such treatments are often imitations of natural processes involved in stand development (Smith *et al*. 1996).

Understanding the dynamics of complex stands has recently become a management priority in northwestern North America and is the subject of a number of studies. Complex stands are created by minor disturbances and occur as mosaics of small single-cohorts, regularly distributed throughout the stand (Oliver and Larson 1996). Partial cutting is assumed to mimic small-scale natural disturbances and has created many multi-cohort stands in western conifer forests. Most successful silvicultural activities in these forests is conducted where site factors are restrictive enough that species composition can be kept under control (Smith *et al*. 1996) or focused towards only the most valuable commercial species, which tend to be relatively shade intolerant conifers.

An understanding of regeneration patterns in complex stands is lacking, in part, because of the emphasis in recent decades on pure single-species stands (Oliver and Larson 1996; Smith *et al*. 1996). Less is known about complex stands because of the complexity of their structures and species composition, and the fact that they rarely have uniform regeneration patterns (Oliver and Larson 1996).

The time scales involved in forest dynamics greatly exceed human life spans. Modelling is a means to overcome this problem. Several models have been developed to predict the course of secondary succession following different silvicultural treatments or natural disturbances in complex stands; however, few of them have been dedicated to predicting the consequences of timber harvest on the establishment of regeneration. Ek and his colleagues (1997) speculated that imprecision in estimating post-harvest conditions has prevented the widespread development of regeneration models.

Boisvenue (1999) calibrated the regeneration establishment component of the Prognosis^{BC} model for Interior Cedar Hemlock moist warm zone variant (ICHmw2) stands following partial cutting. Her results were inconclusive; accurate prediction of regeneration proved difficult in a range of situations. Model calibration and testing exercise suffered from a shortage of representative data.

Shortage of data has often been a constraint in forest ecosystem or forest stand modelling (e.g., Guldin and Lorimer 1985; Favrichon 1998). The high cost and time required to collect detailed data limit the size of sample that is feasible.

Imputation techniques have shown several potential advantages over classical estimation methods in different studies (e.g., Moeur and Stage 1995; Moeur *et al*. 1995; Ek *et al*. 1997; Haara *et al*. 1997; Van Deusen 1997; Maltamo and Kangas 1998; Moeur 2000, Moeur and Hershey 1998; Temesgen and LeMay 2000b,). It is hoped that this approach will make better use of limited data to predict regeneration.

The purpose of this study was to test imputation techniques for predicting regeneration in the complex mixed-species stands prevalent in the ICHmw2 subzone variant in the vicinity of Nelson, BC, and to display tabular results that can be readily accessible to users. The data collected by Boisvenue (1999) was used, augmented by additional data collected in the 2000 field season. Boisvenue's data was collected primarily from partially cut stands, with a wide-range of retention levels. The 2000 data were collected from "open" stands (i.e., <20 % crown closure), since these conditions were not well represented in her data.

The specific objective of this research was (i) explore the applicability of using imputation techniques to predict regeneration rather than more traditional regression techniques and (ii) to present the results of the selected models. The remainder of this report is divided into three major sections. Section 2 provides some background on the study area and details of some forestry applications of imputation techniques. Section 3 describes the methods used to collect the 1998 and 2000 field data, and the analytical methods employed. Section 4 summarizes the data collected and presents the partial results from the tabular imputation and most similar neighbour techniques. Section 5 contains a brief summary of the report. The literature cited is presented in Section 6, and tables showing the average regeneration by species and height class are given in the Appendices.

2. Background

2.1. The Columbia-Shuswap Moist Warm Variant of the Interior Cedar-Hemlock Zone (ICHmw2)

The Interior Cedar-Hemlock (ICH) Zone is one of the largest biogeoclimatic zones in the Nelson Forest Region and occurs at lower to middle elevations. It has the greatest tree species diversity of all the zones in British Columbia (BC) (Braumandl and Curran 1992) and is considered to be the most productive zone in the interior of BC. The zone extends south into eastern Washington, Idaho, and western Montana (Ketcheson *et al*. 1991). ICHmw2 is the largest subzone variant in the ICH zone in the Nelson Forest Region, and occurs at elevations ranging from 500 to 1450 m in the northern part of its range, and from 1200 to 1450 m in the southern part. These forests have an interior continental climate, characterized by cool wet winters and warm dry summers. The zone is one of the wettest in the interior of BC (Ketcheson *et al*. 1991). Morainal soils, with loamy or silty surface textures, occur throughout the ICH.

The vegetation of the ICHmw2 is composed of complex (mixed-species, multi-cohort) stands, where western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and western redcedar (*Thuja plicata* Donn) constitute the climax trees species. Other trees species present are given in Table 1 (Ketcheson *et al*. 1991; Braumandl and Curran 1992). Along with this complex mixture of tree species, ICHmw2 often includes substantial and diversified shrubs, herbs, mosses and lichens.

Table 1. Local and scientific names, and species codes for trees found in ICHmw2.

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

Most mixed-species stands are the result of natural regeneration (Burkhart and Tham 1992), and the ICHmw2 stands are no exception. These complex stands resulted from sporadic forest disturbances in the past. Fire, and other natural disturbances such as windthrow, insects, disease, slides, and avalanches constitute the most common disturbance agents (Anonymous 1998; Boisvenue 1999). An increase in partial cutting in recent years has made such multi-cohort mixed stands more common (Smith *et al*. 1996). Pest outbreaks are increasingly apparent in ICH (Boisvenue 1999). The main pests are: laminated root rot (*Phellinus weirii*), armillaria root rot (*Armillaria ostoyae*), white pine blister rust (*Cronartium ribicola*), spruce beetle (*Dendroctonus rufipennis*), dwarf mistletoe (*Aceuthobium americanum*), dwarf larch mistletoe (*Arceuthobium laricis*), spruce leader weevil (*Pissodes terminalis*), hemlock sawfly (*Neodiprion tsugae*), and Douglas-fir beetle (*Dendroctonus pseudotsugae*).

[1] Tree species codes follow the British Columbia Ministry of Forests, Inventory Branch Standards.

2.2 Imputation Methods

Imputation involves replacing missing (i.e., not sampled) measurements for any unit in the population with measurements from another unit with similar characteristics (Ek *et al*. 1997; Rubin 1987; Van Deusen 1997). In forestry, imputation techniques have been used for forest inventory (Moeur and Stage 1995), modelling (Rubin 1987), regeneration prediction (Ek *et al*. 1997), and is currently being explored for use in growth and yield modelling (Temesgen and LeMay 2000b).

Predicted post-harvest stand conditions, expressed as a tree list, can be determined directly from a database (Ek *et al*., 1997). Unlike the information provided by classic sampling and estimation techniques, such as stratified sampling or regression, imputation methods:

1) provide a mixture of spatial and temporal information on regeneration attributes considered important in combination. This allows complex relationships to be maintained. Ek *et al* (1997) ascribed this to the similar variance-covariance matrix of the population and the samples;
2) are often not vulnerable to violation of a random sampling assumptions. The advantage is important since it allows the use of any form of data; and
3) are flexible and easy updated. As new ground-based inventory data become available, they can be added to the database and used thereafter.

Imputation methods include tabular imputation, nearest neighbour, most similar neighbour, k-nearest neighbour, and geo-statistical estimation.

Tabular Imputation

A tabular imputation model was developed to estimate post-harvest stand characteristics by Ek *et al*. (1997). A simple tabular analysis of forest inventory plot data that showed tree and stand attributes by forest cover type was used. The output tables generated were used as input regeneration to growth models and were projected further into the future. This approach can be used to relate growth and yield model inputs to aerial attributes as well (Temesgen and LeMay 2000a).

Nearest Neighbour Method (NN)

The coarsest imputation approach (known as random imputation) is where a reference unit is picked randomly from the inventoried units to replace a target unit. Moeur (2000) used auxiliary variables to refine and filter the selection. The selection of the reference unit was based on the minimum Euclidean distance, computed on the entire set of chosen auxiliary variables. Moeur's application assumed that the post-harvest conditions of the reference stand represented the post-harvest conditions of the target stand.

Most Similar Neighbour Method (MSN)

As well as the auxiliary variables used in the NN method, MSN takes also into account inventory variables and the relationship among them to guide the selection of the appropriate reference stand. The most similar unit is selected based on different distance measures on the auxiliary variables weighted by the importance of the inventory variables (correlation coefficient between the auxiliary and inventory variables). Moeur and Stage (1995) used a squared difference function, whereas Moeur (2000) chose the Euclidean distance. The more accurate imputed estimates obtained by Moeur (2000) resulted from weighting the Euclidean distance using canonical correlation coefficients. Reasonable imputation results were obtained at a 20% threshold of sampled stands under normal sampling conditions (no under-sampled conditions) (Moeur 2000; Temesgen and LeMay 2000b).

Moeur and Hershey (1998) compared three MSN techniques that assessed the value of including location information to estimate forest species composition:

1) developed from the inventory and low resolution data excluding location information ("spatially naive MSN");
2) "partially spatially informed MSN", where the geographic coordinates of the sample plot and grid cell locations were added to the variables used in the previous MSN; and
3) "fully spatially informed MSN", where a spatial variogram function was added to the previous MSN.

The selection of the most similar neighbour (sample plot) was based upon its satellite signature (Landsat TM spectral bands and band transformations). Imputation results obtained by the three MSN methods were similar, even though the "partially spatially informed MSN" produced the closest match.

Temesgen and LeMay (2000a) pointed out that non-response Vegetation Resources Inventory (VRI) samples could be replaced using MSN. Non-response VRI samples occur when: (i) the access to private land is denied, (ii) access route problems are present, or (iii) it is dangerous to sample at a given location

K-Nearest Neighbour (K-NN)

Unlike MSN, where measured reference stand attributes were used to find the nearest neighbour, the K-NN method uses the weighted average of the attributes of a chosen number of reference units to compute target unit estimates (Haara et *al*. 1997). Thus, post-harvest stand characteristics of a target stand (or plot) can be predicted with a weighted average of the attributes of the K-NN reference stands (or plots). Haara *et al.* (1997) found that the results and the accuracy obtained by K-NN method were similar to those obtained by conventional (parametric) methods.

According to Maltamo and Kangas (1998), the K-NN method requires three decisions to be made before its application: (1) identify the distance function type to be used to find the most similar reference units, (2) determine the number of nearest neighbours to be used, and (3) specify the weighting function form for the reference units. Maltamo and Kangas (1998) tested the performance of three different methods of K-NN for predicting the diameter distribution of a target stand. The methods studied were: (1) Weibull distributions of k-nearest neighbours, (2) distributions of k-nearest neighbours smoothed with the kernel method, and (3) empirical distributions of the k-nearest neighbours. The latter approach provided the most accurate prediction, but the first two approaches performed quite well also.

Geostatistical Estimation (GS)

This approach may be used to estimate the distribution of tree species across the landscape. Estimation is based on the observed spatial distribution of the tree species, without taking into account their relationships with other species or other covariates such as lower tree layers. Thus, predictions developed by GS preserve only the spatial structure inherent in the sample data used.

To interpolate species distribution maps from sampled to unsampled stands, Moeur and Hershey (1998) used sequential Gaussian conditional simulation (sgCS) combined separately with indicator Kriging (IK) and sequential indicator conditional simulation (siCS). The process used for each combination had two-steps. The first consisted of estimating species occurrence using a Boolean or IK techniques, and the second estimated species percent by basal area per acre using sgCS. They assumed that broad-scale species variation could be adequately represented; however, accurate fine-scale species distribution cannot be expected when using only sample plot data. Thus, the accuracy of the data source, reference forest cover maps in this case, limited the reliability of the estimates (interpolated forest cover maps).

3. Methods

3.1 Sampling Procedures Used in 1998

Data were first collected in the summer of 1998 in ICHmw2 stands in the vicinity of Nelson, BC that were partially disturbed in the last 30 years. More details of the sampling design and plot measurement procedures are given in Boisvenue (1999).

Boisvenue (1999) attributed the poor performance of the re-calibrated Prognosis regeneration equations, in part, to the sampling design and data collected. According to her, the plot distribution did not present the full range of site series and species mixtures, including under-representation of more open stands.

Based on Boisvenue’s (1999) recommendations, the sampling procedure used for the summer 2000 field season was modified slightly from that used in 1998. A brief description of the design used follows.

3.2 Sampling Procedures Used in 2000

Sampling covered the entire ICHmw2, irrespective of ownership. For budget constraints, the polygons chosen were limited to those less than a two-hour drive from the forest district offices. The sampling frame was comprised of polygons that were accessible, disturbed between five and 25 years ago, and that had residual crown closures less than 20 percent. From the total number of polygons identified, priority was given to those presenting different ranges of site preparation, regeneration methods, aspect, slope, elevation and the identified site series taken from the Ministry of Forests' silvicultural (ISIS) database. Polygons were selected and subsequently located using ISIS and inventory data bases, along with topographical maps of Arrow and Kootenay Lake Districts.

Once sites were selected, plots were established using systematic sampling with a random start. Plots were established at least 50 m from the roads or any other openings to avoid edge effects. The number of plots established on a selected polygon and the distance between plots depended on the size of the polygon and the degree of structure variability present. Sites with a high degree of structure variability were sampled more heavily than more homogenous sites. On most sites, a distance of 100 m was used between plots. At least two plots were established on all polygons.

For each plot established, the BEC site series was identified and recorded *in-situ*, along with other site factors. Site information recorded included: elevation, slope angle (percent), slope position, aspect (degrees), and site preparation whenever it was identifiable. Any other information deemed of importance was also recorded.

Trees on each plot were characterized as regeneration, small trees, or large trees. Regeneration was defined as being at least 15 and 30 cm tall for shade tolerant and shade intolerant species, respectively, and less than 2.0 cm dbh (diameter at breast height) (Ferguson *et al*. 1986; Ferguson and Carlson 1993). Small trees had a dbh between 2.0 and 7.5 cm, and large trees were greater than 7.5 cm dbh.

Concentric plots were used to sample the three tree types. Large trees were sampled with a 11.28 m radius (0.04 ha) plot. These trees were tallied to identify over-story species composition, to estimate retention level and residual basal area, and consequently to study the resultant impact of residual cover on regeneration establishment and growth. Dbh (diameter outside bark at 1.3 m above ground) and species were recorded for all tallied trees. If numbers of tree allowed, two trees were chosen randomly for each species present and their heights measured. Other relevant information, such as presence of scars, diseases, fire signs and any other physical deformation, was also recorded.

Small trees were sampled using a 3.99 m radius (0.005 ha) plot. For all small trees tallied, dbhs and heights were measured. Small trees were sub-sampled for total height and five-year height growth. Two trees of each determinant species, when more than two were present, were selected randomly and felled for measurement when whorls could not be confidently counted. For non-determinant species, all trees were felled and sectioned until the 5-year height increment was reached. The previous 5-years height growth was measured as of the end of the previous growing season to ensure that all trees sampled reflected the same growing period.

Regeneration was sampled using a 2.07 m radius (0.00135 ha) plot. All established and viable regeneration was counted and tallied into height classes. Classes used were: (1) 15 - 49.9 cm; (2) 50 - 99.9 cm; (3) 100 - 129.9 cm; and (4) >130 cm. Trees greater than 2 cm dbh, tallied also as small trees, were noted to avoid double counting on plot summaries. Regeneration was sub-sampled for height and total age for some of the "best trees" on each plot. The criteria for "best trees" following Ferguson and Carlson (1993) were: (1) the two tallest trees, regardless of species, (2) the one tallest tree of each additional species present, and (3) the tallest of the remaining trees until at least four were sampled. If only one species was present on the plot, height and total age measurements on the four tallest trees were taken. According to Wellner (1940), often more trees occupy a stocking plot than will survive to rotation and best trees are more likely to survive than others. Non-determinant species were destructively sub-sampled for total age and height; for determinant species, these measurements were made on standing trees whenever possible. Tree condition, such as any evidence of damage, disease, or insects, was noted as well.

To provide information about stocking probability, four regeneration satellite plots were established at 11.28 m from the central plot, along cardinal directions. Within each satellite regeneration plot, regeneration was tallied by species and height class. Also, whether regeneration was advance or subsequent to the most recent disturbance was estimated.

When the regeneration center plot was not stocked, one of the four regeneration satellite plots was selected randomly and used for "best tree" sampling. Plot layout is illustrated in Figure 1.

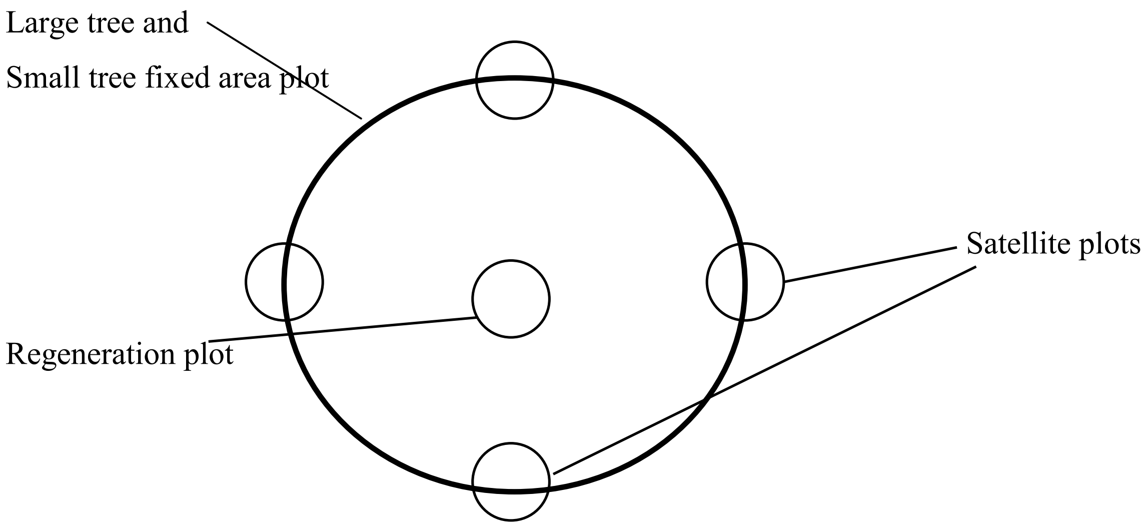

Figure 1. Plot layout for sampling large tree, small tree and regeneration sub-populations.

3.3 Analyses Procedures

3.3.1 Data Preparation and Summary

The data collected during the two field seasons were entered into Excel spreadsheets, separated into plot information, large tree, small tree, and regeneration components. The files were manipulated to provide various data summary tables. For further summaries and analyses, the data were transferred to SAS files (Statistical Analysis Systems Institute (SAS), version 6.12).

For the imputation analysis, most of the 1998 data collected by Boisvenue (1999) were combined with the 2000 data. The plots retained were those that were disturbed (clear-cut or partially cut) and harvested between 5 and 25 years ago.

A preliminary analysis to determine correlation between the amount of regeneration and the variables considered in this study was accomplished using generalized linear model with the SAS software. Owing to low representation of some categorical variables, certain variables were combined into larger classes. As regeneration is a count variable, the Poisson distribution was selected as the response probability distribution and "log" as the link function. A significance level of 5% was chosen as the acceptable level of significance for testing the parameters included to the model.

To prevent the possibility of zero error degrees of freedom the number of dependent variables in the MSN analysis was limited. The 15 species present in this study were classified into three shade tolerant species groups plus a hardwood group, based on the recommendation by Temesgen and LeMay (2000b) to generate tree lists by species group or species guild rather than individual tree species to obtain possibly better estimates. The Hardwood group included cottonwood, trembling aspen, white birch, Douglas maple, willow and yew[1]; the shade intolerant species were lodgepole pine and larch; the shade tolerant species group was composed of grand-fir, subalpine-fir, western redcedar, hemlock, and spruce; and the shade semi-tolerant species group included Douglas-fir and white pine. Plot information attributes were the same for all the analyses.

3.3.2 Tabular Imputation Models

Tabular imputation results were obtained by simple averaging sample regeneration per ha values for stand site and overstory variables. Based on the results of the preliminary analysis and empirical knowledge, site series, time since disturbance and basal area were selected as the main factors that would affect regeneration establishment. Plot and individual tree information were used to create tables that displayed average stems per hectare of shade tolerant species groups by site class at some time following disturbance (harvesting) for different residual basal area categories. Site classes were determined by

[1] Although western yew is a coniferous species, it was placed together with the hardwood species because it is rare, not commercial, and because it can be used in the present version of Prognosis^{BC} to provide a species code for hardwood species, which otherwise are excluded from the model.

grouping similar site series. The years since last disturbance were divided into 5-year classes. Basal area per ha of 5 m^2/ha was chosen to divide the residual basal area (BA) into two categories, dividing the data approximately equally. Within each residual basal area category, plot aggregation was based on years-since-disturbance class interval and site class criteria. It was assumed that trees belonging to the same plot, block, and years-since-disturbance class had roughly the same stand history.

Initially, tables showing the average regeneration per hectare by site class and years-since-disturbance class for each residual basal area category were created. To examine patterns of species distribution, these tables were disaggregated by shade tolerant groups (and by species) and then into four height classes. For each cell in the regeneration tables, the standard error of the mean was calculated and used to study of the patterns of variability within and between all models. Following the protocol used by Ek and others (1997), means, standard deviations and coefficients of variation were used to test whether the initially heterogeneous regeneration became more stable at some time following the disturbance.

To test the stability of tabular model and make its performance comparable to that of MSN later, the full data set was randomly split into five subsets (20%). Each subset represented target plots and the remaining 80% of the plots served to construct the tables. These reduced tables used the same plots that correspond to those called "reference" plots of MSN runs. Each target plot was assigned to a specific table from which regeneration estimates were imputed. Plots were assigned to imputation tables based on the combination of the three stand characteristics used in the tabulation process (BA, site series, and year since disturbance classes). Initially, it was thought to use the table that had "Mesic" (Modal) site series class and similar BA and year-since-disturbance classes as the target plot when a table was based on less than 3 plots. However, this approach was abandoned because the bias values obtained from tabular approach were high and consistently negative, indicating that this approach led to overestimation of the regeneration. The densest stands occur on "Mesic" sites. It was subsequently decided to use the appropriate table provided it was based on at least one plot. For the target plots that mapped into tables that had no plot, the table of the closest stand conditions (in either direction- drier or wetter) was chosen for imputation.

3.3.3 The MSN Method

Data identical to that used for the tabular imputation models were summarized, formatted, and analyzed using SAS and MSN software provided by Moeur[2]. Three MSN analyses were conducted using different levels of categorical dependent variables involving: (1) four height classes (as defined earlier); (2) two height classes (0.15 to 1.30 m and > 1.3 m); and (3) no height classes.

[2] United States Department of Agriculture, Forest Service, Intermountain Research Station in Moscow, Idaho (1999).

MSN analysis takes place in three steps (Moeur 2000): (1) establish canonical correlations between the amount of regeneration by height class (Y set) and the full coverage of plot information level variables (X set) to calculate weights for the neighbour similarity function; (2) select the most similar sampled plot based on the plot level variables, weighted by correlations to the amount of regeneration, and assign its regeneration to the target plot; and (3) test the accuracy by comparing the imputed number of regeneration (predicted) to their observed values.

For each MSN type, five runs were performed to assess the reasonability and the stability of the approach. The overall sample was randomly split into five data sets (20%). In each run, one data set represented target plots and the remaining 80% of the plots represented reference plots. Reference plots were those plots assumed to have complete coverage of attributes. These included plot indicator attributes that were provided by Ministry of Forests' silviculture data base (ISIS), maps and stand records from the first-phase sample (history), plot information recorded on the field, and the corresponding ground data obtained during the second-phase sample (data collection). Target plots were excluded from the model development and reserved for testing the accuracy of the estimates. Only site and overstory variables were assumed to be available for target plots. The most similar neighbour for each target plot was selected from the reference plots, and the neighbour's regeneration conditions were imputed to the target plot.

The dependent variables (Y set) that were used in the MSN analysis were the amount of regeneration per hectare (SPH) by species group and four height classes, two height classes or no height classes. The independent variables (X set) that were used in this analysis were those that are commonly measured to describe the stands. They included: aspect (radians), elevation (m), slope (%), site series, years since disturbance, residual basal area per hectare (BA), number of residual trees per hectare (TPH), crown competition factor (CCF), site preparation (class value), and slope position (class value). Site preparation and slope position were each represented by a set of five dummy variables. BA and TPH were assumed known, since they can be measured on an existing stand, or predicted using Prognosis^{BC}. Ground inventory and plot information attributes retained for these analyses are listed in Table 2.

After substituting the values of the reference plot for the target plot, regeneration by species group with and without height classes of the target and the selected reference (most similar) plots were compared using bias (mean deviation), mean absolute deviation, and the precision (root mean square error- RMSE). Based on the three criteria, the best MSN type was further analyzed.

Table 2. Ground inventory and plot information attributes used in the MSN analyses.

Inventory Variables (Regeneration per ha)	Plot Information Attributes
MSN 1 (by four height classes):	*All Three Types of Analyses:*
Species group and height class (16 variables)	Number of years since disturbance
	Site series
MSN 2 by (two height classes):	Aspect (radians)
Species group and height class (8 variables)	Elevation (m)
	Slope (%)
MSN 3 (no height classes):	Residual trees per ha (TPH)
Species group (4 variables)	Residual basal area per ha (BA)
	Crown competition factor (CCF)
	Slope position: lower, level, middle, plateau, upper, and none
	Site preparation: none, burning (burn), Brushing (brush), brushing and burning (bbrush), and mechanical (mech)

The target and the most similar reference plots were compared using a combination of the number of matched categories and RMSE. For MSN 1, a good match was defined as exactly predicting the presence of at least 15 regeneration cells. A moderate match included all the plots that had between 8 and 14 agreements between the actual and the predicted regeneration cells. Finally, all the plots that showed less than 8 agreements were classified as poor matches. Within each match category, target plots were classified into low (<1000 stems/ha), medium (1000-2000), and high (>2000) RMSE. The same comparison was also performed using the combination of the number of matched categories and the ratio of the RMSE to the actual regeneration of each target plot. Within each match category, target plots were classified into low (<=0.20), medium (0.20-0.40), and high (>0.40) ratios. A graphical illustration of examples of important criteria combinations was also presented.

The plots that were deemed to be "good" matches, but had high RMSE were examined to detect specific characteristics responsible for producing high errors. Plots of relevant auxiliary variables versus the bias were used to identify the plots and the factors that could affect the MSN performance and produced highly biased results. All the plots that were outside the band limited by –1000 and +1000 stems/ha were considered as outliers and were further analyzed, along with the plots classified as "poor match and high RMSE". First, the auxiliary variables of all identified plots and their most similar neighbour were descriptively compared. Secondly, for the outlier plots, the average values of the continuous auxiliary variables and the number by category of the class variables of target plots and their most similar neighbour plots were also compared.

3.3.4 Comparison of the Two Approaches

The predictive capability of both methods was tested using the bias, the mean absolute deviation, and the RMSE. This comparison included also the combination of the criteria already defined: (1) the number of matched categories and RMSE, and (2) the number of matched categories and the ratio of the RMSE to the actual regeneration of each plot.

For tabular imputation, as was the case for MSN, residual plots of the most important independent variables versus the bias were used to identify the outlier target plots. The identified outlier plots, along with the plots that were poorly matched and had high RMSE, were further examined to detect possible factors that could have caused highly biased results and poor predictions. First, the characteristics of the imputation tables from which the regeneration was imputed were analyzed using standard deviations, standard errors, and coefficient of variations. Second, the individual auxiliary variables of the outlier plots were compared to the average values of the continuous auxiliary variables and the number by category of the class variables in the reference plots.

3.3.5 Sensitivity of Prognosis^{BC} to MSN and Tabular Regeneration Predictions

The Prognosis^{BC} model was evaluated to determine the sensitivity of its yield projections over 50 years to regeneration predictions from the developed MSN and tabular imputation models. Specifically, differences in 50-year volume yield projection for a target plot using its true regeneration and its estimated regeneration were determined.

The plots classified as "Good match-low RMSE", "moderate match-medium RMSE", and "poor match-high RMSE" represent the best, the medium, and the worst regeneration predictions, respectively. For each imputation approach, the sensitivity analysis was carried out on 16 randomly chosen target plots: four plots from each of the two first classes and eight plots from the third. This analysis used tree lists from the 16 target plots and their selected most similar neighbours, resulting in 32 simulations for each approach.

The input data used in the Prognosis^{BC} model simulations included tree list (small and large trees) for the target plots, the observed regeneration, and the plot information, particularly site series, the aspect, the slope, the elevation, and the year of disturbance. The runs were repeated using the imputed regeneration together with the other information for the target plots. All the trees that had dbhs between 2.0 and 7.5 cm within the 3.99 m small tree plot were considered as small trees when computing the tree lists. This ensured the avoidance of double counting of regeneration best trees as small trees. Yield differences and standard deviations of these differences were determined by imputation method and regeneration prediction category.

4. RESULTS

4.1 Summary of the Combined 1998 and 2000 Data

Seventeen plots were discarded from the 1998 sample data since they did not meet the required selection criteria. Two plots were cut more than 25 years ago and 15 plots were not disturbed at all. The remaining data comprised 333 plots and 138 blocks. Table 3 provides ranges of data for eight variables for the combined 1999 and 2000 data.

About the half of the plots were disturbed in the last 10 years and nearly 28% between 15 and 25 years ago. More than 54% of the plots occurred on warm exposures (S, SE, SW, W) and about 59% were found on slopes less than 30 percent. With the exception of elevations more than 1500 m, the plots covered the full range of elevation classes. Most plots (66%) were located on mid-slopes. Residual basal areas sampled ranged from 0 to 92 m^2/ha. A little more than the half of the plots (59%) had no site preparation; the remaining plots were subjected to four types of site preparation. Burning was the most frequently used treatment (about 25%).

4.2 Tabular Imputation Approach

4.2.1 The Tabular Imputation Models

The tabular imputation model used a data set made up of 333 plots from 138 blocks. The site series were combined into five site classes: (1) dry: site series 01 and 02; (2) slightly dry: site series 04; (3) modal: site series 01; (4) slightly wet: site series 05; and (5) wet: site series 06, 07 and 08. The years since last disturbance were classified into five-year years-since-disturbance classes and the residual basal area was stratified into two categories ($\leq$ 5.0 m^2 representing open stands and > 5.0 m^2 representing dense stands).

Tables 4 and 5 show the average regeneration per ha by years-since-disturbance class and site class for each residual basal area category. For both residual basal area categories, data existed for most of the site and years-since-disturbance classes. For the dense category, no plots were sampled in the wet site for years-since-disturbance classes 1 and 3 and regeneration was not found for the wet site series for years-since-disturbance class 2. For the open category, only the wet site series for the first years-since-disturbance class lacked sampled plots.

Table 3. Number of plots in the combined data set summarized by variable class.

Years Since Last Disturbance	No. Plots
2	15
3	17
4	8
5	16
6	23
7	22
8	8
9	19
10	36
11	32
12	21
13	14
14	8
15	2
16	7
17	13
18	20
19	11
20	4
21	12
23	8
24	6
25	11

Site Series	
02	0
03	114
04	88
01	54
05	54
06	7
07	13
08	3

Site Preparation Method	No. Plots
Brushing	22
Burning	88
Burning and Brushing	16
Mechanical	13
None	194

Elevation (100 m)	
7 - 8	34
8 – 9	25
9 – 1	33
10 – 11	56
11 – 12	52
12 – 13	45
13 – 14	58
14 – 15	27
15 – 16	3

Aspect	
E	57
Flat	6
N	36
NE	30
NW	22
S	57
SE	35
SW	59
W	31

Residual Basal Area (m^2/ha)	No. Plots
0	33
1 - 5	134
5 - 10	55
10 - 15	32
15 - 20	28
20 - 25	9
25 - 30	12
30 - 35	6
35 - 40	7
> 40	17

Slope Position	
Crest	7
Lower	30
Depression	11
Middle	220
Plateau	15
Toe	6
Top	4
Upper	28
Level	10
Blank	2

Slope Percent	
0 - 10	56
10 - 20	66
20 - 30	72
30 - 40	62
40 - 50	40
50 - 60	19
> 60	18

Table 4. Average regeneration per ha by years-since-disturbance class interval and site class for basal area class “Dense” (* indicates no plots).

Years Since Disturbance Class	Site Class				
	Dry	Slightly dry	Modal	Slightly Wet	Wet
1 (1 - 5)	13663	9389	5944	10933	*
2 (6 –10)	4969	16853	32568	6316	0
3 (11-15)	15253	20592	12482	1486	*
4 (16-20)	4458	6316	14024	10897	3220
5 (21-25)	5015	6439	7616	13077	6687

Table 5. Average regeneration per ha by years-since-disturbance class interval and site class for basal area class “Open” (* indicates no plots).

Years Since Disturbance Class	Site Class				
	Dry	Slightly dry	Modal	Slightly Wet	Wet
1 (1 - 5)	7430	9288	11145	1672	*
2 (6 –10)	4776	12956	5480	5052	2972
3 (11-15)	6538	4334	14365	2724	1486
4 (16-20)	6780	9659	2043	4235	2415
5 (21-25)	8173	1486	0	3344	2477

The most regeneration was found on the modal sites for both dense and open stands, but at different times after harvesting (Tables 4 and 5). Within each years-since-disturbance class for both types of stands, the amount of regeneration varied with site conditions. For dense stands, the most regeneration was found on dry, modal, slightly dry, modal and wet for years-since-disturbance classes 1, 2, 3, 4 and 5, respectively. Slightly dry, modal and slightly wet sites had the highest amount of regeneration over all.

Tables 6 to 15 present species composition and their frequencies by years-since-disturbance class for residual basal area categories and site classes. More than 15 species contributed to the regeneration (nine softwood and six hardwood species). Due to the high number of species, cottonwood, trembling aspen, white birch, Douglas maple, yew and willow were grouped into a hardwood species group. These species, with the exception of yew, are shade-intolerant and behave biologically and ecologically similarly.

Species composition for the dry sites is given in Tables 6 and 7. Dense stands were dominated by shade semi-tolerant and tolerant species during all years-since-disturbance intervals. Shade intolerant species (hardwood, western larch, and lodgepole pine) became prominent 5 years after harvesting and were present thereafter (Table 6). Shade intolerant species, especially hardwood, dominated the species composition for the first four years-since-disturbance classes in open stands (Table 7). Shade tolerant species, together with Douglas-fir, dominated dry and open stands 20 years after disturbance.

Table 6. Average regeneration per ha by species and years-since-disturbance class for basal area category "Dense" and "Dry" sites.

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	0	83	2146	3467	2023	206	1073	1321	1651	1692	13663
2 (6 –10)	0	279	1532	1300	0	0	232	279	93	1254	4969
3 (11-15)	481	0	981	7692	175	1005	2448	787	44	2142	15690
4 (16-20)	0	0	0	743	0	0	0	743	0	0	1486
5 (21-25)	186	0	0	2415	0	743	186	186	0	1300	5015

Table 7. Average regeneration per ha by species and years-since-disturbance class for basal area category "Open" and "Dry" sites.

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	0	1486	637	1592	106	425	743	106	531	1804	7430
2 (6 –10)	35	35	708	425	142	743	1769	106	0	814	4776
3 (11-15)	111	186	520	929	149	1152	483	223	2118	2043	6501
4 (16-20)	0	93	929	2415	0	0	1115	93	93	2043	6780
5 (21-25)	0	0	1486	2972	1486	1486	0	0	743	0	8173

In dense and slightly dry stands, western redcedar, western hemlock, and Douglas-fir constituted the bulk of the species for the first three years-since-disturbance intervals (Table 8). Douglas-fir, grand fir and subalpine fir were the major species components during the later two years-since-disturbance intervals. In open, slightly dry stands, shade intolerant species (hardwoods, lodgepole pine, and western larch) were the most prevalent for the first two years-since-disturbance intervals (Table 9). Douglas-fir was consistently present; it dominated the species composition in these stands for the last three years-since-disturbance class intervals.

Table 8. Average regeneration per ha by species and years-since-disturbance class for basal area category "Dense" and "Slightly Dry" sites.

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	1148	540	2634	1486	2094	338	203	675	0	270	9389
2 (6 –10)	101	169	2837	3816	7160	0	34	743	0	1993	16853
3 (11-15)	318	1274	5201	3609	1274	2654	0	3078	212	2972	20592
4 (16-20)	0	1858	372	3344	0	0	0	0	372	372	6316
5 (21-25)	1238	62	867	1672	495	0	0	1548	0	557	6439

Table 9. Average regeneration per ha by species and years-since-disturbance for basal area category "Open" and "Slightly Dry" sites.

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	0	0	1238	743	0	619	2601	0	0	4087	9288
2 (6 –10)	46	232	929	1579	1347	557	3761	46	604	3854	12956
3 (11-15)	0	0	0	2229	124	743	248	124	0	867	4334
4 (16-20)	372	0	0	5944	0	372	0	0	0	2972	9659
5 (21-25)	0	0	372	743	0	0	372	0	0	0	1486

The majority of regeneration in dense stands across all years-since-disturbance classes on modal sites was composed of western redcedar and western hemlock (Table 10). Hardwood species were relatively important by the third years-since-disturbance interval. In this class, Douglas-fir dominated the species composition; it was second behind western hemlock in the fourth years-since-disturbance interval. In open stands on modal sites, western larch, hardwood and Douglas-fir were the leading species during the first 10 years after harvesting (Table 11). Afterwards, tolerant species (especially western redcear and spruce) were dominant. They were accompanied by hardwood, Douglas-fir and lodgepole pine.

Table 10. Average regeneration per ha by species and years-since-disturbance class for basal area category "Dense" and "Modal" site series.

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	0	0	2972	372	2229	0	0	372	0	0	5944
2 (6 –10)	248	248	4334	1300	23838	62	1300	619	0	557	32506
3 (11-15)	0	2526	297	4012	743	149	0	892	892	2972	12482
4 (16-20)	186	557	2879	2972	4830	372	0	650	279	1300	14024
5 (21-25)	0	186	2229	372	2601	0	0	0	743	1486	7616

Table 11. Average regeneration per ha by species and years-since-disturbance class for basal area category "Open" and "Modal" sites.

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	0	0	1486	2229	743	4458	0	743	0	1486	11145
2 (6 –10)	0	0	93	1393	1115	279	372	0	279	1950	5480
3 (11-15)	83	743	5779	908	578	660	83	165	3385	1321	13705
4 (16-20)	0	0	372	0	557	0	186	0	186	743	2043
5 (21-25)	0	0	0	0	0	0	0	0	0	0	0

With the exception of years-since-disturbance class 3, where western larch was the sole species present, western hemlock, western redcedar, grand fir, and Douglas-fir dominated slightly wet, dense stands (Table 12). Grand fir was the leading species for years-since-disturbance classes 4 and 5. Like most of the previous open stands, hardwood was the major component of the regeneration immediately after disturbance in the slightly wet and open stands (Table 13). After the second years-since-disturbance class, regeneration of the tolerant species increased and remained dominant thereafter. Semi-tolerant and intolerant species were present during the entire time period, but to a lesser extent in the older years-since-disturbance classes.

Table 12. Average regeneration per ha by species and years-since-disturbance class for basal area category "Dense" and "Slightly Wet" sites.

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	0	212	3927	1274	4883	106	106	0	425	0	10933
2 (6 –10)	0	0	4830	0	743	743	0	0	0	0	6316
3 (11-15)	0	0	0	0	0	1486	0	0	0	0	1486
4 (16-20)	5201	0	1486	0	1981	0	0	743	991	495	10897
5 (21-25)	6687	0	2675	3566	892	0	0	0	446	0	14266

Table 13. Average regeneration per ha by species and years-since-disturbance class for basal area category "Open" and "Slightly Wet" sites.

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	0	0	0	0	0	0	0	372	0	1300	1672
2 (6 –10)	0	297	1486	149	297	149	0	149	297	2229	5052
3 (11-15)	83	165	413	660	248	248	0	0	660	248	2724
4 (16-20)	0	297	1858	520	669	74	74	74	223	446	4235
5 (21-25)	0	929	372	464	0	0	0	93	1022	464	3344

As was noted previously, no information was available on the wet sites during the first and third years-since-disturbance classes for dense stands and for the first years-since-disturbance class for open stands (Table 14). Although shade intolerant species were present, semi-tolerant species constituted most of the regeneration in open stands for the second years-since-disturbance class (Table 15). For the third years-since-disturbance class, approximately the same regeneration level of hardwood and western redcedar was found. Western redcedar and hardwood comprised most of the regeneration for dense stands in the older years-since-disturbance classes. Surprisingly, the open stands were dominated by a shade tolerant species (western redcedar), although semi-tolerant and intolerant species were present as well.

Table 14. Average regeneration per ha by species and years-since-disturbance class for basal area class "Dense" and " Wet" sites (* indicates no plots).

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	*	*	*	*	*	*	*	*	*	*	*
2 (6 –10)	0	0	0	0	0	0	0	0	0	0	0
3 (11-15)	*	*	*	*	*	*	*	*	*	*	*
4 (16-20)	0	0	2972	0	0	0	0	0	248	0	3220
5 (21-25)	0	0	0	0	0	0	0	0	0	6687	6687

Table 15. Average regeneration per ha by species and years-since-disturbance class for basal area class "Open" and "Wet" sites (* indicates no plots).

Years Since Disturbance Class	Species										Total
	Bg	Bl	Cw	Fd	Hw	Lw	Pl	Pw	Sx	Hardwood	
1 (1 - 5)	*	*	*	*	*	*	*	*	*	*	*
2 (6 –10)	0	186	557	1115	186	186	186	0	372	186	2972
3 (11-15)	248	0	495	0	0	0	0	0	0	743	1486
4 (16-20)	0	0	1486	372	0	0	0	0	372	186	2415
5 (21-25)	0	124	1610	124	0	0	0	124	124	372	2477

Breaking down the species composition tables by height class created tables for 50 regeneration conditions. Tables 16 and 17 are examples of these tables, containing information on the amount of average regeneration per ha by shade tolerant group, species, height class on dry sites for dense and open stands that were disturbed during the first years-since-disturbance interval. Tables in Appendix I cover the other combinations of conditions.

These tables can be used to provide young stand data for any existing individual-tree or whole stand based growth and yield model. As Prognosis^{BC} grows stands based on the interaction among trees, it can use the data from the developed tables or by randomly selecting a single plot from those having the desired characteristics. For example, using the means, regeneration of 13663 stems per ha would be estimated for dense and dry stands 2.5 years (midpoint of years-since-disturbance class 1) after disturbance (Table 16). For an open stand, 7430 stems per ha would be estimated (Table 17). The information provided for species composition by height class can be used to help differentiate between advance and subsequent regeneration, based on knowledge of average height growth rates.

Table 16. Average regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Dense" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	18	Bg	0	0	0	0	0
		Bl	0	41	41	0	83
		Cw	991	743	165	248	2146
		Hw	1445	165	206	206	2023
		Sx	1486	83	41	41	1651
		Tolerant	**3921**	**1032**	**454**	**495**	**5903**
		Fd	2064	660	330	413	3467
		Pw	826	289	41	165	1321
		Semi-tolerant	**2889**	**949**	**372**	**578**	**4788**
		Hardwood	**454**	**248**	**248**	**743**	**1692**
		Lw	165	41	0	0	206
		Pl	1032	0	41	0	1073
		Intolerant	**1195**	**41**	**41**	**0**	**1280**
		All Species	**8462**	**2270**	**1115**	**1816**	**13663**

Table 17. Average regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Open" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	7	Bg	0	0	0	0	0
		Bl	1486	0	0	0	1486
		Cw	0	425	0	212	637
		Hw	0	106	0	0	106
		Sx	318	106	0	106	531
		Tolerant	**1804**	**637**	**0**	**318**	**2760**
		Fd	1380	212	0	0	1592
		Pw	106	0	0	0	106
		Semi-tolerant	**1486**	**212**	**0**	**0**	**1698**
		Hardwood	**0**	**425**	**425**	**955**	**1804**
		Lw	425	0	0	0	425
		Pl	531	106	106	0	743
		Intolerant	**955**	**106**	**106**	**0**	**1168**
		All Species	**4246**	**1380**	**531**	**1274**	**7430**

4.2.2 Validation of the Tabular Imputation Model

Validation tests showed that predictions based on less than 10 plots resulted in very high standard errors of the mean (SEM), reaching 500% of the mean in some cases. SEM decreased in those predictions based on between 10 and 20 plots (see examples in Tables 18 and 19). Tables in Appendix II cover the validation tests of the developed tables.

Table 18. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Dense" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**Total**
Dry	18	Bg	0	0	0	0	**0**
		Bl	0	41	41	0	**57**
		Cw	524	334	128	120	**895**
		Hw	966	128	168	206	**1175**
		Sx	1093	57	41	41	**1163**
		Tolerant	**1344**	**324**	**200**	**225**	**2174**
		Fd	892	323	161	371	**1083**
		Pw	429	249	41	165	**812**
		Semi-tolerant	**883**	**379**	**162**	**396**	**1265**
		Hardwood	**371**	**208**	**104**	**618**	**1042**
		Lw	128	41	0	0	**145**
		Pl	738	0	41	0	**736**
		Intolerant	**736**	**41**	**41**	**0**	**880**
		Total	**2902**	**587**	**296**	**774**	**3253**

Table 19. Standard error of the mean regeneration per ha by height class, species for years-since-disturbance class 1, basal area class "Open" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**Total**
Dry	7	Bg	0	0	0	0	**0**
		Bl	903	0	0	0	**903**
		Cw	0	425	0	212	**637**
		Hw	0	106	0	0	**106**
		Sx	221	106	0	106	**420**
		Tolerant	**840**	**411**	**0**	**221**	**1324**
		Fd	548	212	0	0	**677**
		Pw	106	0	0	0	**106**
		Semi-tolerant	**513**	**212**	**0**	**0**	**682**
		Hardwood	**0**	**274**	**221**	**531**	**1571**
		Lw	221	0	0	0	**221**
		Pl	212	106	106	0	**324**
		Intolerant	**137**	**106**	**106**	**0**	**454**
		Total	**1510**	**937**	**352**	**1035**	**2507**

The question of whether regeneration becomes more stable with increasing time since disturbance in these complex stands, as is the case in even-aged stands, was addressed using the means, standard deviations, and coefficients of variations. Average regeneration per hectare for various conditions, with their respective standard deviations and coefficients of variation, are given in Tables 20 and 21 for dense and open stands, respectively. For dense stands, coefficients of variation were high in the early years-since-disturbance classes and decreased with increasing years-since-disturbance class in dry conditions. Decreases in variability were more or less constant. For the rest of the conditions examined, coefficients of variation fluctuated with time since disturbance and no clear trends were evident. The lack of trend may indicate that regeneration is constantly occurring in complex stands; it is likely that the regeneration present after disturbance is dominated by regeneration already present before the most recent disturbance (advance regeneration).

Table 20. Average regeneration per ha (SPH) with corresponding standard deviations (STD) and coefficients of variations (CV) for the dense stands modelled (* indicates no plots).

Site Series	Years Since Disturbance	SPH	STD	CV
Dry	1-5	13663	13802	1.01
	6-10	4969	4618	0.93
	11-15	15690	13275	0.84
	16-20	1486	1051	0.71
	21-25	5015	2134	0.43
Slightly dry	1-5	9389	8460	0.90
	6-10	16853	21625	1.28
	11-15	20592	11659	0.57
	16-20	6316	1576	0.25
	21-25	6439	6457	1.00
Modal	1-5	5944	8460	1.41
	6-10	32506	38698	1.19
	11-15	12482	11236	0.90
	16-20	14024	15688	1.12
	21-25	7616	7919	1.04
Slightly wet	1-5	10933	15092	1.38
	6-10	6316	6830	1.08
	11-15	1486	0	0
	16-20	10897	15179	1.39
	21-25	14266	20998	1.47
Wet	1-5	*	*	*
	6-10	0	0	0
	11-15	*	*	*
	16-20	3220	4947	1.54
	21-25	6689	0	0

Table 21. Average regeneration per ha (SPH) with corresponding standard deviations (STD) and coefficients of variations (CV) for the open stands modelled (* indicates no plots).

Site Series	Years Since Disturbance	SPH	STD	CV
Dry	1-5	7430	6632	0.89
	6-10	4776	6342	1.33
	11-15	6501	5800	0.89
	16-20	6780	6686	0.99
	21-25	8173	0	0
Slightly dry	1-5	9288	2648	0.29
	6-10	12956	11804	0.91
	11-15	4334	2634	0.61
	16-20	9659	2644	0.27
	21-25	1486	1051	0.71
Modal	1-5	11145	0	0
	6-10	5480	6009	1.10
	11-15	13704	18452	1.35
	16-20	2043	2670	1.31
	21-25	0	0	0
Slightly wet	1-5	1672	2455	1.47
	6-10	5052	2800	0.55
	11-15	2724	3174	1.17
	16-20	4235	8267	1.95
	21-25	3344	3051	0.91
Wet	1-5	*	*	*
	6-10	2972	2350	0.79
	11-15	1486	1966	1.32
	16-20	2415	3344	1.38
	21-25	2477	1975	0.80

The performance of the tabular model was also evaluated by using the combinations of (1) the number of match categories and the RMSE and (2) the number of matched categories and the ratio of the RMSE to the observed regeneration of target plots (Tables 22 and 23). On average, 2.4% of the plots (1.6 out of 66.6) were classified as a good match and there were as many moderate as poor matched categories (49%). The combination "moderate match-low RMSE" had the highest percentage of 37% followed by "moderate match-high RMSE" with 27%. Those of the "poor match-low RMSE" and "poor match-high RMSE" were 21 and 16%, respectively. The 22% of the plots that had high RMSE were shared between moderate and poor match categories (Table 22).

Table 22. Classification results of the comparison between true and tabular imputed regeneration per ha for the target plots using a combination of RMSE and match category for each of the five runs separately, and averaged over the five runs.

RMSE	**No. Target Plots for Each Run**	**Match Category**			**Total**
		Good	**Moderate**	**Poor**	
Low	68	2	22	12	36
	65	1	15	16	32
	65	0	18	14	32
	64	0	21	12	33
	71	52	10	16	28
Average	**66.6**	**1.0**	**24.4**	**14.0**	**32.3**
Medium	68	0	7	12	19
	65	2	6	13	21
	65	0	10	8	18
	64	0	12	7	19
	71	1	7	13	21
Average	**66.6**	**0.6**	**18.2**	**10.6**	**19.6**
High	68	0	6	7	13
	65	0	2	10	12
	65	0	8	7	15
	64	0	6	6	12
	71	0	12	10	22
Average	**66.6**	**0**	**6.8**	**8.0**	**14.8**
Total	68	2	35	31	68
	65	3	23	39	65
	65	0	36	29	65
	64	0	39	25	64
	71	3	29	39	71
Average	**66.6**	**1.6**	**32.4**	**32.6**	**66.6**

Using the ratio of RMSE to the observed regeneration per ha for target plots (Table 23), the results were:

1) the percentage of the plots that had low and high ratios were equal to those that had low and high RMSE;
2) the percentage of the plots classified as medium ratio was smaller than the percentage of the plots classified by the first comparison as medium RMSE;
3) For plots with zero regeneration, the ratio is undefined (11%); and
4) the percentage of plots that belongs to "good match-undefined ratio" combination was classified by the first comparison as "good match-low RMSE".

Unlike Table 22 using RMSE, the combination "moderate match-low ratio" had the highest percentage of about 29% followed by "poor match-low ratio" with 19%.

Table 23. Classification results of the comparison between true and tabular imputed regeneration per ha for the target plots using a combination of the ratio of RMSE to the actual regeneration and plot match category.

Ratio	No. Target Plots for Each Run	Match Category			Total
		Good	Moderate	Poor	
Low	68	0	19	14	**33**
	65	2	15	19	**36**
	65	0	15	9	**24**
	64	0	25	9	**34**
	71	0	22	12	**34**
Average	**66.6**	**0.4**	**19.2**	**12.6**	**32.2**
Medium	68	1	4	11	**16**
	65	1	3	6	**10**
	65	0	11	8	**19**
	64	0	7	5	**12**
	71	1	1	8	**10**
Average	**66.6**	**0.6**	**5.2**	**7.6**	**13.4**
High	68	0	7	2	**9**
	65	0	4	10	**14**
	65	0	6	7	**13**
	64	0	5	9	**14**
	71	0	3	15	**19**
Average	**66.6**	**0.2**	**5.0**	**8.6**	**13.8**
Undefined (regeneration=0)	68	1	5	4	**10**
	65	0	1	4	**5**
	65	0	4	5	**9**
	64	0	2	2	**4**
	71	1	3	4	**8**
Average	**66.6**	**0.4**	**3.0**	**3.8**	**7.2**
Total	68	2	35	31	**68**
	65	3	23	39	**65**
	65	0	36	29	**65**
	64	0	39	25	**64**
	71	3	29	39	**71**
Average	**66.6**	**1.6**	**32.4**	**32.6**	**66.6**

4.2.3 Causes of Low Regeneration Predictions for the Tabular Procedure

Residuals for tabular procedure plotted over important variables. Figure 2 shows the scatter plot of bias versus four independent variables of Run 1. Similar results were obtained for the other four runs. On average, about 8% of target plots had residuals of more than 1000 stems/ha (outliers). The outlier plots tended to have very large or very small stand density variable values (TPH, BA, and CCF), compared to the average values of the references plot variables, resulting in a poorer match.

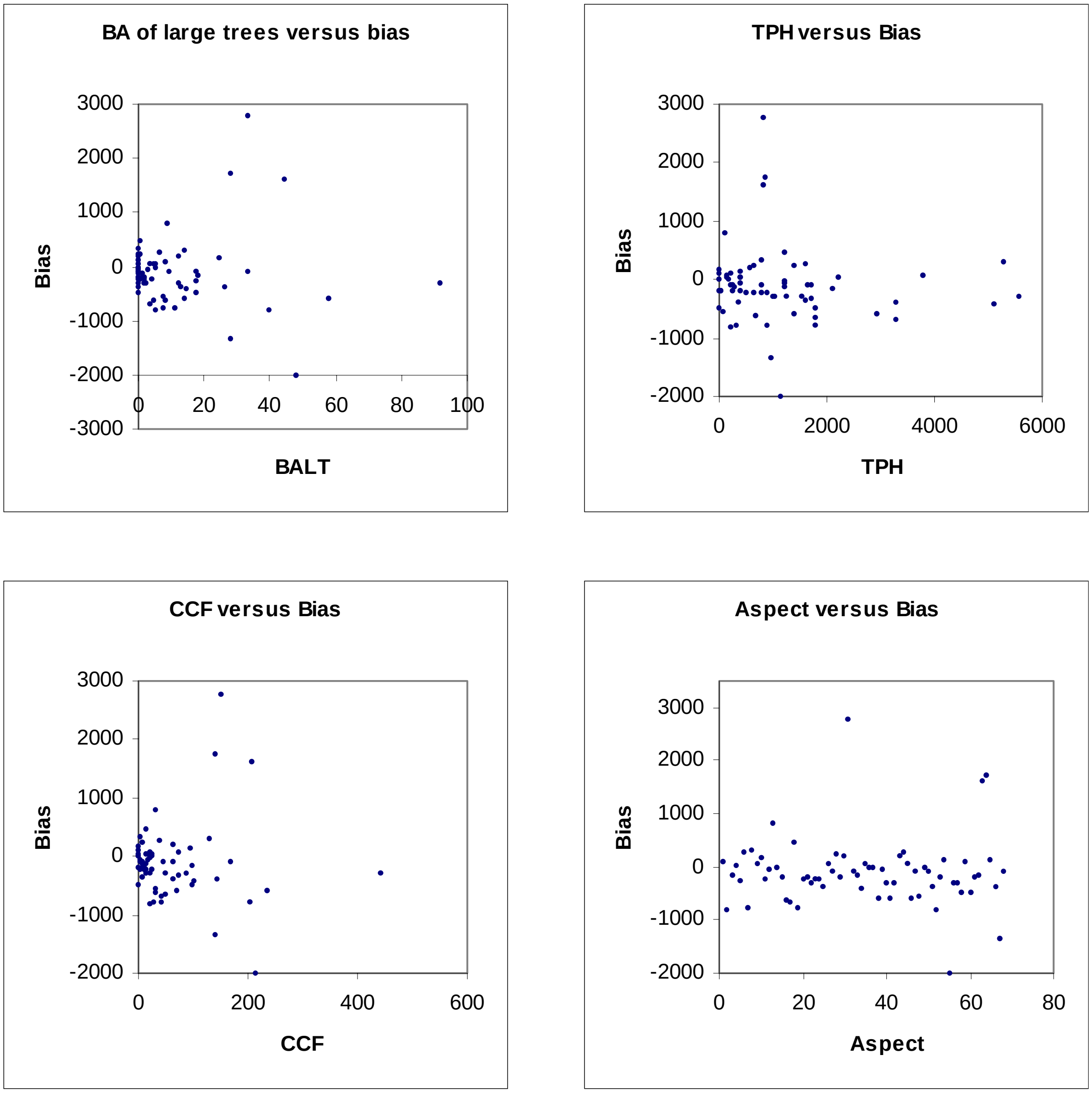

Figure 2. Scatter plot of the regeneration bias versus residual basal area of large trees, residual number of trees (TPH), crown competition factor (CCF), and aspect for 68 target plots in Run 1 of the Tabular model. Bias is observed minus predicted regeneration averaged over all regeneration variables.

4.3 The MSN Approach

For MSN 1, 16 regeneration and 18 plot information variables for each plot were used, whereas 8 and 4 regeneration variables were used for MSN 2 and 3, respectively. For the five runs, 80% of sample data reserved as reference plots and remaining plots were target plots. The reference plots ranged from 0 to 60,183 seedlings per hectare. The maximum regeneration was associated with shade tolerant species height class 1. The plot information variables were similar for reference and target plots, ranging from zero to about 92 m^2 for residual BA, zero to 7750 for TPH, and 2 to 25 years for years since disturbance.

Table 24 shows simple cross-correlations between ground (Y) and plot information (X) variables for MSN 1 and for Run 1. Similar results were obtained for the other four runs.

Table 24. Correlations between the auxiliary and ground variables used in MSN analysis of the Run 1.

SPH[1]	Years since disturbance	Site series	Aspect	Elevation	Slope	TPH	BA	CCF
Tol1	-0.083	-0.126	-0.117	-0.256	-0.020	0.080	0.240	0.261
Tol2	-0.090	-0.130	-0.048	-0.049	-0.005	0.124	0.138	0.142
Tol3	-0.091	0.033	-0.001	-0.050	-0.062	0.134	0.193	0.204
Tol4	0.098	-0.012	-0.028	-0.021	-0.017	0.320	0.115	0.143
Semi1	-0.084	-0.090	-0.000	-0.145	-0.009	-0.085	0.131	0.139
Semi2	-0.007	-0.077	-0.040	-0.073	0.003	-0.086	-0.043	-0.046
Semi3	-0.014	-0.052	-0.030	-0.058	0.131	0.109	0.012	0.006
Semi4	-0.150	-0.050	0.020	-0.058	0.005	0.111	-0.037	-0.038
Intol1	-0.114	-0.097	-0.004	0.078	-0.082	-0.019	-0.105	-0.118
Intol2	-0.046	-0.088	0.001	0.073	-0.077	0.110	-0.104	-0.111
Intol3	-0.020	-0.055	0.094	0.036	-0.060	0.097	-0.083	-0.091
Intol4	-0.018	0.001	0.040	0.023	-0.104	0.157	-0.090	-0.089
Hard1	-0.090	-0.028	-0.028	-0.111	0.032	-0.029	-0.022	-0.014
Hard2	0.011	-0.039	-0.094	-0.145	0.046	0.006	-0.064	-0.063
Hard3	-0.110	-0.001	-0.025	-0.077	0.022	-0.065	-0.081	-0.085
Hard4	0.004	-0.092	0.046	-0.019	0.127	0.007	-0.098	-0.103

[1] Tol refers to tolerant species, semi to semi-tolerant species, intol to intolerant species, and hard to hardwood species. The numbers refer to height classes 1 to 4. TPH: number of residual tree per hectare; BA: residual basal area per hectare; CCF: crown coefficient factor.

Correlations between the regeneration and the auxiliary variables were low. The highest correlation coefficient for Run 1 was obtained between elevation and tolerant species height class 1 and was -0.26. BA and CCF correlated in most cases with tolerant species height class 1 and 2 with coefficients ranging from 0.20 to 0.30. TPH had a correlation coefficient of 0.32 with tolerant species height class 4. In general, the variables BA, TPH, and CCF are all measures of density and were all moderately well correlated with most of the regeneration variables.

The strength of the relationship between ground and plot information variables drove the selection of the most similar reference plot. Tables of the canonical correlation reports from the five runs showed that eight canonical vectors explained 90% of the variance. BA, CCF, and TPH had the largest canonical coefficients in the most canonical variates. Elevation weighted on the variate 6. BA, CCF, and TPH had consistently the highest coefficients and, therefore, carried high weights for obtaining the most similar neighbours for all five runs.

4.3.1 Comparison of MSN Models

A summary of the three criteria used to compare among the three MSN types are presented in Table 25. The bias, mean absolute deviation, and RMSE were calculated over all regeneration variables and over all target plots combined.

Table 25. Bias, mean absolute deviation (MAD), and RMSE values for the three types of MSN for each of five runs and averaged over the five runs.

Run	**No. Target Plots for Each Run**	**MSN Type 1 (Four height classes)**			**MSN Type 2 (Two height classes)**			**MSN Type 3 (No height class)**		
		Bias	MAD	RMSE	Bias	MAD	RMSE	Bias	MAD	RMSE
1	68	36	638	1,432	111	813	1,492	43	2,250	3,193
2	65	-35	666	1,547	61	800	1,601	-3	2,073	3,200
3	65	154	576	1,214	120	718	1,234	1	2,192	3,103
4	64	-143	792	1,802	-111	880	1,661	230	1,981	2,879
5	71	58	594	1,323	93	791	1,405	-59	2,166	3,099
Mean	**66.7**	**14**	**653**	**1,463**	**55**	**801**	**1,479**	**42**	**2,133**	**3,095**

Unexpectedly, the MSN Type 3, with less information, was less biased than MSN Type 2 (55 versus 42) (Table 25). However, MSN Type 2 was considerably more precise (lower RMSE) than MSN Type 3. MSN Type 1 was superior to the two other MSN types, with the lowest criteria values. Hence, MSN Type 1 model was further analyzed.

4.3.2 MSN Type 1 Model

4.3.2.1 Regeneration per ha Validation

To check whether the reference plots constituted a reasonable pool for estimating the target plots, the MSN report provides a test of validity for the selected variables. For each reference plot, its second most similar neighbour was assigned (the most similar being the plot itself) and paired t-tests (test for average difference is equal to zero) were used to compare the observed and predicted values. Table 26 shows the results of 16 ground variables and six selected auxiliary variables using reference observations for Run 1; similar results were obtained for the other four runs. In two out of the five MSN runs, only two significant differences (α=0.05) existed between the observed and predicted values for number of residual trees per ha (intolerant species of Run 1). These results confirmed that the reference plots well represented the target plots and that estimates were reasonably accurate.

Table 26. Average observed versus average predicted regeneration per ha for reference plots 265 plots) of Run1.

SPH	OBSERVED		PREDICTED		STD DIFF		RESID MEAN	RMSE	R-SQ	Prob > T
	Mean	STD	Mean	STD	Mean	STD				
Tol1	1790.472	5846.993	1184.385	2319.511	0.025	0.227	606.087	5587.686	0.1032	0.099
Tol2	487.404	913.566	427.117	840.496	0.016	0.339	60.287	1259.449	0.0007	0.332
Tol3	205.615	470.781	187.857	469.840	0.008	0.278	17.758	619.932	0.0174	0.569
Tol4	309.117	777.651	218.694	670.576	0.020	0.238	90.423	1063.683	0.0044	0.070
Semi1	1242.102	3058.170	1401.921	3743.925	0.009	0.274	-159.819	4685.457	0.0040	0.406
Semi2	490.672	1326.874	556.562	1639.911	0.013	0.390	-65.891	2029.786	0.0059	0.457
Semi3	128.974	409.047	154.208	469.881	0.011	0.276	-25.234	615.214	0.0007	0.568
Semi4	183.649	560.178	217.294	595.506	0.011	0.262	-33.645	779.412	0.0087	0.363
Intol1	375.713	1163.393	281.792	809.875	0.013	0.202	93.921	1425.527	0.0001	0.203
Intol2	259.351	931.520	144.396	560.511	0.019	0.181	114.955	1081.654	0.0006	0.048*
Intol3	98.132	471.641	67.291	408.564	0.021	0.409	30.842	608.378	0.0027	0.293
Intol4	246.736	1441.196	220.106	1261.485	0.003	0.169	26.630	1507.493	0.1475	0.766
Hard1	186.453	919.773	173.834	949.892	0.002	0.257	12.619	1338.878	0.0006	0.826
Hard2	194.864	915.742	193.460	966.846	0.000	0.445	1.404	1323.957	0.0001	0.981
Hard3	175.238	760.402	227.106	831.003	0.014	0.307	-51.868	1140.696	0.0006	0.288
Hard4	601.411	1603.193	772.909	1974.383	0.023	0.327	-171.498	2432.384	0.0084	0.118
Site series	3.487	1.503	3.570	1.301	0.012	0.163	-0.083	1.145	0.4584	0.388
TPH	996.887	1031.581	889.906	870.217	0.021	0.100	106.981	531.347	0.7459	0.192
BA	9.871	12.954	8.586	12.173	0.021	0.151	1.284	9.210	0.5449	0.108
Elevation	1117.491	228.854	1118.011	225.627	0.001	0.153	-0.521	132.690	0.6883	0.980
Yrsince	11.340	6.156	11.189	5.956	0.007	0.182	0.151	4.199	0.5783	0.707
CCF	47.145	58.652	40.983	54.866	0.024	0.144	6.162	37.283	0.6275	0.095

Tol refers to tolerant species, semi to semi-tolerant species, intol to intolerant species, and hard to hardwood species. The numbers refer to height classes 1 to 4. BA: basal area of residual trees per ha; TPH: number of residual trees per ha; Yrsince: years since disturbance; RESID= Observed-Predicted; STD: standard deviation; STD DIFF: standard deviations difference of observed and predicted; RMSE: root mean square error; R-SQ: root squared; * indicates a significant difference from a mean of zero.

4.3.2.2 Frequency Selection of Target Plots

Another useful diagnostic tool for measuring the quality of the sampling and the prediction is the number of times each reference plot was selected as a second-MSN for both reference and target plots, and the normalized distance associated with them. For the reference plots, on average about 15 plots were selected three times as most similar neighbour. About three plots were selected four times, and one plot served five times as most similar neighbours. The latter case could be interpreted as the plot was over-selected. However, only about two reference plots were selected three times as most similar neighbour for target plots.

4.3.2.3 Performance of the MSN Type 1 Model

The comparison between true target plots and the data of their selected most similar neighbour was conducted in two different ways, each using a combination of two different criteria. First, combining the number of match categories and the RMSE resulted in classifying the plots into nine different plot categories (Table 27). About 82% of the plots were classified as "moderate match" and nearly 48% of the plots had low RMSE. The combination "moderate match-low RMSE" had the highest percentage of 37 % followed by "moderate match-medium RMSE" and "moderate match-high RMSE" (Table 27). "Good match-low RMSE" and "poor match-high RMSE" combinations represent the best and the worst predictions and had about 11 and 2.5% respectively. Three of the nine combinations were chosen to illustrate graphically comparisons between the target and the predicted regeneration (Figure 3).

Table 27. Results of a comparison between true and most similar neighbour data for the target plots using a combination of RMSE and match category for each run and averaged over the five runs.

RMSE	No. Target Plots for Each Run	Match Category			Total
		Good	Moderate	Poor	
Low	68	12	19	0	31
	65	6	28	0	34
	65	5	31	0	36
	64	8	17	0	25
	71	5	27	0	32
Average	**66.6**	**7.2**	**24.4**	**0.0**	**31.6**
Medium	68	2	18	0	20
	65	3	16	1	20
	65	1	17	0	18
	64	1	20	1	22
	71	2	20	2	24
Average	**66.6**	**1.8**	**18.2**	**0.8**	**20.8**
High	68	2	13	2	17
	65	1	10	0	11
	65	1	7	3	11
	64	0	14	3	17
	71	2	13	0	15
Average	**66.6**	**1.2**	**11.4**	**1.6**	**14.2**
Total	68	16	50	2	68
	65	10	54	1	65
	65	7	55	3	65
	64	9	51	4	64
	71	9	60	2	71
Average	**66.6**	**10.2**	**54.0**	**2.4**	**66.6**

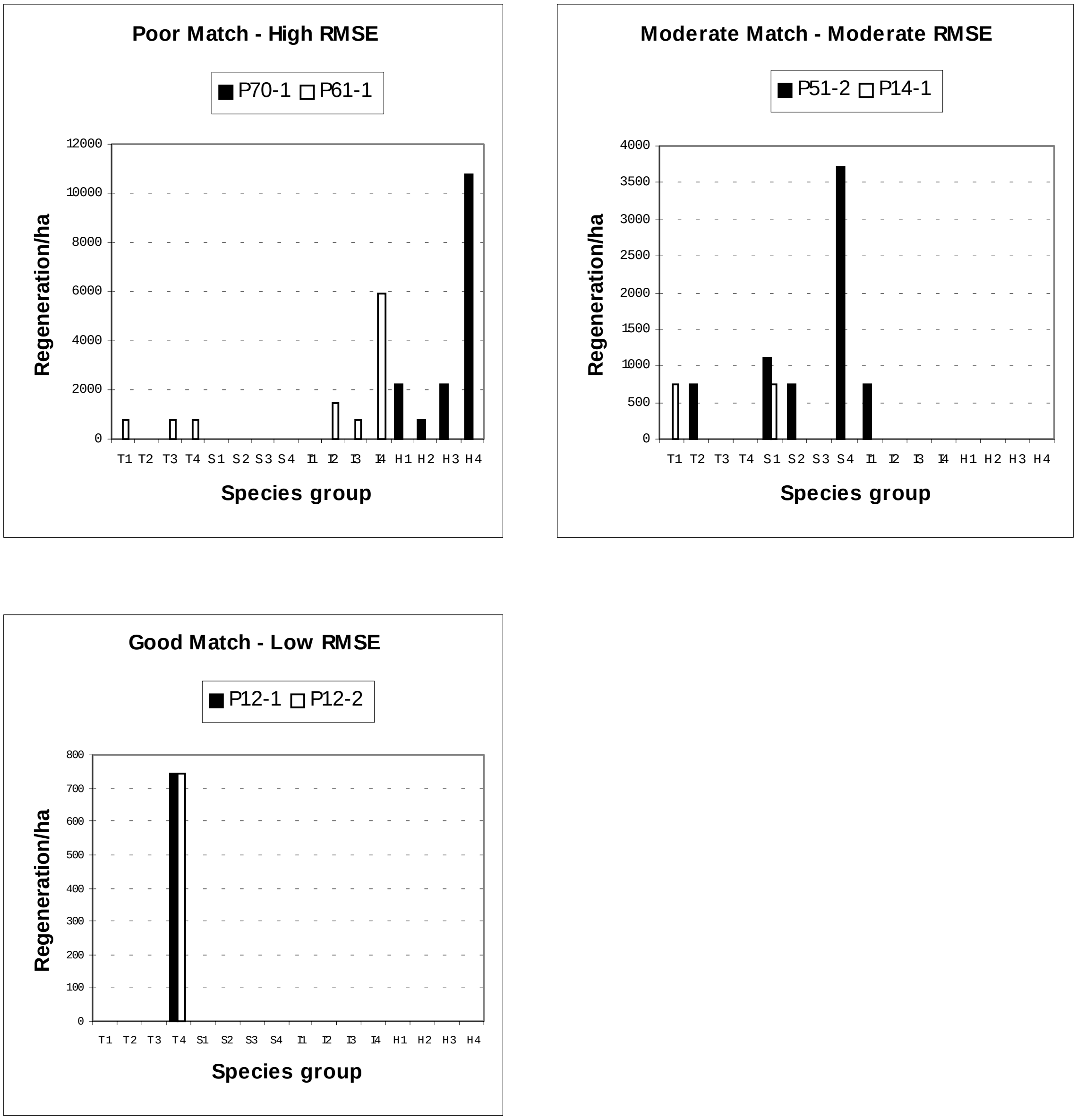

Figure 3. Observed and estimated regeneration of three plots illustrating three different criteria combinations. The black bar is the true regeneration of the target plot, and the white bar is the regeneration of the selected reference plot by MSN as the most similar neighbour.

For the “good match-high RMSE”, all the plots had at least 13 cells with no regeneration (zeros), the regeneration differences between the filled-in cells were very high, and the regeneration type (advance and subsequent) mismatched between some of the target and their neighbour plots.

The comparison using the combination of the number of matched categories and the ratio of the RMSE to the observed regeneration of target plots had 12 plot combination categories (Table 28). The notable differences with the first comparison are that: (1) the “poor match-high ratio” plots combination, considered as representing the worst predictions, decreased from 2.4 to 0.3%; (2) the undefined plot category represented about the 11%; an undefined ratio is defined as a plot that had no regeneration (zero) but its RMSE was greater than zero (this fact resulted from an over-estimation); and (3) 4% of the combination “good match-undefined ratio” was classified by the first comparison as “good match-low RMSE” combination. Like the first comparison, the combination “moderate match-low ratio” had the highest percentage of about 38 % followed by “moderate match-medium ratio” and “moderate match-high ratio” with 20 and 17%, respectively.

4.3.2.4 Causes of Extreme Regeneration Predictions

The plot of the bias versus the most important independent variables displayed the same distribution form for the five data sets but revealed the presence of few residuals (plots) outside the band limited between by ± 1000 stems/ha. Close examination of these outlier plots showed disparities between their TPH, BA, and CCF and those of their pair reference plots. When the average values of the continuous auxiliary variables and the number by category of the class variables of outlier target plots were compared to those of their paired reference plots, and the examination of the plots unsatisfactory predicted (poor match-high RMSE), there was a confirmation of the disagreement between the target plots’ stand density indicators (BA, TPH, and CCF) and those of their paired reference plots. Difference in regeneration composition (advance and subsequent) appears to be another factor that could influence the predictions. Three of the five runs experienced this difference.

Table 28. Classification results of the comparison between true and most similar neighbour data for the target plots using the combination of ratio of RMSE to the actual regeneration (relative RMSE) and plot match category for each run and averaged over the five runs.

Relative RMSE	No. Target Plots for Each Run	Match Category			Total
		Good	Moderate	Poor	
Low	68	7	24	1	**32**
	65	4	25	1	**30**
	65	2	27	2	**31**
	64	4	23	3	**30**
	71	4	26	1	**31**
Average	**66.6**	**4.2**	**25.0**	**1.6**	**30.8**
Medium	68	3	13	0	**16**
	65	2	14	0	**16**
	65	3	12	1	**16**
	64	1	12	1	**14**
	71	1	17	1	**19**
Average	**66.6**	**2.0**	**13.6**	**0.6**	**16.2**
High	68	0	9	1	**10**
	65	2	12	0	**14**
	65	1	8	0	**9**
	64	3	13	0	**16**
	71	0	13	0	**13**
Average	**66.6**	**1.2**	**11.0**	**0.2**	**12.4**
Undefined (regeneration=0)	68	6	4	0	**10**
	65	2	3	0	**5**
	65	1	8	0	**9**
	64	1	3	0	**4**
	71	4	4	0	**8**
Average	**66.6**	**2.8**	**4.4**	**0.0**	**7.2**
Total	68	16	50	2	**68**
	65	10	54	1	**65**
	65	7	55	3	**65**
	64	9	51	4	**64**
	71	9	60	2	**71**
Average	**66.6**	**10.2**	**54.0**	**2.4**	**66.6**

4.4. Comparison of Approaches

Like MSN, the tabular model with four height classes (Type 1) produced the lowest values for the three criteria compared to using two or no height clases (Types 2 and 3) (Tables 29 to 31). Table 30 shows that the bias produced by the MSN model was low compared to the tabular method. Although the mean absolute deviation (MAD) did not differ substantially between the methods and both had almost the same RMSE levels, MSN produced slightly lower values. The ranges of the three criteria values were wider for the MSN approach.

Table 29. Bias, mean absolute deviation (MAD), and RMSE values of Type 1 MSN and the corresponding tabular approach for each run and averaged over the five runs.

Run	Number of target plots	Type 1 MSN (Four Height Classes)					
		MSN			Tabular		
		Bias	MAD	RMSE	Bias	MAD	RMSE
1	68	36	638	1,432	-110	698	1,472
2	65	-35	666	1,547	-188	705	1,407
3	65	154	576	1,214	-144	773	1,578
4	64	-143	792	1,802	-99	660	1,298
5	71	58	594	1,323	-200	813	1,701
Mean	**66.6**	**14**	**653**	**1,463**	**-148**	**730**	**1,491**

Unlike the MSN approach, where biases alternated between negative and positive values, the tabular approach produced consistently negative biases (Table 29). This was due to the rule set for assigning imputation tables to target plots that did not possess corresponding tables. This situation occurred when, for example, a given table is based on only two plots and both plots were in target data set. All the candidate plots that experienced this problem and belonged to either dry and wet sites, extreme conditions and low regeneration abundance, were attributed regeneration of tables with more abundant regeneration that represent conditions such as mesic and slightly dry stands. This fact resulted in overestimation of regeneration.

Table 30. Bias, mean absolute deviation (MAD), and RMSE values for Type 2 MSN and the corresponding Tabular approach for each run and averaged over the five runs.

Run	Number of target plots	Type 2 MSN (Two Height Classes)					
		MSN			Tabular		
		Bias	MAD	RMSE	Bias	MAD	RMSE
1	68	111	813	1,492	-557	1,203	2,098
2	65	61	800	1,601	-612	1,185	1,989
3	65	120	718	1,234	-626	1,231	2,104
4	64	-111	880	1,661	-518	1,077	1,860
5	71	93	791	1,405	-655	1,404	2,287
Mean	**66.6**	**55**	**801**	**1,479**	**-594**	**1,220**	**2,068**

Table 31. Bias, mean absolute deviation (MAD), and RMSE values of Type 3 MSN and the corresponding Tabular approach for each run and averaged over the five runs.

Run	Number of target plots	Type 3 MSN (No Height Classes)					
		MSN			Tabular		
		Bias	MAD	RMSE	Bias	MAD	RMSE
1	68	43	2,250	3,193	-788	2,504	3,568
2	65	-3	2,073	3,200	-939	2,281	3,121
3	65	1	2,192	3,103	-903	2,470	3,460
4	64	230	1,981	2,879	-608	2,250	3,026
5	71	-59	2,166	3,099	-911	2,742	3,852
Mean	**66.6**	**42**	**2,133**	**3,095**	**-830**	**2,449**	**3,406**

The approaches were also compared using the combination of the criteria previously used for assessing the MSN Type 1 model. The results of the combination of number of matched categories with RMSE, and number of matched categories with the ratio of RMSE to the actual plot regeneration for tabular and MSN models are shown in Tables 22 and 23, and 27 and 28, respectively. The results achieved with the MSN model were quite different from those produced by the tabular. When the “match category-RMSE” combination was used (Tables 22 and 27), on average, both approaches yielded almost the same percentage of RMSE categories (low, medium, and high RMSE). However, 86% of the plots classified by the MSN approach were comprised of plots that were good and moderate matches; only 51% were produced by tabular approach. The tabular produced as many moderate as poor matched categories (Table 22). MSN showed a clear superiority over the tabular approach by classifying 10% more of the plots as “good match-low RMSE”, and 10% plots less in “poor match-high RMSE” combinations (Tables 22 and 27).

Similarly, using the number of matched categories with the ratio of RMSE to the actual regeneration combination, the MSN approach consistently produced higher percentages of the plots that fell in the “good match with low ratio” combination. Almost no plot was classified in the worse performance category represented by the combination “poor match-high ratio” combination (Tables 24 and 29). The tabular approach resulted in classifying 13% of the plots in the “poor match-high ratio” combination.

4.5 Sensitivity of Prognosis^{BC} to MSN and Tabular Regeneration Predictions

The sensitivity analysis of Prognosis^{BC} for MSN regeneration predictions revealed that small volume differences existed between the observed and predicted regeneration for the three fit categories (Table 32). Ranges of differences were observed within each of the three fit categories. As expected, the highest differences were observed in the “poor match-high RMSE” plot category, and standard deviations of volume differences were smaller for the “good match-low RMSE” plot category. Plots 2 (106-6) and 4 (104-3) of the “poor match-high RMSE” plot category are examples of Prognosis^{BC} apparent sensitivity and insensitivity to MSN regeneration predictions, respectively. Examining the characteristics of these plots showed that plot 4 and its most similar neighbour had the same site series and aspect, were highly stocked, and both had regeneration in height classes 3 and 4, considered as having a high probability of survival. Plot 2 differed with its selected most similar neighbour plot in aspect, slope, stand density measures (BA, TPH, CCF), residual trees composition, and a disproportionate regeneration species group and amount of regeneration in height classes 3 and 4. Examining the remaining plots did not show any pattern that enabled identification of sensitive variables.

Table 32. Summary of sensitivity analysis for the MSN Model

Category	Plot number	Plot_id	Plot type	Regeneration	TPH	Merchantable volume	Difference	STD	Average difference
Good Match & Low RMSE	1	57-2	Target	0	900	308.6	0	50.1	**-9.7**
		58-2	MSN	0		308.6			
	2	114-2	Target	743	825	265.7	32.8		
		114-4	MSN	0		232.9			
	3	12-2	Target	743	275	240.4	-81.9		
		12-1	MSN	743		322.3			
	4	12-1	Target	743	275	58.8	10.4		
		12-2	MSN	743		48.4			
Moderate Match & Medium RMSE	1	93-1	Target	10402	1400	437.4	-51.5	74.8	**7.5**
		29-2	MSN	11888		488.9			
	2	29-3	Target	7430	475	306.1	-29		
		112-2	MSN	17089		335.1			
	3	125-1	Target	6687	0	111.7	111.7		
		86-1	MSN	0		0			
	4	116-1	Target	8916	375	308.7	-1.3		
		99-4	MSN	1486		310			
Poor Match & High RMSE	1	70-1	Target	26748	1400	113.6	-132.6	91.6	**21.5**
		61-1	MSN	8916		246.2			
	2	106-6	Target	4458	0	342.2	170.6		
		66-2	MSN	22290		171.6			
	3	43-1	Target	19318	425	331	-39.8		
		60-1	MSN	17832		370.8			
	4	104-3	Target	33435	425	273.5	0.5		
		104-2	MSN	14117		273			
	5	136-1	Target	17089	625	312.5	65.9		
		81-2	MSN	14860		246.6			
	6	19-1	Target	8173	2625	258	22.1		
		61-1	MSN	8916		235.9			
	7	66-2	Target	22290	425	603.9	96		
		106-6	MSN	4458		507.9			
	8	96-6	Target	15603	3075	258.8	-10.9		
		85-1	MSN	8961		269.7			

TPH: number of residual trees per ha; STD: standard deviation of the difference

Table 33 shows the results of the sensitivity analysis of Prognosis^{BC} for tabular regeneration predictions. On average, the differences of the projected merchantable volumes of the three plot categories were small. Nevertheless, the standard deviation of the "poor match-high RMSE" plot category was more than three times higher than the two other plot categories. The variability of the volume differences for the two other categories was almost equal and their standard deviations were higher than their respective average difference volumes. Individually, some of the plots classified as "poor match-high RMSE" yielded small differences in their projected volumes and were comparable to the plots in the two other fit categories. Unexpectedly, and unlike MSN, those plots classified as "moderate match-medium RMSE" had slightly smaller average differences and standard deviations than the plots classified as "good match-low RMSE".

Table 33. Summary of sensitivity analysis for the Tabular Model

Category	Plot number	Plot_id	Plot type	Regeneration	TPH	Merchantable volume	Difference	STD	Average difference
Good Match & Low RMSE	1	65-2	Target	743	400	328.4	95.4	46.5	**25.8**
		45	Tabular	0		233.0			
	2	135-2	Target	0	1485	444.3	0		
		23	Tabular	0		444.3			
	3	37-2	Target	743	425	240.1	7.9		
		61	Tabular	0		232.2			
	4	140-6	Target	0	475	16.6	0		
		34	Tabular	0		16.6			
Moderate Match & Medium RMSE	1	51-2	Target	6687	825	212.3	-85.1	44.36	**-19.3**
		40	Tabular	13005		297.4			
	2	122-1	Target	2972	1650	634.4	-0.7		
		40	Tabular	13005		635.1			
	3	122-2	Target	2229	1275	601.3	-3.5		
		40	Tabular	12136		604.8			
	4	132-3	Target	14860	1150	232.8	12		
		58	Tabular	5674		220.8			
Poor Match & High RMSE	1	49-1	Target	5201	3275	294.2	11.5	142.87	**-39.4**
		50	Tabular	15285		282.7			
	2	70-1	Target	26748	1400	113.6	-201.5		
		29	Tabular	12402		315.1			
	3	14-1	Target	2972	0	332.2	135.4		
		41	Tabular	16346		196.8			
	4	89-2	Target	11145	300	327.1	17.9		
		16	Tabular	17157		309.2			
	5	106-4	Target	2972	325	273.2	15.4		
		28	Tabular	18327		257.8			
	6	36-1	Target	34178	1400	206.4	-295.5		
		29	Tabular	11395		501.9			
	7	7-1	Target	50524	400	277.2	-64.1		
		16	Tabular	10897		341.3			
	8		Target	2927	50	362.4	65.4		
			Tabular	16346		297.0			

TPH: number of residual trees per ha; STD: standard deviation of the difference

Plots 1 (49-1) and 6 (36-1) are examples of cases that generated contrasting results (small and big differences) for the "poor match-high RMSE" plot category. Examining the plots' characteristics revealed clear differences in species composition and type of regeneration between the observed regeneration of target plots and those of the tables from where the estimates were imputed. For plot 1 with a small volume difference, the observed regeneration in height classes 3 and 4 were closely predicted by tabulation, especially in two of the species groups. Target plot 6, which yielded the biggest merchantable volume difference, had more shade- and semi-tolerant species, whereas its corresponding tables contained only intolerant seral species.

There was no single variable that was apparent in the sensitivity analysis that provided a pattern to the results. The results showed that poor regeneration prediction did not necessarily impact on the merchantable volume yield projected over 50 years, but that there was a higher probability of getting very close agreements in the "good match-low RMSE" plot category.

5. Summary

A series of tabular imputation models were developed and their performance in predicting the regeneration were evaluated. The tabular approach used site group (five), residual density class (two), and years-since-disturbance class (five) as main variables to depict average regeneration by species groups and height class. As Prognosis^{BC} grows stands based on the interaction among trees, the user can provide data either by randomly selecting a single plot from those having the same variables, or by using the means from the table that has the desired characteristics. As more data become available, these tables can be easily updated and the reliability of tables based on small sample size can be improved. There were not a lot of obvious trends apparent in the tabulated data. This may be due to the dominance of advance regeneration among the regeneration present. Advance regeneration would be more affected by the conditions that existed prior to the most recent disturbance than the conditions that exist today. Designing a sampling that separates advance from subsequent regeneration will without doubt improve the results.

The full MSN imputation model (four height classes) was the best predictor for regeneration. Stand density indicators (BA, TPH, and CCF) were the driving variables in the most similar neighbour selection process. When the number of match categories and the RMSE were used as comparison criteria, about 97.5% of the target plots imputations were classified as being moderate to good. Perfect matches with high precision corresponded to those plots that had high number of cells with no regeneration (zero). However, the use of the number of matched categories and the ratio of the RMSE to the observed regeneration of target plots provided better results by decreasing the number of bad predictions from 2.4% to 0.3%. The mismatch of BA, TPH, CCF, and seemingly, the presence/absence of advance regeneration were considered as a major cause of poor predictions.

A sensitivity analysis showed that Prognosis^{BC} was insensitive to regeneration predictions from both imputation models during the first 50 years of the projection, except for very few cases where very poor regeneration estimates were used as inputs. With longer periods of simulation, it is likely that the model would be more sensitive to tabular predictions. This sensitivity analysis did not find any particular variable that appeared to affect the prediction quality. Even though poor regeneration predictions did not normally impact on the merchantable volume during the simulation period, the probability of getting very close predictions was higher when using plots in the "good match-low RMSE" plot category for MSN imputation, and plots in the "moderate match-medium RMSE" and "good match-low RMSE" categories for the tabular imputation approach.

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Appendix I – Tabular Imputation Models[1]

Table I.1. Average regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Dense" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Dry	11	Bg	1013	135	0	0	1148
		Bl	405	68	68	0	540
		Cw	1418	946	203	68	2634
		Hw	540	338	675	540	2094
		Sx	0	0	0	0	0
		Tolerant	**3377**	**1486**	**946**	**608**	**6417**
		Fd	946	135	338	68	1486
		Pw	540	135	0	0	675
		Semi-tolerant	**1486**	**270**	**338**	**68**	**2161**
		Hardwood	**270**	**0**	**0**	**0**	**270**
		Lw	203	135	0	0	338
		Pl	135	68	0	0	203
		Intolerant	**338**	**203**	**0**	**0**	**541**
		All Species	**5471**	**1959**	**1283**	**675**	**9389**

Table I.2. Average regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Open" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Dry	6	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	867	372	0	0	1238
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**867**	**372**	**0**	**0**	**1238**
		Fd	743	0	0	0	743
		Pw	0	0	0	0	0
		Semi-tolerant	**743**	**0**	**0**	**0**	**743**
		Hardwood	**495**	**619**	**1981**	**991**	**4087**
		Lw	619	0	0	0	619
		Pl	2229	372	0	0	2601
		Intolerant	**2848**	**619**	**1981**	**991**	**3220**
		All Species	**4953**	**1362**	**1981**	**991**	**9288**

Table I.3. Average regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Dense" and "Mesic" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	372	2229	372	0	2972
		Hw	1858	372	0	0	2229
		Sx	0	0	0	0	0
		Tolerant	**2229**	**2601**	**372**	**0**	**5201**
		Fd	0	372	0	0	372
		Pw	0	372	0	0	372
		Semi-tolerant	**0**	**743**	**0**	**0**	**743**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**2229**	**3344**	**372**	**0**	**5944**

[1] Tables showing the conditions that were not represented in this study (three conditions that had the number of plots equal to zero) are not included in this Appendix.

Table I.4. Average regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Open" and "Mesic" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	743	743	0	0	1486
		Hw	743	0	0	0	743
		Sx	0	0	0	0	0
		Tolerant	**1486**	**743**	**0**	**0**	**2229**
		Fd	743	1486	0	0	2229
		Pw	743	0	0	0	743
		Semi-tolerant	**1486**	**1486**	**0**	**0**	**2972**
		Hardwood	**0**	**1486**	**0**	**0**	**1486**
		Lw	3715	743	0	0	4458
		Pl	0	0	0	0	0
		Intolerant	**3715**	**743**	**0**	**0**	**4458**
		All Species	**6687**	**4458**	**0**	**0**	**11145**

Table I.5. Average regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Dense" and "Slightly Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	7	Bg	0	0	0	0	0
		Bl	0	106	0	106	212
		Cw	2123	955	531	318	3927
		Hw	4776	0	0	106	4883
		Sx	425	0	0	0	425
		Tolerant	**7324**	**1061**	**531**	**531**	**9447**
		Fd	1274	0	0	0	1274
		Pw	0	0	0	0	0
		Semi-tolerant	**1274**	**0**	**0**	**0**	**1274**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	106	0	0	0	106
		Pl	106	0	0	0	106
		Intolerant	**212**	**0**	**0**	**0**	**212**
		All Species	**8810**	**1061**	**531**	**531**	**10933**

Table I.6. Average regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Open" and "Slightly Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	4	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	372	0	0	0	372
		Semi-tolerant	**372**	**0**	**0**	**0**	**372**
		Hardwood	**0**	**0**	**557**	**743**	**1300**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**372**	**0**	**557**	**743**	**1672**

Table I.7. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Dense” and “Dry” sites.

Site	Number of plots	Species	Height class				**All Heights**
			1	2	3	4	
Dry	16	Bg	0	0	0	0	0
		Bl	186	93	0	0	279
		Cw	836	418	0	279	1532
		Hw	0	0	0	0	0
		Sx	93	0	0	0	93
		Tolerant	**1115**	**511**	**0**	**279**	**1904**
		Fd	1207	46	46	0	1300
		Pw	139	139	0	0	279
		Semi-tolerant	**1347**	**186**	**46**	**0**	**1579**
		Hardwood	**418**	**46**	**511**	**279**	**1254**
		Lw	0	0	0	0	0
		Pl	46	186	0	0	232
		Intolerant	**46**	**186**	**0**	**0**	**232**
		All Species	**2926**	**929**	**557**	**557**	**4969**

Table I.8. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Open” and “Dry” sites.

Site	Number of plots	Species	Height class				**All Heights**
			1	2	3	4	
Dry	21	Bg	35	0	0	0	35
		Bl	0	0	35	0	35
		Cw	601	35	35	35	708
		Hw	106	35	0	0	142
		Sx	0	0	0	0	0
		Tolerant	**743**	**71**	**71**	**35**	**920**
		Fd	318	106	0	0	425
		Pw	106	0	0	0	106
		Semi-tolerant	**425**	**106**	**0**	**0**	**531**
		Hardwood	**0**	**142**	**71**	**601**	**814**
		Lw	389	283	71	0	743
		Pl	566	495	35	672	1769
		Intolerant	**955**	**778**	**106**	**672**	**2512**
		All Species	**2123**	**1097**	**248**	**1309**	**4776**

Table I.9. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Dense” and “Slightly Dry” sites.

Site	Number of plots	Species	Height class				**All Heights**
			1	2	3	4	
Slightly Dry	22	Bg	68	34	0	0	101
		Bl	101	34	34	0	169
		Cw	1756	608	270	169	2837
		Hw	7059	101	34	0	7160
		Sx	0	0	0	0	0
		Tolerant	**8984**	**777**	**338**	**169**	**10267**
		Fd	3344	304	68	101	3816
		Pw	642	68	0	34	743
		Semi-tolerant	**3985**	**372**	**68**	**135**	**4559**
		Hardwood	**1317**	**270**	**203**	**203**	**1993**
		Lw	0	0	0	0	0
		Pl	34	0	0	0	34
		Intolerant	**34**	**0**	**0**	**0**	**34**
		All Species	**14320**	**1418**	**608**	**507**	**16853**

Table I.10. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Open” and “Slightly Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Dry	16	Bg	46	0	0	0	46
		Bl	93	93	0	46	232
		Cw	557	93	232	46	929
		Hw	372	418	139	418	1347
		Sx	511	0	93	0	604
		Tolerant	**1579**	**604**	**464**	**511**	**3158**
		Fd	604	511	93	372	1579
		Pw	0	0	46	0	46
		Semi-tolerant	**604**	**511**	**139**	**372**	**1625**
		Hardwood	**464**	**557**	**743**	**2090**	**3854**
		Lw	0	510	46	0	557
		Pl	232	1115	511	1904	3761
		Intolerant	**232**	**1625**	**557**	**1904**	**4318**
		All Species	**2879**	**3297**	**1904**	**4876**	**12956**

Table I.11. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Dense” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	12	Bg	0	186	62	0	248
		Bl	62	0	62	124	248
		Cw	3467	557	186	124	4334
		Hw	21795	1734	124	186	23838
		Sx	0	0	0	0	0
		Tolerant	**25324**	**2477**	**433**	**433**	**28667**
		Fd	1238	62	0	0	1300
		Pw	433	186	0	0	619
		Semi-tolerant	**1672**	**248**	**0**	**0**	**1919**
		Hardwood	**0**	**248**	**124**	**186**	**557**
		Lw	62	0	0	0	62
		Pl	495	557	186	62	1300
		Intolerant	**557**	**557**	**186**	**62**	**1919**
		All Species	**27553**	**3529**	**743**	**681**	**32506**

Table I.12. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Open” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	8	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	93	0	0	0	93
		Hw	743	186	0	186	1115
		Sx	93	186	0	0	279
		Tolerant	**929**	**372**	**0**	**186**	**1486**
		Fd	372	743	186	93	1393
		Pw	0	0	0	0	0
		Semi-tolerant	**372**	**734**	**186**	**93**	**1393**
		Hardwood	**929**	**0**	**93**	**929**	**1950**
		Lw	186	0	93	0	279
		Pl	0	279	93	0	372
		Intolerant	**186**	**279**	**186**	**0**	**650**
		All Species	**2415**	**1393**	**464**	**1207**	**5480**

Table I.13. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Dense” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class				All Heights
			1	2	3	4	
Slightly Wet	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	4458	372	0	0	4830
		Hw	743	0	0	0	743
		Sx	0	0	0	0	0
		Tolerant	**5201**	**372**	**0**	**0**	**5573**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	372	372	0	0	743
		Pl	0	0	0	0	0
		Intolerant	**372**	**372**	**0**	**0**	**743**
		All Species	**5573**	**743**	**0**	**0**	**6316**

Table I.14. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Open” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class				All Heights
			1	2	3	4	
Slightly Wet	5	Bg	0	0	0	0	**0**
		Bl	0	297	0	0	**297**
		Cw	743	446	149	149	**1486**
		Hw	297	0	0	0	**297**
		Sx	0	0	0	297	**297**
		Tolerant	**1040**	**743**	**149**	**446**	**2378**
		Fd	0	0	149	0	**149**
		Pw	149	0	0	0	**149**
		Semi-tolerant	**149**	**0**	**149**	**0**	**297**
		Hardwood	**149**	**0**	**0**	**2080**	**2229**
		Lw	149	0	0	0	**149**
		Pl	0	0	0	0	**0**
		Intolerant	**149**	**0**	**0**	**0**	**149**
		All Species	**1486**	**743**	**297**	**2526**	**5052**

Table I.15. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Dense” and “Wet” sites.

Site	Number of plots	Species	Height class				All Heights
			1	2	3	4	
Wet	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**0**	**0**

Table I.16. Average regeneration per ha by height class and species for years-since-disturbance class 2, basal area class "Open" and "Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Wet	4	Bg	0	0	0	0	0
		Bl	0	0	0	186	186
		Cw	372	186	0	0	557
		Hw	0	0	186	0	186
		Sx	0	186	0	186	372
		Tolerant	**372**	**372**	**186**	**372**	**1300**
		Fd	743	372	0	0	1115
		Pw	0	0	0	0	0
		Semi-tolerant	**743**	**372**	**0**	**0**	**1115**
		Hardwood	**0**	**0**	**0**	**186**	**186**
		Lw	0	186	0	0	186
		Pl	186	0	0	0	186
		Intolerant	**186**	**186**	**0**	**0**	**372**
		All Species	**1300**	**929**	**186**	**557**	**2972**

Table I.17. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class "Dense" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	17	Bg	393	44	0	44	481
		Bl	0	0	0	0	0
		Cw	219	350	262	87	918
		Hw	131	44	0	0	175
		Sx	44	0	0	0	44
		Tolerant	**787**	**437**	**262**	**131**	**1617**
		Fd	4982	2142	306	262	7692
		Pw	393	262	44	87	787
		Semi-tolerant	**5376**	**2404**	**350**	**350**	**8479**
		Hardwood	**44**	**262**	**175**	**1661**	**2142**
		Lw	437	437	44	87	1005
		Pl	1267	612	219	350	2448
		Intolerant	**1705**	**1049**	**262**	**437**	**3453**
		All Species	**7911**	**4152**	**1049**	**2579**	**15690**

Table I.18. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class "Open" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	20	Bg	111	0	0	0	111
		Bl	74	111	0	0	186
		Cw	74	74	223	149	520
		Hw	0	74	37	37	149
		Sx	223	0	0	0	223
		Tolerant	**483**	**260**	**260**	**186**	**1189**
		Fd	372	297	37	223	929
		Pw	186	334	37	74	631
		Semi-tolerant	**557**	**632**	**74**	**297**	**1560**
		Hardwood	**223**	**372**	**111**	**1412**	**2118**
		Lw	0	297	297	557	1152
		Pl	223	0	0	260	483
		Intolerant	**223**	**297**	**297**	**817**	**1635**
		All Species	**1486**	**1560**	**743**	**2712**	**6501**

Table I.19. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class "Dense" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	7	Bg	212	106	0	0	318
		Bl	318	849	106	0	1274
		Cw	3397	1380	106	318	5201
		Hw	212	743	106	212	1273
		Sx	212	0	0	0	212
		Tolerant	**4352**	**3078**	**318**	**531**	**8279**
		Fd	2654	637	212	106	3609
		Pw	1380	1698	0	0	3078
		Semi-tolerant	**4033**	**2335**	**212**	**106**	**6687**
		Hardwood	**106**	**212**	**212**	**2441**	**2972**
		Lw	1486	849	212	106	2654
		Pl	0	0	0	0	0
		Intolerant	**1486**	**849**	**212**	**106**	**2654**
		All Species	**9977**	**6475**	**955**	**3184**	**20592**

Table I.20. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class "Open" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	6	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	124	0	0	0	124
		Sx	0	0	0	0	0
		Tolerant	**124**	**0**	**0**	**0**	**124**
		Fd	991	991	124	124	2229
		Pw	124	0	0	0	124
		Semi-tolerant	**1115**	**991**	**124**	**124**	**2353**
		Hardwood	**0**	**124**	**372**	**372**	**867**
		Lw	619	124	0	0	743
		Pl	0	0	124	124	248
		Intolerant	**619**	**124**	**124**	**124**	**991**
		All Species	**1858**	**1238**	**619**	**619**	**4334**

Table I.21. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class "Dense" and "Mesic" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Mesic	5	Bg	0	0	0	0	0
		Bl	1189	297	297	743	2526
		Cw	149	0	0	149	297
		Hw	446	149	0	149	743
		Sx	0	149	297	446	892
		Tolerant	**1783**	**594**	**594**	**1486**	**4458**
		Fd	2378	892	0	743	4012
		Pw	594	0	297	0	892
		Semi-tolerant	**2972**	**892**	**297**	**743**	**4904**
		Hardwood	**0**	**149**	**446**	**2378**	**2972**
		Lw	149	0	0	0	149
		Pl	0	0	0	0	0
		Intolerant	**149**	**0**	**0**	**0**	**149**
		All Species	**4904**	**1635**	**1337**	**4607**	**12482**

Table I.22. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Open” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	9	Bg	83	0	0	0	83
		Bl	743	0	0	0	743
		Cw	4458	1321	0	0	5779
		Hw	413	83	83	0	578
		Sx	3220	165	0	0	3385
		Tolerant	**8916**	**1569**	**83**	**0**	**10567**
		Fd	495	165	83	165	908
		Pw	165	0	0	0	165
		Semi-tolerant	**660**	**165**	**83**	**165**	**1073**
		Hardwood	**0**	**248**	**0**	**1073**	**1321**
		Lw	330	330	0	0	660
		Pl	0	0	0	83	83
		Intolerant	**330**	**330**	**0**	**83**	**743**
		All Species	**9907**	**2312**	**165**	**1321**	**13705**

Table I.23. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Dense” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	743	0	743	1486
		Pl	0	0	0	0	0
		Intolerant	**0**	**743**	**0**	**743**	**1486**
		All Species	**0**	**743**	**0**	**743**	**1486**

Table I.24. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Open” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	9	Bg	83	0	0	0	83
		Bl	165	0	0	0	165
		Cw	83	248	0	83	413
		Hw	165	83	0	0	248
		Sx	413	248	0	0	660
		Tolerant	**908**	**578**	**0**	**83**	**1569**
		Fd	495	165	0	0	660
		Pw	0	0	0	0	0
		Semi-tolerant	**495**	**165**	**0**	**0**	**660**
		Hardwood	**0**	**83**	**0**	**165**	**248**
		Lw	248	0	0	0	248
		Pl	0	0	0	0	0
		Intolerant	**248**	**0**	**0**	**0**	**248**
		All Species	**1651**	**826**	**0**	**248**	**2724**

Table I.25. Average regeneration per ha by height class and species for years-since-disturbance class 3, basal area class "Open" and "Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
et	3	Bg	248	0	0	0	248
		Bl	0	0	0	0	0
		Cw	0	495	0	0	495
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**248**	**495**	**0**	**0**	**743**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**743**	**743**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**248**	**495**	**0**	**743**	**1486**

Table I.26. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Dense" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	372	372	0	0	743
		Pw	743	0	0	0	743
		Semi-tolerant	**1115**	**372**	**0**	**0**	**1486**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**1115**	**372**	**0**	**0**	**1486**

Table I.27. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Open" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	8	Bg	0	0	0	0	0
		Bl	0	0	93	0	93
		Cw	93	279	186	372	929
		Hw	0	0	0	0	0
		Sx	0	0	93	0	93
		Tolerant	**93**	**279**	**372**	**372**	**1115**
		Fd	836	929	279	372	2415
		Pw	93	0	0	0	93
		Semi-tolerant	**929**	**929**	**279**	**372**	**2508**
		Hardwood	**372**	**1579**	**93**	**0**	**2043**
		Lw	0	0	0	0	0
		Pl	743	279	93	0	1115
		Intolerant	**743**	**279**	**93**	**0**	**1115**
		All Species	**2136**	**3065**	**836**	**743**	**6780**

Table I.28. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Dense" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	2	Bg	0	0	0	0	0
		Bl	1486	372	0	0	1858
		Cw	0	0	0	372	372
		Hw	0	0	0	0	0
		Sx	372	0	0	0	372
		Tolerant	**1858**	**372**	**0**	**372**	**2602**
		Fd	372	743	372	1858	3344
		Pw	0	0	0	0	0
		Semi-tolerant	**372**	**743**	**372**	**1858**	**3344**
		Hardwood	**0**	**0**	**0**	**372**	**372**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**2229**	**1115**	**372**	**2601**	**6316**

Table I.29. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Open" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	4	Bg	372	0	0	0	372
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**372**	**0**	**0**	**0**	**372**
		Fd	1486	2415	557	1486	5944
		Pw	0	0	0	0	0
		Semi-tolerant	**1486**	**2415**	**557**	**1486**	**5944**
		Hardwood	**0**	**186**	**0**	**2786**	**2972**
		Lw	186	186	0	0	372
		Pl	0	0	0	0	0
		Intolerant	**186**	**186**	**0**	**0**	**372**
		All Species	**2043**	**2786**	**557**	**4272**	**9659**

Table I.30. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Dense" and "Mesic" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Mesic	8	Bg	186	0	0	0	186
		Bl	279	93	93	93	557
		Cw	1393	929	93	464	2879
		Hw	3715	650	186	279	4830
		Sx	186	93	0	0	279
		Tolerant	**5758**	**1765**	**372**	**836**	**8730**
		Fd	2693	93	93	93	2972
		Pw	650	0	0	0	650
		Semi-tolerant	**3344**	**93**	**93**	**93**	**3622**
		Hardwood	**186**	**0**	**0**	**1115**	**1300**
		Lw	93	93	93	93	372
		Pl	0	0	0	0	0
		Intolerant	**93**	**93**	**93**	**93**	**372**
		All Species	**9380**	**1950**	**557**	**2136**	**14024**

Table I.31. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class “Open” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	4	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	372	0	0	372
		Hw	186	186	0	186	557
		Sx	0	186	0	0	186
		Tolerant	**186**	**743**	**0**	**186**	**1115**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**743**	**743**
		Lw	0	0	0	0	0
		Pl	0	186	0	0	186
		Intolerant	**0**	**186**	**0**	**0**	**186**
		All Species	**186**	**929**	**0**	**929**	**2043**

Table I.32. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class “Dense” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	3	Bg	2229	1238	495	1238	5201
		Bl	0	0	0	0	0
		Cw	1486	0	0	0	1486
		Hw	991	495	248	248	1981
		Sx	743	248	0	0	991
		Tolerant	**5449**	**1981**	**743**	**1486**	**9659**
		Fd	0	0	0	0	0
		Pw	248	495	0	0	743
		Semi-tolerant	**248**	**495**	**0**	**0**	**743**
		Hardwood	**0**	**0**	**248**	**248**	**495**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**5696**	**2477**	**991**	**1734**	**10897**

Table I.33. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class “Open” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	10	Bg	0	0	0	0	0
		Bl	74	74	74	74	297
		Cw	1486	74	0	297	1858
		Hw	520	74	0	74	669
		Sx	223	0	0	0	223
		Tolerant	**2303**	**223**	**74**	**446**	**3046**
		Fd	223	149	74	74	520
		Pw	0	0	74	0	74
		Semi-tolerant	**223**	**149**	**148**	**74**	**594**
		Hardwood	**0**	**0**	**223**	**223**	**446**
		Lw	0	0	0	74	74
		Pl	0	0	74	0	74
		Intolerant	**0**	**0**	**74**	**74**	**148**
		All Species	**2526**	**372**	**520**	**817**	**4235**

Table I.34. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Dense" and "Wet" sites.

Site	Number of plots	Species	Height class				**All**
			1	2	3	4	**Heights**
Wet	3	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	743	743	495	991	2972
		Hw	0	0	0	0	0
		Sx	248	0	0	0	248
		Tolerant	**991**	**743**	**495**	**991**	**3220**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**991**	**743**	**495**	**991**	**3220**

Table I.35. Average regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Open" and "Wet" sites.

Site	Number of plots	Species	Height class				**All**
			1	2	3	4	**Heights**
Wet	4	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	372	557	372	186	1486
		Hw	0	0	0	0	0
		Sx	186	0	0	186	372
		Tolerant	**557**	**557**	**372**	**372**	**1858**
		Fd	186	0	0	186	372
		Pw	0	0	0	0	0
		Semi-tolerant	**186**	**0**	**0**	**186**	**372**
		Hardwood	**0**	**0**	**0**	**186**	**186**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**743**	**557**	**372**	**743**	**2415**

Table I.36. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Dense" and "Dry" sites.

Site	Number of plots	Species	Height class				**All**
			1	2	3	4	**Heights**
Dry	4	Bg	0	0	186	0	186
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**186**	**0**	**186**
		Fd	2043	186	186	0	2415
		Pw	186	0	0	0	186
		Semi-tolerant	**2229**	**186**	**186**	**0**	**2601**
		Hardwood	**0**	**0**	**557**	**743**	**1300**
		Lw	186	186	0	372	743
		Pl	0	0	0	186	186
		Intolerant	**186**	**186**	**0**	**558**	**929**
		All Species	**2415**	**372**	**929**	**1300**	**5015**

Table I.37. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Open" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Dry	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	743	743	1486
		Hw	0	743	0	743	1486
		Sx	743	0	0	0	743
		Tolerant	**743**	**743**	**743**	**1486**	**3715**
		Fd	1486	743	0	743	2972
		Pw	0	0	0	0	0
		Semi-tolerant	**1486**	**743**	**0**	**743**	**2972**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	743	0	0	743	1486
		Pl	0	0	0	0	0
		Intolerant	**743**	**0**	**0**	**743**	**1486**
		All Species	**2972**	**1486**	**743**	**2972**	**8173**

Table I.38. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Dense" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	12	Bg	929	124	0	186	1238
		Bl	62	0	0	0	62
		Cw	681	0	62	124	867
		Hw	372	62	62	0	495
		Sx	0	0	0	0	0
		Tolerant	**2043**	**186**	**124**	**310**	**2662**
		Fd	991	186	62	433	1672
		Pw	310	495	186	557	1548
		Semi-tolerant	**1300**	**681**	**248**	**991**	**3220**
		Hardwood	**0**	**0**	**0**	**557**	**557**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**3344**	**867**	**372**	**1858**	**6439**

Table I.39. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Open" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	372	0	0	0	372
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**372**	**0**	**0**	**0**	**372**
		Fd	0	0	0	743	743
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**743**	**743**
		Hardwood	**0**	**0**	**0**	**0**	0
		Lw	0	0	0	0	0
		Pl	0	0	0	372	**372**
		Intolerant	**0**	**0**	**0**	**372**	**372**
		All Species	**372**	**0**	**0**	**1115**	**1486**

Table I.40. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Dense" and "Mesic" sites.

Site	Number of plots	Species	Height class				**All Heights**
			1	2	3	4	
Mesic	4	Bg	0	0	0	0	0
		Bl	0	0	0	186	186
		Cw	0	372	0	1858	2229
		Hw	0	0	0	2601	2601
		Sx	0	0	0	743	743
		Tolerant	**0**	**372**	**0**	**5387**	**5758**
		Fd	0	0	0	372	372
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**372**	**372**
		Hardwood	**0**	**0**	**0**	**1486**	**1486**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**372**	**0**	**7244**	**7616**

Table I.41. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Open" and "Mesic" sites.

Site	Number of plots	Species	Height class				**All Heights**
			1	2	3	4	
Mesic	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**0**	**0**

Table I.42. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Dense" and "Slightly Wet" sites.

Site	Number of plots	Species	Height class				**All Heights**
			1	2	3	4	
Slightly Wet	5	Bg	5944	743	0	0	6687
		Bl	0	0	0	0	0
		Cw	1040	1337	149	149	2675
		Hw	297	149	297	149	892
		Sx	0	149	0	297	446
		Tolerant	**7281**	**2378**	**446**	**594**	**10699**
		Fd	3269	297	0	0	3566
		Pw	0	0	0	0	0
		Semi-tolerant	**3269**	**297**	**0**	**0**	**3566**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**10550**	**2675**	**446**	**594**	**14265**

Table I.43. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Open" and "Slightly Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Wet	8	Bg	0	0	0	0	0
		Bl	929	0	0	0	929
		Cw	0	0	0	372	372
		Hw	0	0	0	0	0
		Sx	650	93	0	297	1022
		Tolerant	**1579**	**93**	**0**	**650**	**2322**
		Fd	279	93	0	93	464
		Pw	0	93	0	0	93
		Semi-tolerant	**279**	**186**	**0**	**93**	**557**
		Hardwood	**0**	**0**	**0**	**464**	**464**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**1858**	**279**	**0**	**1207**	**3344**

Table I.44. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Dense" and "Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Wet	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**6687**	**6687**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**6687**	**6687**

Table I.45. Average regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Open" and "Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Wet	6	Bg	0	0	0	0	0
		Bl	124	0	0	0	124
		Cw	991	124	0	495	1610
		Hw	0	0	0	0	0
		Sx	124	0	0	0	124
		Tolerant	**1238**	**124**	**0**	**495**	**1858**
		Fd	124	0	0	0	124
		Pw	124	0	0	0	124
		Semi-tolerant	**248**	**0**	**0**	**0**	**248**
		Hardwood	**0**	**248**	**0**	**124**	**372**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**1486**	**372**	**0**	**619**	**2477**

Appendix II- Validation Tables[1]

Table II.1. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Dense" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Dry	11	Bg	875	135	0	0	1009
		Bl	117	68	68	0	376
		Cw	999	348	104	68	1148
		Hw	334	209	406	414	944
		Sx	0	0	0	0	0
		Tolerant	**1048**	**265**	**376**	**411**	**1713**
		Fd	680	91	338	68	729
		Pw	414	135	0	0	544
		Semi-tolerant	**729**	**151**	**338**	**68**	**1196**
		Hardwood	**151**	**0**	**0**	**0**	**151**
		Lw	145	91	0	0	232
		Pl	91	68	0	0	145
		Intolerant	**154**	**105**	**0**	**0**	**348**
		All Species	**2093**	**523**	**540**	**406**	**2551**

Table II.2. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Open" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Dry	6	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	589	254	0	0	829
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**589**	**254**	**0**	**0**	**829**
		Fd	470	0	0	0	470
		Pw	0	0	0	0	0
		Semi-tolerant	**470**	**0**	**0**	**0**	**470**
		Hardwood	**367**	**355**	**1405**	**313**	**1702**
		Lw	298	0	0	0	298
		Pl	1383	372	0	0	1544
		Intolerant	**1204**	**372**	**0**	**0**	**1352**
		All Species	**1113**	**403**	**1418**	**367**	**1081**

Table II.3. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 1, basal area class "Dense" and "Mesic" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	372	2229	372	0	2972
		Hw	1858	372	0	0	2229
		Sx	0	0	0	0	0
		Tolerant	**1486**	**1858**	**372**	**0**	**5201**
		Fd	0	372	0	0	372
		Pw	0	372	0	0	372
		Semi-tolerant	**0**	**0**	**0**	**0**	**743**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**2229**	**3344**	**372**	**0**	**5944**

[1] Tables showing the conditions that were not represented in this study (three conditions that had the number of plots equal to zero) are not included in this Appendix

Table II.4. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 1, basal area class “Open” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**0**	**0**

Table II.5. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 1, basal area class “Dense” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	7	Bg	0	0	0	0	0
		Bl	0	106	0	106	212
		Cw	833	505	212	221	1635
		Hw	4776	0	0	106	4760
		Sx	425	0	0	0	425
		Tolerant	**4397**	**483**	**212**	**212**	**5338**
		Fd	927	0	0	0	927
		Pw	0	0	0	0	0
		Semi-tolerant	**927**	**0**	**0**	**0**	**927**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	106	0	0	0	106
		Pl	106	0	0	0	106
		Intolerant	**137**	**0**	**0**	**0**	**212**
		All Species	**4061**	**483**	**212**	**212**	**5704**

Table II.6. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 1, basal area class “Open” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	4	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	372	0	0	0	372
		Semi-tolerant	**372**	**0**	**0**	**0**	**372**
		Hardwood	**0**	**0**	**557**	**743**	**1300**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**372**	**0**	**557**	**743**	**1227**

Table II.7. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Dense” and “Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	16	Bg	0	0	0	0	0
		Bl	127	93	0	0	202
		Cw	395	214	0	134	680
		Hw	0	0	0	0	0
		Sx	93	0	0	0	93
		Tolerant	**384**	**222**	**0**	**134**	**658**
		Fd	964	46	46	0	1007
		Pw	75	101	0	0	150
		Semi-tolerant	**955**	**107**	**46**	**0**	**1053**
		Hardwood	**418**	**46**	**417**	**279**	**646**
		Lw	0	0	0	0	0
		Pl	46	186	0	0	188
		Intolerant	**46**	**186**	**0**	**0**	**188**
		All Species	**1060**	**267**	**415**	**292**	**1154**

Table II.8. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Open” and “Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	21	Bg	35	0	0	0	35
		Bl	0	0	35	0	35
		Cw	601	35	35	35	635
		Hw	106	35	0	0	110
		Sx	0	0	0	0	0
		Tolerant	**605**	**49**	**49**	**35**	**739**
		Fd	131	58	0	0	141
		Pw	58	0	0	0	58
		Semi-tolerant	**131**	**58**	**0**	**0**	**163**
		Hardwood	**0**	**110**	**71**	**372**	**515**
		Lw	167	130	71	0	285
		Pl	177	322	35	497	895
		Intolerant	**193**	**326**	**78**	**497**	**908**
		All Species	**891**	**372**	**107**	**598**	**1384**

Table II.9. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Dense” and “Slightly Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Dry	22	Bg	47	34	0	0	56
		Bl	101	34	34	0	138
		Cw	664	275	126	68	914
		Hw	4335	56	0	0	4378
		Sx	0	0	0	0	0
		Tolerant	**4233**	**265**	**127**	**68**	**4372**
		Fd	1762	126	47	74	1817
		Pw	241	47	0	34	249
		Semi-tolerant	**1720**	**127**	**47**	**79**	**1906**
		Hardwood	**693**	**270**	**171**	**140**	**1342**
		Lw	0	0	0	0	0
		Pl	34	0	0	0	34
		Intolerant	**34**	**0**	**0**	**0**	**34**
		All Species	**4581**	**362**	**205**	**179**	**4610**

Table II.10. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Open” and “Slightly Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Dry	16	Bg	46	0	0	0	46
		Bl	93	93	0	46	232
		Cw	349	63	188	46	421
		Hw	325	225	101	418	1020
		Sx	232	0	93	0	237
		Tolerant	**417**	**227**	**213**	**417**	**1316**
		Fd	237	211	63	136	484
		Pw	0	0	46	0	46
		Semi-tolerant	**237**	**211**	**75**	**136**	**485**
		Hardwood	**345**	**186**	**395**	**918**	**1715**
		Lw	0	370	46	0	415
		Pl	112	708	376	1139	2158
		Intolerant	**112**	**750**	**375**	**1139**	**2205**
		All Species	**1008**	**915**	**825**	**1820**	**2951**

Table II.11. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Dense” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	12	Bg	0	186	62	0	248
		Bl	62	0	62	124	248
		Cw	1800	276	133	83	1963
		Hw	9253	1537	83	186	10098
		Sx	0	0	0	0	0
		Tolerant	**8651**	**1490**	**143**	**214**	**11464**
		Fd	504	62	0	0	534
		Pw	143	186	0	0	301
		Semi-tolerant	**420**	**190**	**0**	**0**	**723**
		Hardwood	**0**	**248**	**83**	**133**	**344**
		Lw	62	0	0	0	62
		Pl	495	557	133	62	1172
		Intolerant	**494**	**557**	**133**	**62**	**1167**
		All Species	**10677**	**1628**	**330**	**266**	**11171**

Table II.12. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class “Open” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	8	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	93	0	0	0	93
		Hw	466	186	0	186	659
		Sx	93	122	0	0	**195**
		Tolerant	**438**	**199**	**0**	**186**	**756**
		Fd	281	643	186	93	1083
		Pw	0	0	0	0	0
		Semi-tolerant	**281**	**643**	**186**	**93**	**1083**
		Hardwood	**929**	**0**	**93**	**624**	**1199**
		Lw	186	0	93	0	195
		Pl	0	195	93	0	281
		Intolerant	**186**	**195**	**122**	**0**	**296**
		All Species	**1139**	**800**	**279**	**909**	**2115**

Table II.13. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class "Dense" and "Slightly Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	3715	372	0	0	4087
		Hw	743	0	0	0	743
		Sx	0	0	0	0	0
		Tolerant	**2780**	**372**	**0**	**0**	**4830**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	372	372	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**372**	**372**	**0**	**0**	**0**
		All Species	**4830**	**0**	**0**	**0**	**4830**

Table II.14. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class "Open" and "Slightly Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	5	Bg	0	0	0	0	0
		Bl	0	182	0	0	182
		Cw	743	446	149	149	779
		Hw	297	0	0	0	297
		Sx	0	0	0	297	297
		Tolerant	**728**	**407**	**149**	**297**	**952**
		Fd	0	0	149	0	149
		Pw	149	0	0	0	149
		Semi-tolerant	**149**	**0**	**149**	**0**	**182**
		Hardwood	**149**	**0**	**0**	**1398**	**1370**
		Lw	149	0	0	0	149
		Pl	0	0	0	0	0
		Intolerant	**149**	**0**	**0**	**0**	**149**
		All Species	**1308**	**576**	**297**	**1460**	**1252**

Table II.15. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class "Dense" and "Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Wet	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**0**	**0**

Table II.16. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 2, basal area class "Open" and "Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Wet	4	Bg	0	0	0	0	0
		Bl	0	0	0	186	186
		Cw	372	186	0	0	557
		Hw	0	0	186	0	186
		Sx	0	186	0	186	372
		Tolerant	**372**	**215**	**186**	**215**	**766**
		Fd	743	372	0	0	1115
		Pw	0	0	0	0	0
		Semi-tolerant	**743**	**372**	**0**	**0**	**1115**
		Hardwood	**0**	**0**	**0**	**186**	**186**
		Lw	0	186	0	0	186
		Pl	186	0	0	0	186
		Intolerant	**186**	**186**	**0**	**0**	**372**
		All Species	**766**	**356**	**186**	**356**	**1175**

Table II.17. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class "Dense" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	17	Bg	271	44	0	44	270
		Bl	0	0	0	0	0
		Cw	106	182	155	87	363
		Hw	71	44	0	0	101
		Sx	44	0	0	0	44
		Tolerant	**259**	**181**	**155**	**95**	**567**
		Fd	2007	945	111	126	2971
		Pw	248	142	44	60	363
		Semi-tolerant	**1961**	**918**	**113**	**129**	**2940**
		Hardwood	**44**	**155**	**79**	**817**	**873**
		Lw	143	181	44	60	262
		Pl	1013	404	106	212	1668
		Intolerant	**985**	**403**	**109**	**212**	**1739**
		All Species	**2154**	**1045**	**255**	**954**	**3220**

Table II.18. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class "Open" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	20	Bg	61	0	0	0	**61**
		Bl	51	81	0	0	**119**
		Cw	74	51	153	87	**281**
		Hw	0	51	37	37	**116**
		Sx	122	0	0	0	**122**
		Tolerant	**135**	**98**	**155**	**91**	**390**
		Fd	212	136	37	109	**384**
		Pw	74	114	37	51	**189**
		Semi-tolerant	**208**	**145**	**51**	**113**	**365**
		Hardwood	**163**	**232**	**111**	**454**	**747**
		Lw	0	136	156	444	**634**
		Pl	188	74	0	164	**266**
		Intolerant	**188**	**136**	**156**	**457**	**692**
		All Species	**332**	**361**	**280**	**720**	**1297**

Table II.19. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Dense” and “Slightly Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	7	Bg	137	106	0	0	221
		Bl	221	849	106	0	1155
		Cw	2469	909	106	221	3409
		Hw	212	538	106	212	838
		Sx	137	0	0	0	137
		Tolerant	**2243**	**894**	**150**	**267**	**3879**
		Fd	957	341	137	106	937
		Pw	411	420	0	0	1018
		Semi-tolerant	**0**	**0**	**137**	**106**	**931**
		Hardwood	**106**	**137**	**137**	**1392**	**1842**
		Lw	873	548	212	106	1620
		Pl	0	0	0	0	0
		Intolerant	**849**	**548**	**212**	**106**	**1620**
		All Species	**3683**	**2112**	**267**	**1401**	**4407**

Table II.20. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Open” and “Slightly Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	6	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	124	0	0	0	124
		Sx	0	0	0	0	728
		Tolerant	**124**	**0**	**0**	**0**	**124**
		Fd	457	367	124	124	508
		Pw	124	0	0	0	124
		Semi-tolerant	**418**	**367**	**124**	**124**	**522**
		Hardwood	**0**	**124**	**372**	**254**	**728**
		Lw	355	124	0	0	470
		Pl	0	0	124	124	248
		Intolerant	**335**	**124**	**124**	**124**	**531**
		All Species	**534**	**414**	**486**	**228**	**1075**

Table II.21. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Dense” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Mesic	5	Bg	0	0	0	0	0
		Bl	1189	297	297	743	2526
		Cw	149	0	0	149	182
		Hw	297	149	0	149	470
		Sx	0	149	297	446	720
		Tolerant	**1066**	**278**	**364**	**665**	**3170**
		Fd	1378	720	0	743	1655
		Pw	278	0	297	0	278
		Semi-tolerant	**1127**	**720**	**297**	**743**	**1736**
		Hardwood	**0**	**149**	**446**	**2378**	**2972**
		Lw	149	0	0	0	149
		Pl	0	0	0	0	0
		Intolerant	**149**	**0**	**0**	**0**	**149**
		All Species	**1655**	**922**	**892**	**2171**	**5025**

Table II.22. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Open” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Mesic	9	Bg	83	0	0	0	83
		Bl	446	0	0	0	446
		Cw	2733	810	0	0	3506
		Hw	251	83	83	0	322
		Sx	2152	165	0	0	2135
		Tolerant	**2511**	**778**	**83**	**0**	**5303**
		Fd	328	165	83	165	730
		Pw	109	0	0	0	109
		Semi-tolerant	**314**	**165**	**83**	**165**	**743**
		Hardwood	**0**	**175**	**0**	**582**	**917**
		Lw	330	251	0	0	573
		Pl	0	0	0	83	83
		Intolerant	**330**	**251**	**0**	**83**	**567**
		All Species	**5133**	**1158**	**109**	**720**	**6151**

Table II.23. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Dense” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Wet	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**0**	**0**

Table II.24. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Open” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Wet	9	Bg	83	0	0	0	83
		Bl	165	0	0	0	165
		Cw	83	248	0	83	330
		Hw	165	83	0	0	175
		Sx	218	248	0	0	289
		Tolerant	**206**	**322**	**0**	**83**	**587**
		Fd	328	165	0	0	487
		Pw	0	0	0	0	0
		Semi-tolerant	**328**	**165**	**0**	**0**	**487**
		Hardwood	**0**	**83**	**0**	**109**	**175**
		Lw	248	0	0	0	248
		Pl	0	0	0	0	0
		Intolerant	**248**	**0**	**0**	**0**	**248**
		All Species	**664**	**487**	**0**	**124**	**1058**

Table II.25. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 3, basal area class “Open” and “Wet” sites.

Site	Number of plots	Species	Height class				**All**
			1	2	3	4	**Heights**
Wet	3	Bg	248	0	0	0	248
		Bl	0	0	0	0	0
		Cw	0	495	0	0	495
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**248**	**495**	**0**	**0**	**743**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**429**	**429**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**248**	**495**	**0**	**429**	**1135**

Table II.26. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class “Dense” and “Dry” sites.

Site	Number of plots	Species	Height class				**All**
			1	2	3	4	**Heights**
Dry	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	372	372	0	0	0
		Pw	743	0	0	0	743
		Semi-tolerant	**372**	**372**	**0**	**0**	**743**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**1115**	**372**	**0**	**0**	**743**

Table II.27. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class “Open” and “Dry” sites.

Site	Number of plots	Species	Height class				**All**
			1	2	3	4	**Heights**
Dry	8	Bg	0	0	0	0	0
		Bl	0	0	93	0	93
		Cw	93	195	186	281	640
		Hw	0	0	0	0	0
		Sx	0	0	93	0	93
		Tolerant	**93**	**195**	**199**	**281**	**819**
		Fd	260	415	195	281	874
		Pw	93	0	0	0	93
		Semi-tolerant	**233**	**415**	**195**	**281**	**920**
		Hardwood	**281**	**1476**	**93**	**0**	**1747**
		Lw	0	0	0	0	0
		Pl	506	279	93	0	743
		Intolerant	**506**	**297**	**93**	**0**	**743**
		All Species	**650**	**1822**	**454**	**421**	**2364**

Table II.28. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Dense" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	2	Bg	0	0	0	0	0
		Bl	1486	372	0	0	1858
		Cw	0	0	0	372	372
		Hw	0	0	0	0	0
		Sx	372	0	0	0	372
		Tolerant	**1115**	**372**	**0**	**372**	**2601**
		Fd	372	743	372	1858	3344
		Pw	0	0	0	0	0
		Semi-tolerant	**372**	**743**	**372**	**1858**	**3344**
		Hardwood	**0**	**0**	**0**	**372**	**372**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**1486**	**372**	**372**	**1858**	**1115**

Table II.29. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Open" and "Slightly Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	4	Bg	372	0	0	0	372
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**372**	**0**	**0**	**0**	**372**
		Fd	1051	824	356	525	2208
		Pw	0	0	0	0	0
		Semi-tolerant	**1051**	**824**	**356**	**525**	**2208**
		Hardwood	**0**	**186**	**0**	**467**	**1455**
		Lw	186	186	0	0	372
		Pl	0	0	0	0	0
		Intolerant	**186**	**186**	**0**	**0**	**372**
		All Species	**824**	**977**	**356**	**1335**	**1322**

Table II.30. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Dense" and "Mesic" sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Mesic	8	Bg	122	0	0	0	122
		Bl	195	93	93	93	233
		Cw	904	557	93	279	1145
		Hw	2198	431	122	195	2328
		Sx	186	93	0	0	195
		Tolerant	**1808**	**505**	**140**	**260**	**3235**
		Fd	2078	93	93	93	2049
		Pw	552	0	0	0	552
		Semi-tolerant	**2030**	**93**	**93**	**93**	**2583**
		Hardwood	**122**	**0**	**0**	**281**	**521**
		Lw	93	93	93	93	199
		Pl	0	0	0	0	0
		Intolerant	**93**	**93**	**93**	**93**	**199**
		All Species	**5431**	**1031**	**272**	**800**	**5547**

Table II.31. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Open" and "Mesic" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	4	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	372	0	0	372
		Hw	186	186	0	186	557
		Sx	0	186	0	0	186
		Intolerant	**186**	**303**	**0**	**186**	**711**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**525**	**743**
		Lw	0	0	0	0	0
		Pl	0	186	0	0	186
		Intolerant	**0**	**186**	**0**	**0**	**186**
		All Species	**186**	**356**	**0**	**929**	**1335**

Table II.32. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Dense" and "Slightly Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	3	Bg	2229	893	495	1238	4834
		Bl	0	0	0	0	0
		Cw	1486	0	0	0	1486
		Hw	991	248	248	248	1311
		Sx	429	248	0	0	655
		Tolerant	**0**	**0**	**429**	**1135**	**8218**
		Fd	0	0	0	0	0
		Pw	248	495	0	0	743
		Semi-tolerant	**248**	**495**	**0**	**0**	**743**
		Hardwood	**0**	**0**	**248**	**248**	**495**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**5329**	**1786**	**495**	**1379**	**8763**

Table II.33. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Open" and "Slightly Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	10	Bg	0	0	0	0	0
		Bl	74	74	74	74	297
		Cw	1405	74	0	164	1376
		Hw	520	74	0	74	525
		Sx	114	0	0	0	114
		Tolerant	**1399**	**114**	**74**	**164**	**2249**
		Fd	159	99	74	74	351
		Pw	0	0	74	0	74
		Semi-tolerant	**159**	**99**	**99**	**74**	**411**
		Hardwood	**0**	**0**	**223**	**159**	**371**
		Lw	0	0	0	74	74
		Pl	0	0	74	0	74
		Intolerant	**0**	**0**	**74**	**74**	**99**
		All Species	**2134**	**254**	**314**	**259**	**2614**

Table II.34. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Dense" and "Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Wet	3	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	743	743	495	991	2972
		Hw	0	0	0	0	0
		Sx	248	0	0	0	248
		Tolerant	**655**	**743**	**495**	**991**	**2856**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**655**	**743**	**495**	**991**	**2856**

Table II.35. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 4, basal area class "Open" and "Wet" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Wet	4	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	372	557	372	186	1251
		Hw	0	0	0	0	0
		Sx	186	0	0	186	214
		Tolerant	**356**	**557**	**372**	**215**	**1373**
		Fd	186	0	0	186	215
		Pw	0	0	0	0	0
		Semi-tolerant	**186**	**0**	**0**	**186**	**215**
		Hardwood	**0**	**0**	**0**	**186**	**186**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**743**	**557**	**372**	**0**	**1672**

Table II.36. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class "Dense" and "Dry" sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Dry	4	Bg	0	0	186	0	186
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**186**	**0**	**186**
		Fd	929	186	186	0	766
		Pw	186	0	0	0	186
		Semi-tolerant	**803**	**186**	**186**	**0**	**934**
		Hardwood	**0**	**0**	**557**	**525**	**1067**
		Lw	186	186	0	372	743
		Pl	0	0	0	186	186
		Intolerant	**186**	**186**	**0**	**356**	**929**
		All Species	**977**	**214**	**703**	**766**	**1067**

Table II.37. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Open” and “Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Dry	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**0**	**0**

Table II.38. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Dense” and “Slightly Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	12	Bg	803	124	0	133	912
		Bl	62	0	0	0	62
		Cw	560	0	62	124	555
		Hw	372	62	62	0	381
		Sx	0	0	0	0	0
		Tolerant	**924**	**133**	**84**	**170**	**987**
		Fd	551	97	62	266	654
		Pw	214	495	186	378	1173
		Semi-tolerant	**542**	**488**	**190**	**412**	**1456**
		Hardwood	**0**	**0**	**0**	**318**	**318**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**1486**	**612**	**250**	**537**	**1864**

Table II.39. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Open” and “Slightly Dry” sites.

Site	Number of plots	Species	Height class 1	2	3	4	All Heights
Slightly Dry	2	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	372	0	0	0	372
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**372**	**0**	**0**	**0**	**372**
		Fd	0	0	0	743	743
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**743**	**743**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	372	372
		Intolerant	**0**	**0**	**0**	**372**	**372**
		All Species	**372**	**0**	**0**	**1115**	**743**

Table II.40. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Dense” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	4	Bg	0	0	0	0	0
		Bl	0	0	0	186	186
		Cw	0	372	0	1406	1287
		Hw	0	0	0	2134	2134
		Sx	0	0	0	743	743
		Tolerant	**0**	**372**	**0**	**1023**	**4315**
		Fd	0	0	0	372	372
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**372**	**372**
		Hardwood	**0**	**0**	**0**	**803**	**1051**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**372**	**0**	**3982**	**3959**

Table II.41. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Open” and “Mesic” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Mesic	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**0**	**0**

Table II.42. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Dense” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	5	Bg	5944	743	0	0	6687
		Bl	0	0	0	0	0
		Cw	728	1337	149	149	2321
		Hw	182	149	182	149	594
		Sx	0	149	0	297	297
		Tolerant	**5636**	**1252**	**182**	**278**	**6325**
		Fd	3269	297	0	0	3208
		Pw	0	0	0	0	0
		Semi-tolerant	**3269**	**297**	**0**	**0**	**3208**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**8911**	**1888**	**297**	**364**	**9391**

Table II.43. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Open” and “Slightly Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Slightly Wet	8	Bg	0	0	0	0	0
		Bl	828	0	0	0	828
		Cw	0	0	0	372	372
		Hw	0	0	0	0	0
		Sx	431	93	0	297	443
		Tolerant	**836**	**93**	**0**	**431**	**1064**
		Fd	195	93	0	93	241
		Pw	0	93	0	0	93
		Semi-tolerant	**195**	**122**	**0**	**93**	**233**
		Hardwood	**0**	**0**	**0**	**464**	**464**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**1240**	**195**	**0**	**543**	**1079**

Table II.44. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Dense” and “Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Wet	1	Bg	0	0	0	0	0
		Bl	0	0	0	0	0
		Cw	0	0	0	0	0
		Hw	0	0	0	0	0
		Sx	0	0	0	0	0
		Tolerant	**0**	**0**	**0**	**0**	**0**
		Fd	0	0	0	0	0
		Pw	0	0	0	0	0
		Semi-tolerant	**0**	**0**	**0**	**0**	**0**
		Hardwood	**0**	**0**	**0**	**0**	**0**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**0**	**0**	**0**	**0**	**0**

Table II.45. Standard error of the mean regeneration per ha by height class and species for years-since-disturbance class 5, basal area class “Open” and “Wet” sites.

Site	Number of plots	Species	Height class 1	2	3	4	**All Heights**
Wet	6	Bg	0	0	0	0	0
		Bl	124	0	0	0	124
		Cw	627	124	0	495	728
		Hw	0	0	0	0	0
		Sx	124	0	0	0	124
		Tolerant	**565**	**124**	**0**	**495**	**761**
		Fd	124	0	0	0	124
		Pw	124	0	0	0	124
		Semi-tolerant	**157**	**0**	**0**	**0**	**248**
		Hardwood	**0**	**157**	**0**	**124**	**254**
		Lw	0	0	0	0	0
		Pl	0	0	0	0	0
		Intolerant	**0**	**0**	**0**	**0**	**0**
		All Species	**879**	**166**	**0**	**486**	**806**