BAP REPORT #5: SPECIAL HABITAT ELEMENT MODEL DEVELOPMENT

Prepared for Millar Western Forest Products' Biodiversity Assessment Project

Prepared by:

F. Doyon[1] and H.L. MacLeod[2]

[1]Insitut Quebecois d'Amenagement de la Foret Feuillue, St.-Andre-Avellin, Quebec

AND

[2]KBM Forestry Consultants Inc., Thunder Bay, Ontario

May 2000

Table of Contents

List of Tables

List of Figures

5.1 INTRODUCTION

Habitat Supply Models (HSMs) are used to evaluate the potential for Millar Western's FMA area to provide suitable habitat for certain wildlife species selected for study under the Biodiversity Assessment Project (BAP). The models define habitat suitability based on the provision of certain habitat elements required for survival and reproduction (BAP Report #6: Habitat Supply Models, Higgelke *et al*. 2000).

Static environmental conditions (e.g. ecosite), position of infrastructure such as roads, and projected forest conditions (resulting from the rules defined from the projection scenario) provide some of the basic information that can be used in the HSMs. There are also many habitat elements, however, for which information is not provided directly from the usual forest projection tools that describe forest cover in terms of species composition and age. Special Habitat Element (SHE) models are mathematical models that characterise changes in the condition (e.g. abundance, density, coverage) of these habitat elements through forest succession and with disturbance based on empirical relationships, scientific literature, and professional judgement. This paper describes the development of the predictive SHE models. Figure 5.1 shows the role of the models in BAP.

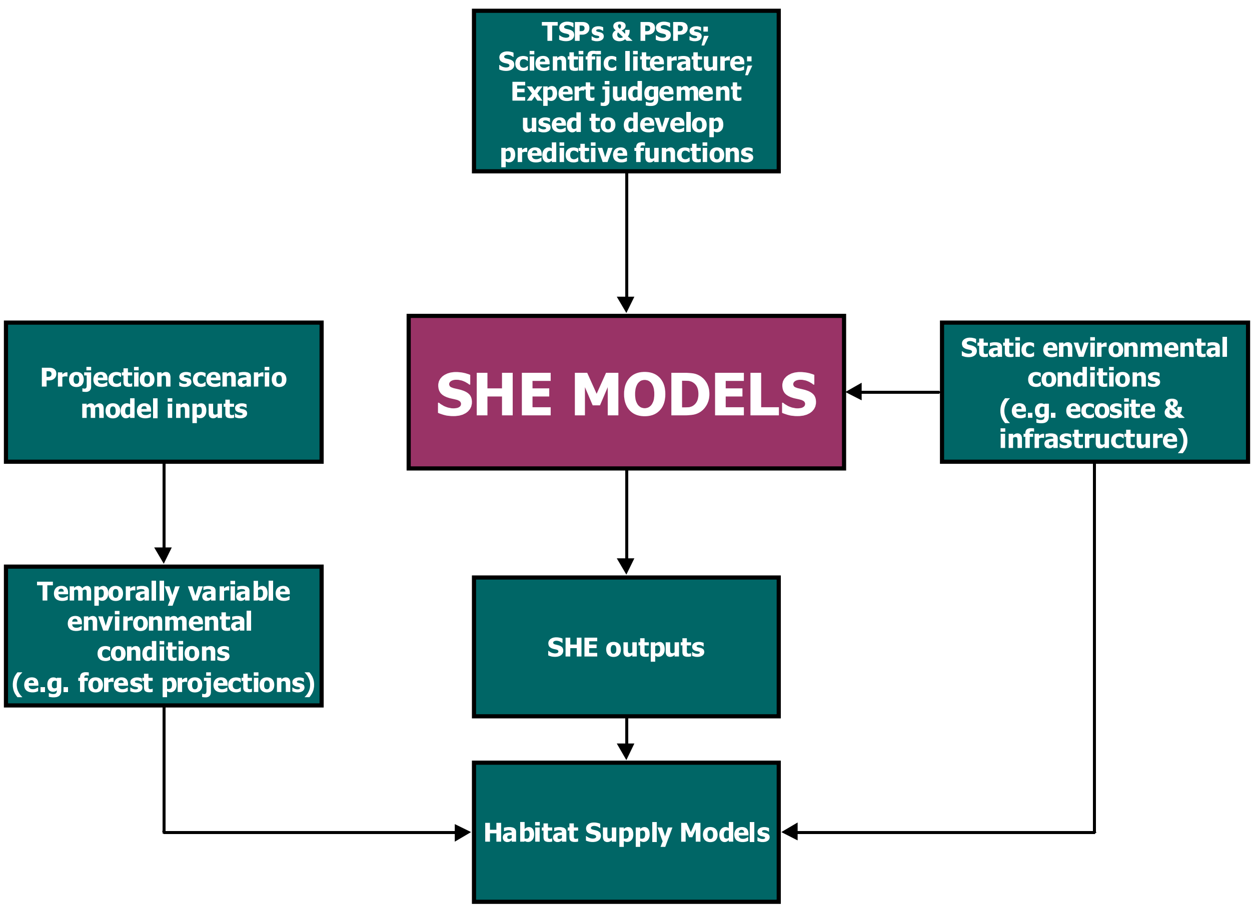

Figure 5.1. Role of the SHE models in BAP.

5.2 METHODS

General

SHE model development has taken place over the last several years along several simultaneous fronts. Between 1995 and 1997, a total of 641 plots were designated Temporary and Permanent Sample Plots (*i.e.*, 562 TSPs and 79 PSPs) within the FMA area. Although these plots were originally established to collect data for use in the development of empirical yield curves, the sampling design also included collection of data related to wildlife habitat elements (Millar Western 1998) to be used in SHE model development.

Field data relating to wildlife habitat requirements were collected in the summers of 1997 and 1998, prior to HSM development. Extensive literature reviews and consultation with wildlife biologists regarding the habitat requirements of selected wildlife species (BAP Report #2: Species Selection Procedure, Doyon and Duinker 2000) were completed and HSMs were developed for these species (BAP Report #6: Habitat Supply Models, Higgelke *et al*. 2000). In addition, mapped inventories showing forest cover (from AVI Volume 2.2) and forest ecosite type (Beckingham and Nielsen 2000) within the FMA area were completed. Thus, it was necessary to balance the list of habitat requirements identified in the scientific literature with the data available from the TSPs and PSPs and the information contained on the prepared maps.

The first step in SHE model creation was the development of a numerical representation of the way SHE variables change during natural stand development. These models were then modified to take into account the changes that are thought to occur under an intensive silviculture regime. The BAP team attempted to identify the potential influence of the various crop planning procedures and modifications that Millar Western plans to apply to selected stands within its landbase.

The factors thought to cause change to the SHEs are listed in Table 5.1. Management activities that are part of the crop planning system are also shown.

Table 5.1. Description of disturbance factors used in SHE model development.

Disturbance Factor	Treatment
Crop Plan	Site Preparation
Crop Plan	Spacing
Crop Plan	Pre-commercial Thinning
Modifier	Commercial Thinning

The SHE variables

The SHE models predict the abundance of 20 habitat elements. Two of these are dependent upon stand age, eight are dependent upon canopy closure and/or ecosite, and 10 are dependent upon habitat type (*i.e.*, a combination of tree species composition and developmental stage). Canopy closure was modelled as a stand age dependent variable for each habitat type-productivity combination. In this manner, all SHE models are time-related functions designed to be compatible with forest projection outputs from GIS COMPLAN and WOODSTOCK/STANLEY simulation tools (Millar Western 2000).

Tables 5.2 to 5.4 present the SHE variables. They have been divided into continuous age-dependent and discrete habitat type variables. Continuous variables have been further subdivided. Continuous variables are those driven by canopy closure and/or ecosite (Table 5.2) and those driven by stand age (Table 5.3). Discrete models are listed in Table 5.4. The application of each SHE variable in HSMs is also presented. For all variables, except canopy closure, data sources were all TSPs and PSPs. For canopy closure, TSPs and PSPs that were affected by anthropogenic disturbances were excluded from the dataset.

Table 5.2. Canopy closure driven continuous SHE variables including variable definitions and application in BAP.

Continuous - Canopy Closure Driven		
SHE Function	**Dependent Variable Definition**	**Application**
Forb cover versus canopy closure by ecosite.	The percentage of the forest floor covered by forbs.	Used in Elk, Moose, and Woodland Caribou HSMs.
Fruit-bearing shrub cover versus canopy closure by ecosite.	The percentage of the forest floor covered by fruit-bearing shrubs. The list of fruit-bearing shrubs included in model development are listed in Appendix B.	Used in Varied Thrush HSM.
Grass and grass-like vegetation cover by canopy closure and ecosite.	The percentage of the forest floor covered by grass and other grass-like vegetation.	Used in Elk and Moose HSMs.
Lichen cover versus canopy closure by ecosite.	The percentage of the forest floor covered by lichens.	Used in Woodland Caribou HSM.
Sedge cover versus canopy closure.	The percentage of the forest floor covered by sedge species.	Used in Elk, Moose, and Woodland Caribou HSMs.
Shrub cover versus canopy closure.	The percentage of the forest floor covered by shrubs (all woody plants, including commercial species) divided into six height classes: 0-25 cm; 25.1-50 cm; 50.1-100 cm; 1.1-2 m; 2.1-3 m; > 3 m.	Used in all HSMs except Barred Owl, Brown Creeper, Canada Lynx, Least Flycatcher, Northern Goshawk, Pileated Woodpecker, and Three-toed Woodpecker.
Willow cover versus canopy closure by ecosite.	The percentage of the forest floor covered by willow.	Used in Moose HSM.
Willow and rose cover versus canopy closure by ecosite.	The percentage of the forest floor covered by willow and rose.	Used in Snowshoe Hare HSM.

Table 5.3. Stand age driven continuous SHE variables including variable definitions and application in BAP.

Continuous - Stand Age Driven		
SHE Function	**Dependent Variable Definition**	**Application**
Canopy closure versus stand age by broad habitat type and productivity combination.	The percentage of the forest floor covered by the crown of the trees.	Used as an independent variable in several other SHE models. As well, used for all HSMs except the Least Flycatcher, Northern Flying Squirrel, Snowshoe Hare, and Southern Red-backed Vole.
Stand height versus stand age by broad habitat type and productivity combination.	Mean height (m) of all trees in a stand; differences between single- and multi-storied stands are not considered.	Used in Elk and Moose HSMs.

Table 5.4. Discrete SHE variables including variable definitions and application in BAP.

Discrete		
SHE Function	**Dependent Variable Definition**	**Application**
Free-to-manoeuvre flying space by habitat type.	A qualitative description of the density of the subcanopy of a stand. It describes the ease with which a flying animal will move through a stand.	Used in Barred Owl, Pileated Woodpecker, and Northern Goshawk HSMs.
Arboreal lichen cover by habitat type.	The proportion of tree branches and boles covered by lichens of the genera Uspea, Bovoria, and Alectoria.	Used in Northern Flying Squirrel and Woodland Caribou HSMs.
Density of trees with height to live crown < 1 m and dbh > 5 cm by habitat type.	Number of trees per ha.	Used in Marten, Northern Flying Squirrel, Ruffed Grouse, Southern Red-backed Vole, and Spruce Grouse HSMs.
Density of dead, damaged, and diseased trees > 16 cm dbh by habitat type.	Number of trees per ha.	Used in Pileated Woodpecker HSM.
Density of dead, damaged, and diseased trees > 20 m height and > 25 cm dbh by habitat type.	Number of trees per ha.	Used in Three-toed Woodpecker HSM.
Density of dead, damaged, and diseased trees > 25 cm dbh by habitat type.	Number of trees per ha.	Used in Brown Creeper HSM.
Density of dead, damaged, and diseased trees 25-40 cm dbh by habitat type.	Number of trees per ha.	Used in Pileated Woodpecker HSM.
Density of dead, damaged, and diseased trees > 40 cm dbh by habitat type.	Number of trees per ha.	Used in Pileated Woodpecker HSM.
Height to live crown by habitat type.	Average height to live crown of all trees in the stand.	Used in Elk, Least Flycatcher, and Moose HSMs.
Downed woody debris cover by habitat type.	The percentage of the forest floor covered by downed woody debris of all sizes, shapes, and stages of decay.	Used in Marten, Northern Flying Squirrel, Snowshoe Hare, Southern Red-backed Vole, and Spruce Grouse HSMs.

Development of SHE models

The SHE models describe natural stand development and succession assuming no recent disturbance. This is consistent with the sample plot design as undisturbed stands were selected. To model the response of each SHE variable to planned timber harvests, modifications were required. These modifications relied exclusively upon reference and expert opinion as opposed to the data-driven natural SHE models.

The SHE model modifications incorporate both disturbance and recovery. The value attributed to a SHE variable for a disturbed stand within a given time step (*i.e.*, scheduled for harvest) is modified by a disturbance factor that is expressed as a percent of the "natural" stand condition. A recovery factor is also expressed as a percent and modifies the SHE variable value during the time steps following the disturbance by an amount added to the preceding time period disturbance or recovery factor. This additive factor is used to modify the "natural" stand condition represented by the SHE variable for that specific time period. The maximum recovery factor is used to limit the recovery from disturbance, generally to a value equal to the stand's natural condition (100%). Over time, some silviculture activities might result in a permanent change in the value of a SHE variable. This is expressed by a maximum recovery factor greater than 100%. SHE variables that never recover to natural conditions following a specific disturbance are given a recovery factor less than 100%.

Assumptions made in SHE model development

We have made some broad assumptions in the application of SHE models and modifiers. First, we assume harvest conditions are well enough represented by setting stand age and canopy closure to origin (*i.e.*, zero). Second, current stand replacing silviculture practices will be tracked along natural yield and SHE model trajectories. As such, modifiers are only assigned to "crop planned" stands, representing an enhanced forest management practice. Site preparation includes some form of mechanical or chemical treatment with subsequent tending. These treatments are thought to influence only the SHE variables describing conditions of the low understorey (*i.e.*, shrub layer and below). Although it is likely that site preparation is used in all managed stands, modifiers for habitat elements above the shrub layer are not required or are accounted for in the species composition changes resulting from a complete silviculture package.

All of the assumptions used in SHE model development and application of modifiers require testing. The monitoring program developed through the DFMP process specifically targets the validation of both the SHE models and the modifications associated with disturbance.

Linear and non-linear regression methods were used to develop equations that best fit data supporting the continuous groups of SHE models. Plots of individual data points or cell average for each broad habitat type were used for the discrete groups of SHE models. The results of all statistical analyses run during relationship and SHE model development have been included in Appendix A.

Development of relationships

It was necessary to identify several general relationships prior to SHE model development (*i.e.*, the relationships between ecosite and productivity class, basal area and stand age, free-to-manoeuvre flying space and habitat type, and arboreal lichen coverage and habitat type).

Ecosite phase-productivity class relationship

Based on information obtained from the Field Guide to Ecosites of West-central Alberta (Beckingham and Archibald 1996) that suggested the soil condition and dominant plant types of each ecosite, the BAP team designated each ecosite type a productivity rating as shown in Table 5.5.

Basal area-stand age relationship

To determine the relationship between basal area and stand age, data from all sample plots were pooled together to obtain a general third-order polynomial relationship (Figure 5.2).

Table 5.5. Designation of productivity class based on ecosite phase.

Land Type	Productivity Class
Blueberry	Fair
Bog/Black Spruce-Tamarack	Fair
Hairy Wild Rye	Fair
Labrador Tea Subhygric	Fair
Lichen	Fair
Labrador Tea Hygric	Medium
Labrador Tea Mesic	Medium
Lowbush Cranberry	Medium
Bracted Honeysuckle	Good
Horsetail	Good

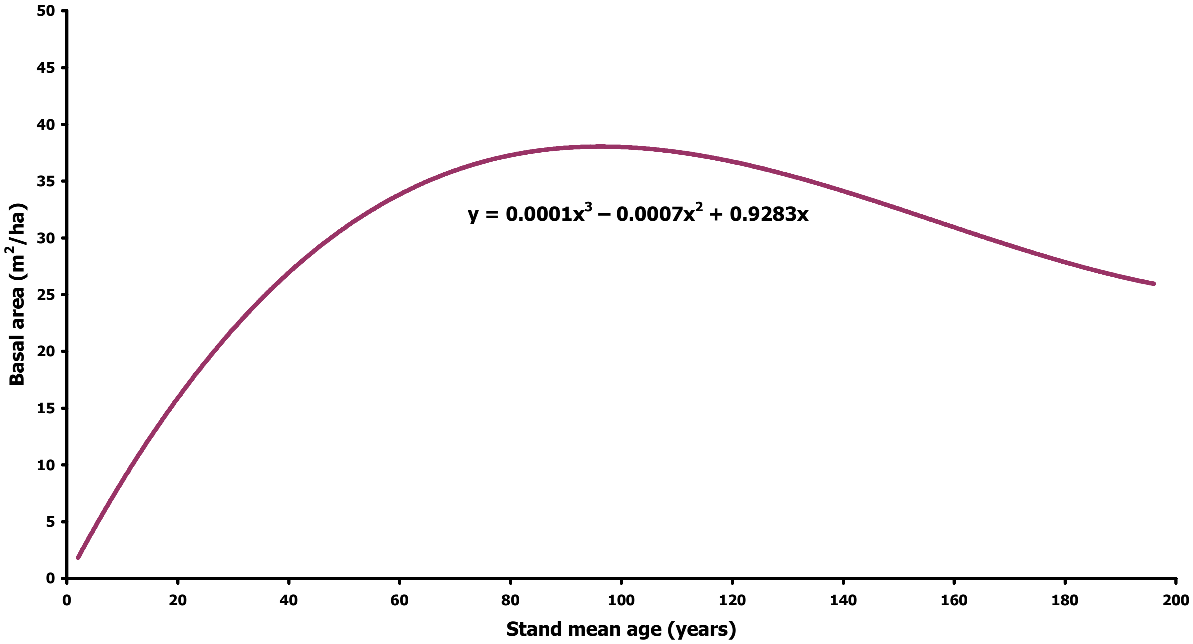

Figure 5.2. General third-order polynomial relationship between basal area (m^2/ha) and mean age (years).

The effect of productivity on basal area is clearly distinguishable. On sites with higher productivity, maximum basal area is reached earlier than on less productive sites. When compared to hardwood and softwood stands, mixedwood stands appear to have higher maximum basal area. Based on these results, the general equation was used to determine the relative difference between productivity and composition classes (Figures 5.3 to 5.5).

Free-to-manoeuvre flying space-habitat type relationship

Free-to-manoeuvre flying space represents the clarity of flyways in the understorey and indicates the influence of vegetation on the manoeuvrability of flying animals. It is characterised by three categories: clear, porous/obstructed, and entangled. To distinguish between these categories requires subjective judgement. Clear flying space would be provided by well spaced trees with no low branches and understorey obstructing movement. Porous/obstructed flyways are those in which some obstacles limit certain passages but it is possible to move from one point to another without having to change direction. Entangled habitats are those in which it would be practically impossible to fly under the canopy (Millar Western 1998).

By comparing the classifying power of several independent variables, we found that habitat type was the most discriminating variable. Therefore, log-linear procedures used broad composition and developmental classes to predict free-to-manoeuvre flying space conditions. Through this, we identified the probability that each of the three free-to-manoeuvre flying space values would be associated with a habitat type. Each category was given a weight based on this probability:

- Clear = 1;
- Porous/obstructed = 2; and
- Entangled = 3.

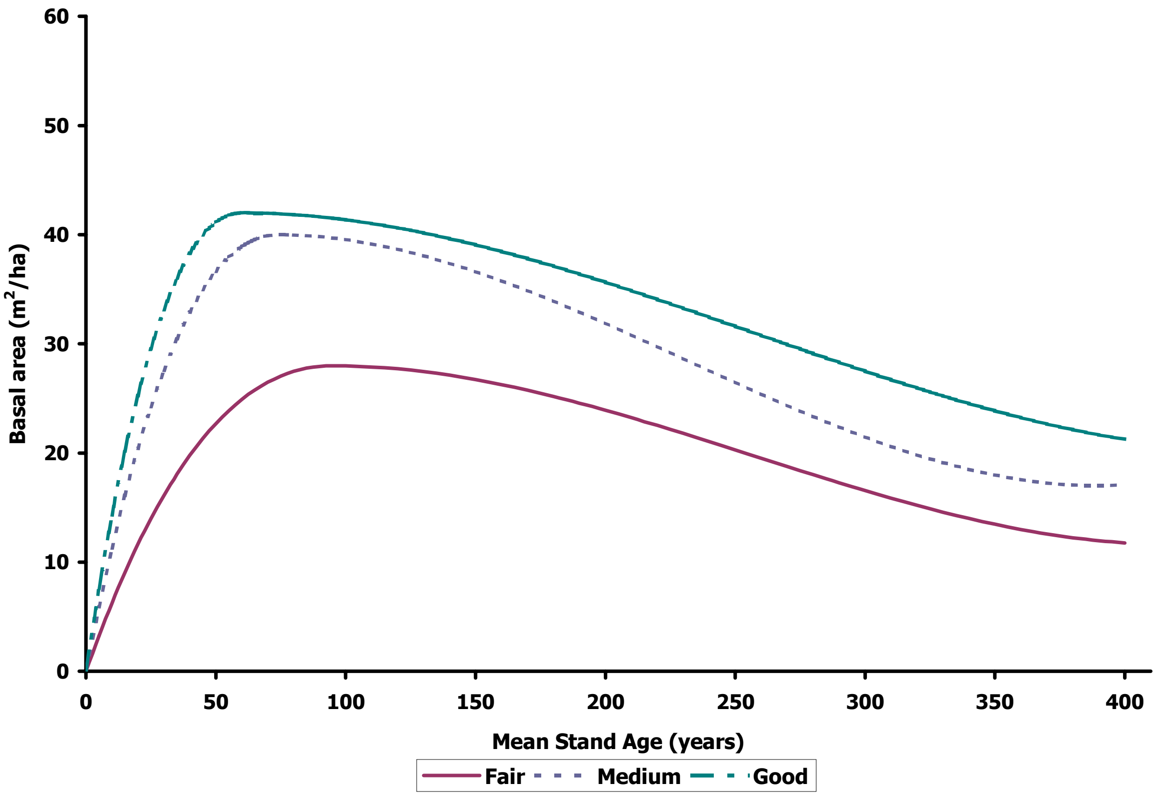

Figure 5.3. **Basal area (m^2/ha) and stand age (years) relationships for different productivity classes in hardwood stands.**

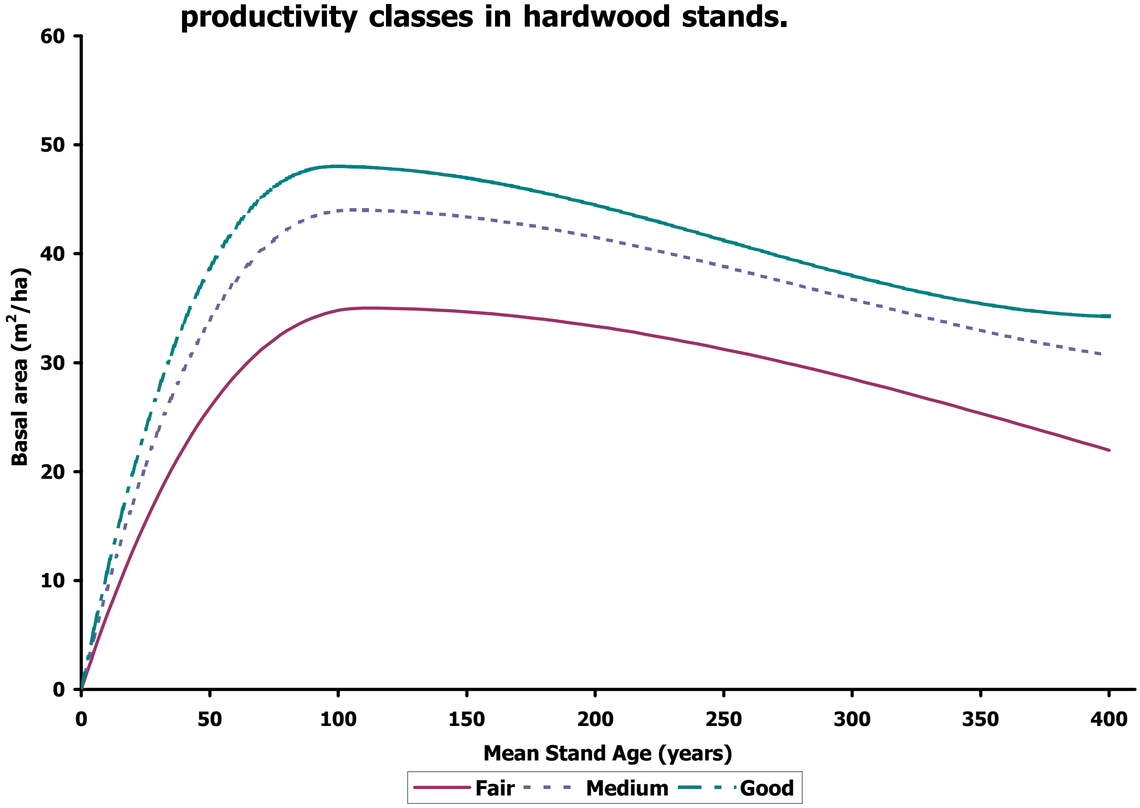

Figure 5.4. **Basal area (m^2/ha) and stand age (years) relationships for different productivity classes in mixedwood stands.**

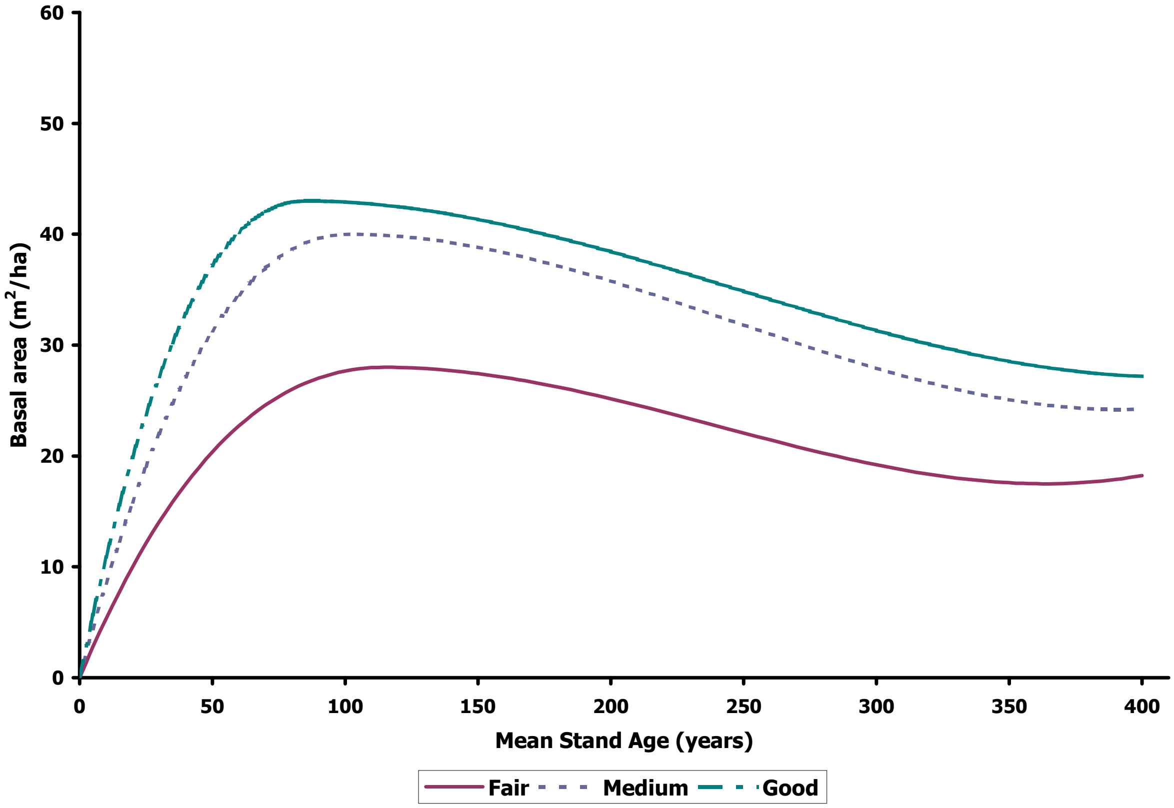

Figure 5.5. Basal area (m^2/ha) and stand age (years) relationships for different productivity classes in softwood stands.

Arboreal lichen coverage-habitat type relationship

To categorise the amount of arboreal lichen present on the branches and boles of trees within the sample plots, the following classification system was used (Table 5.6).

To determine plot level information of arboreal lichen cover, an index of arboreal lichen abundance was calculated for each tree that was sampled. This index considers the arboreal lichen cover class transformed into percentage based on the values shown in Table 5.6, tree height and diameter, height to the first branch (dead or alive), and crown class. The following percentages were assigned to each crown class:

- Dominant = 100%;
- Co-dominant = 75%;
- Intermediate = 50%; and
- Suppressed = 25%.

Table 5.6. Arboreal lichen cover classes and their description.

Class	% expressed	Description
None	0	None
Trace	5	Present
Low	10	Small amounts on most branches
Medium	25	Significant amounts on most branches
High	50	Heavy coverage, draping off most branches

The equation used to determine the arboreal lichen index was:

Tree basal area * (height - height to first branch) * lichen class % * crown class %

The arboreal lichen index was calculated at the plot level. Older developmental stages tend to have more arboreal lichen cover. In addition, softwood-dominated stands have more arboreal lichen than hardwood-dominated stands.

In the Results section, we present explanations of all continuous and discrete SHE models, as well as the changes to the variables expected with disturbance by management. Along with the forested habitat types designated by the BAP team, there are a number of non-forested habitat types (e.g. water bodies, barren and scattered land, and farmsteads) that may support some of the desired SHEs. In BAP, we assume that these non-forested habitat types do not change over time or with disturbance. Therefore, the condition of the SHE variable can be predicted as a static value. These static SHE models are also presented in the Results section.

5.3 RESULTS

Appendix B provides the look-up tables used to identify the relationships shown in this section.

Natural SHE models

Canopy closure

To transform the relationship between basal area and stand age described above into a relationship between canopy closure and stand age, it was assumed that the highest basal area corresponded to 100% canopy closure. Mixedwood stands on highly productive sites exhibit the highest average basal area at 100 years. This was used as a benchmark of 100% average canopy closure to which all of the habitat type and site combinations were compared. The results are shown in Figures 5.6 to 5.8.

Mean stand height

Trend lines for mean stand height and stand age in hardwood, mixedwood, and softwood stands were analysed in ten-year age class groups for each of the productivity classes as shown in Figures 5.9 to 5.11. Trees in stands on productive sites tend to be taller.

Shrub cover

Figure 5.12 shows that increases in canopy closure are associated with decreases in shrub cover. Trends are shown for shrub cover in the following six categories:

- All heights;
- Between 0 and 0.25 m;
- Between 0.26 and 0.50 m;
- Between 0.51 and 1 m;
- Between 1.1 and 2 m;
- Between 2.1 and 3 m; and
- Taller than 3 m.

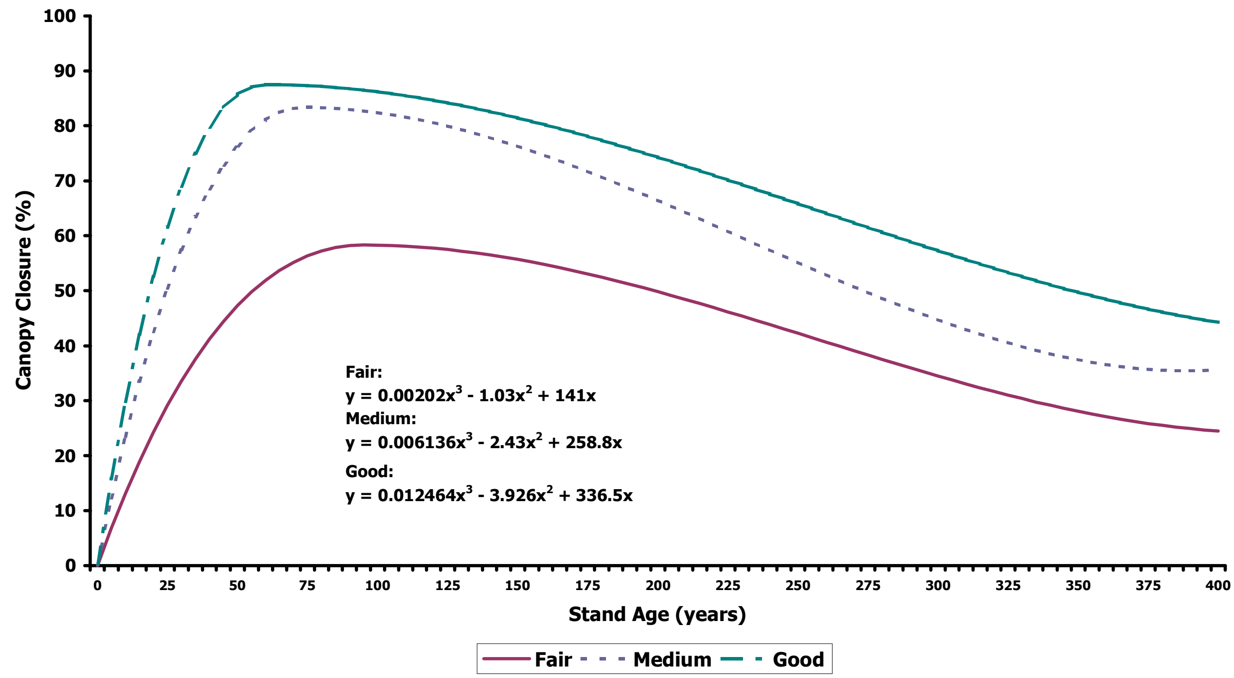

Figure 5.6. **Canopy closure (%) and stand age (years) relationships for different productivity classes in hardwood stands.**

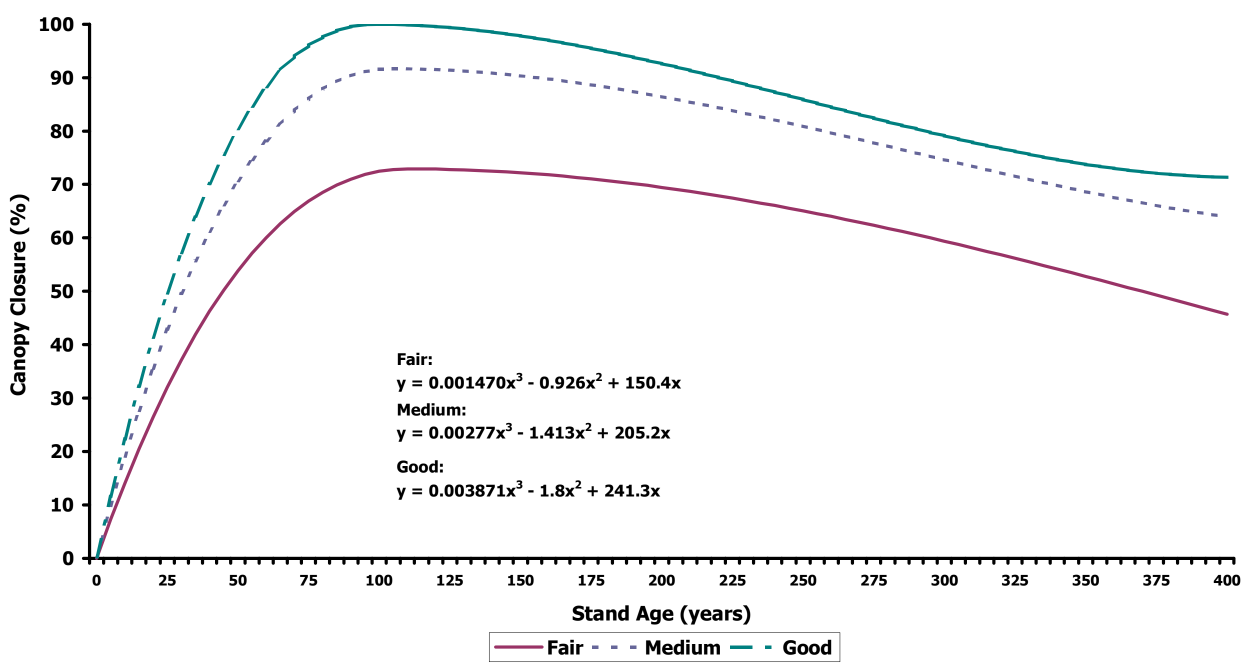

Figure 5.7. **Canopy closure (%) and stand age (years) relationships for different productivity classes in mixedwood stands.**

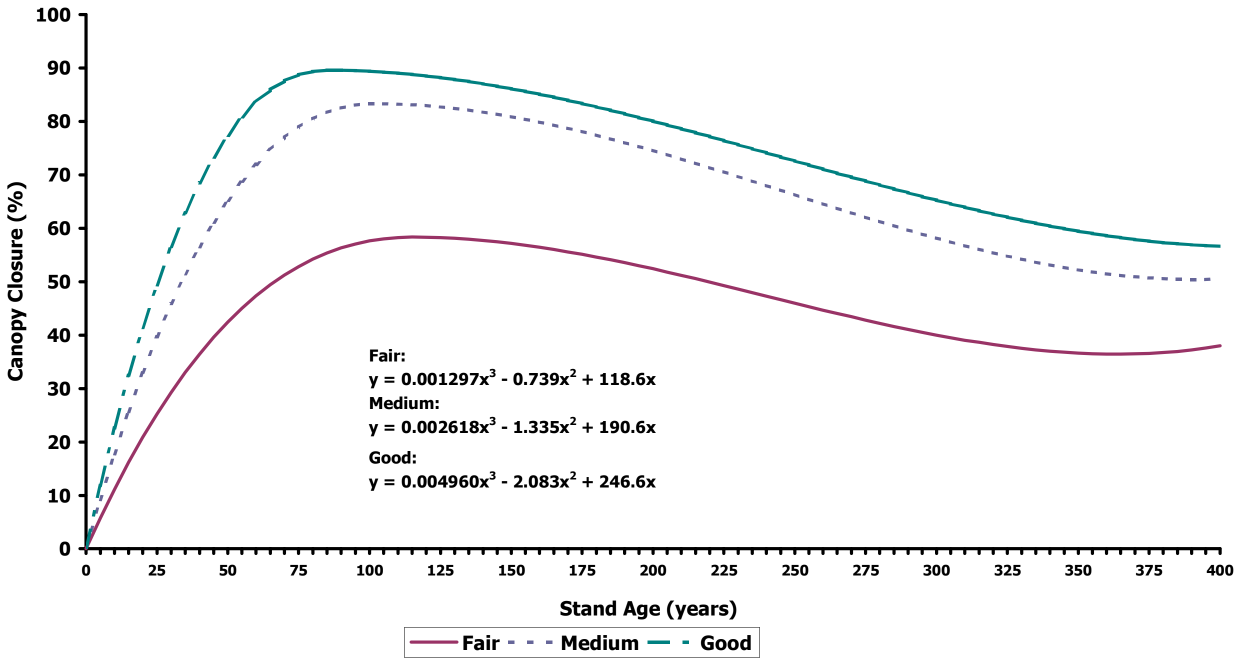

Figure 5.8. Canopy closure (%) and stand age (years) relationships for different productivity classes in softwood stands.

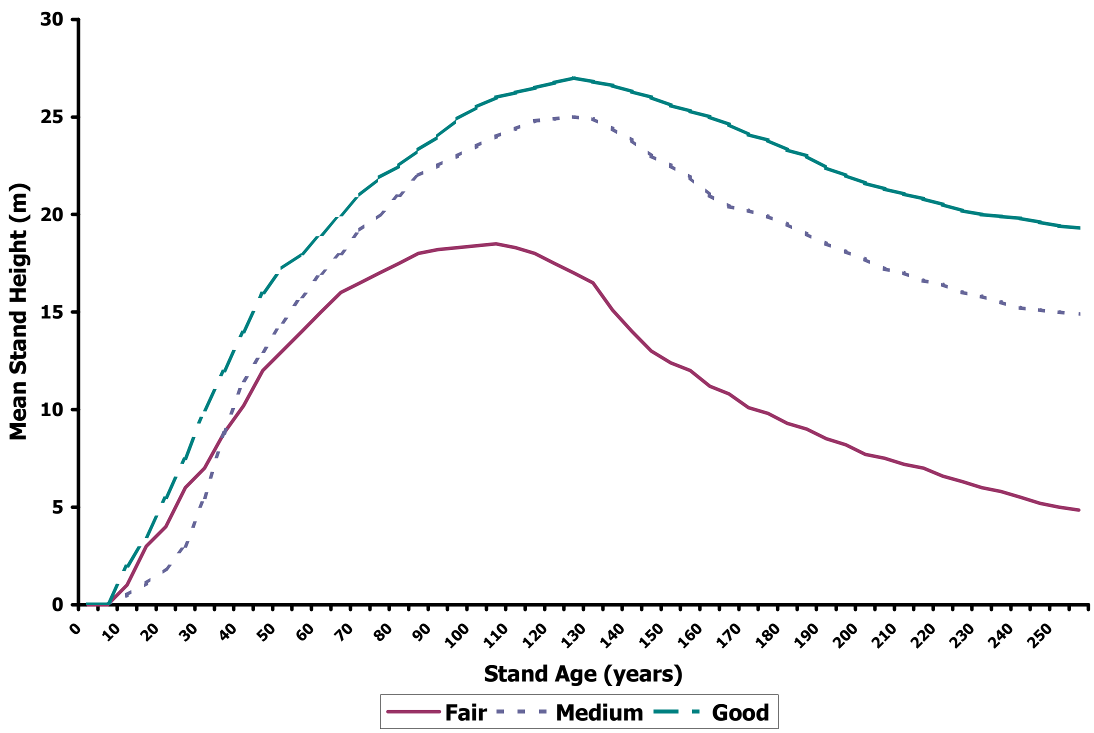

Figure 5.9. Stand height (m) and stand age (years) relationships for different productivity classes in hardwood stands.

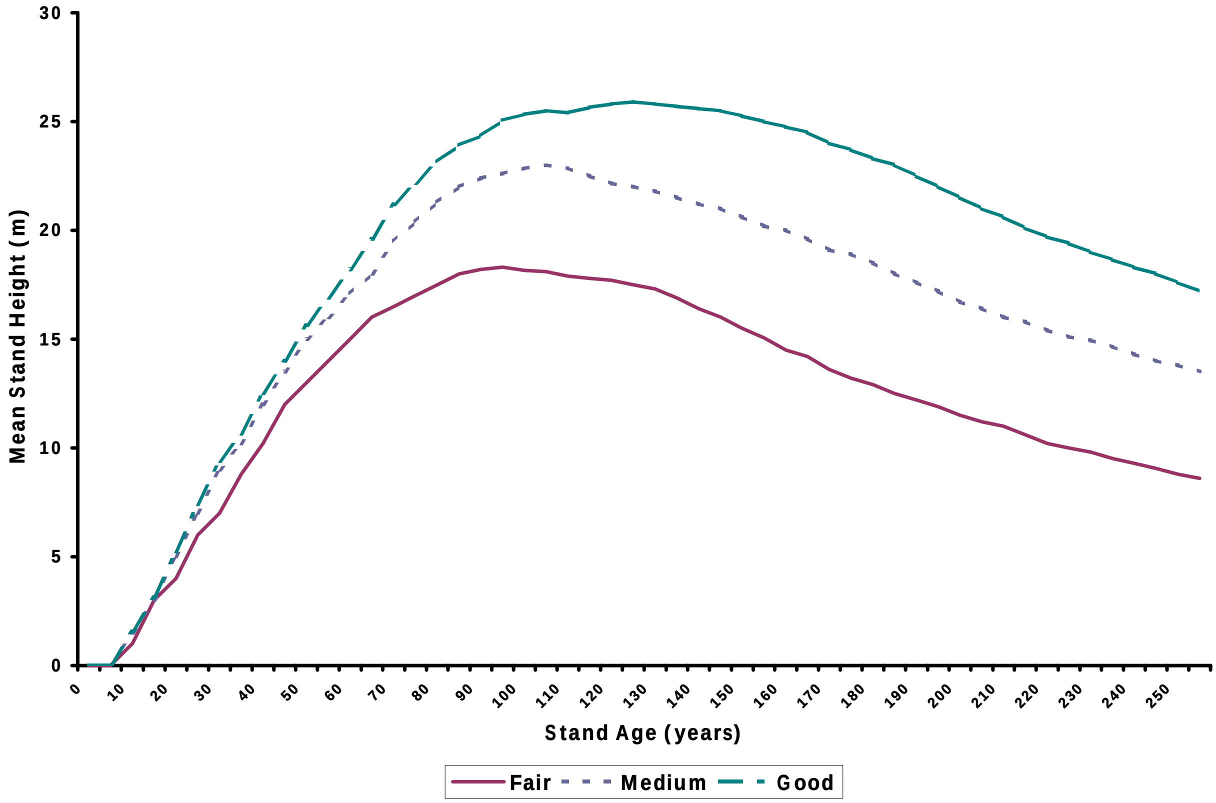

Figure 5.10. Stand height (m) and stand age (years) relationships for different productivity classes in mixedwood stands.

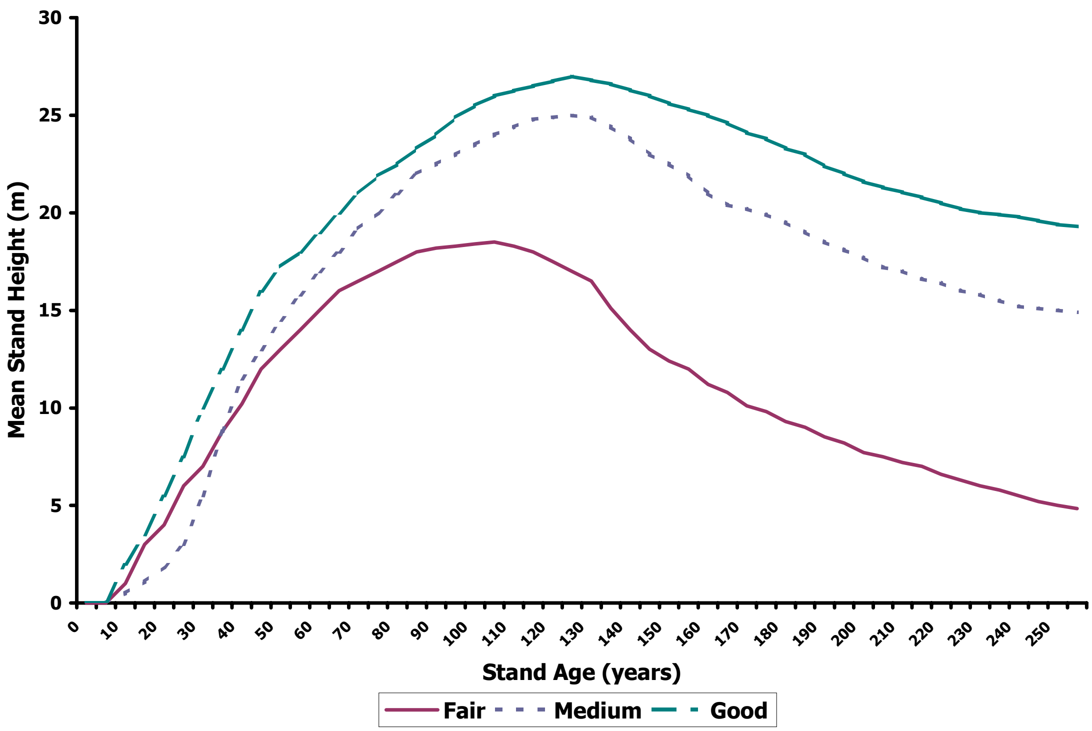

Figure 5.11. Stand height (m) and stand age (years) relationships for different productivity classes in softwood stands.

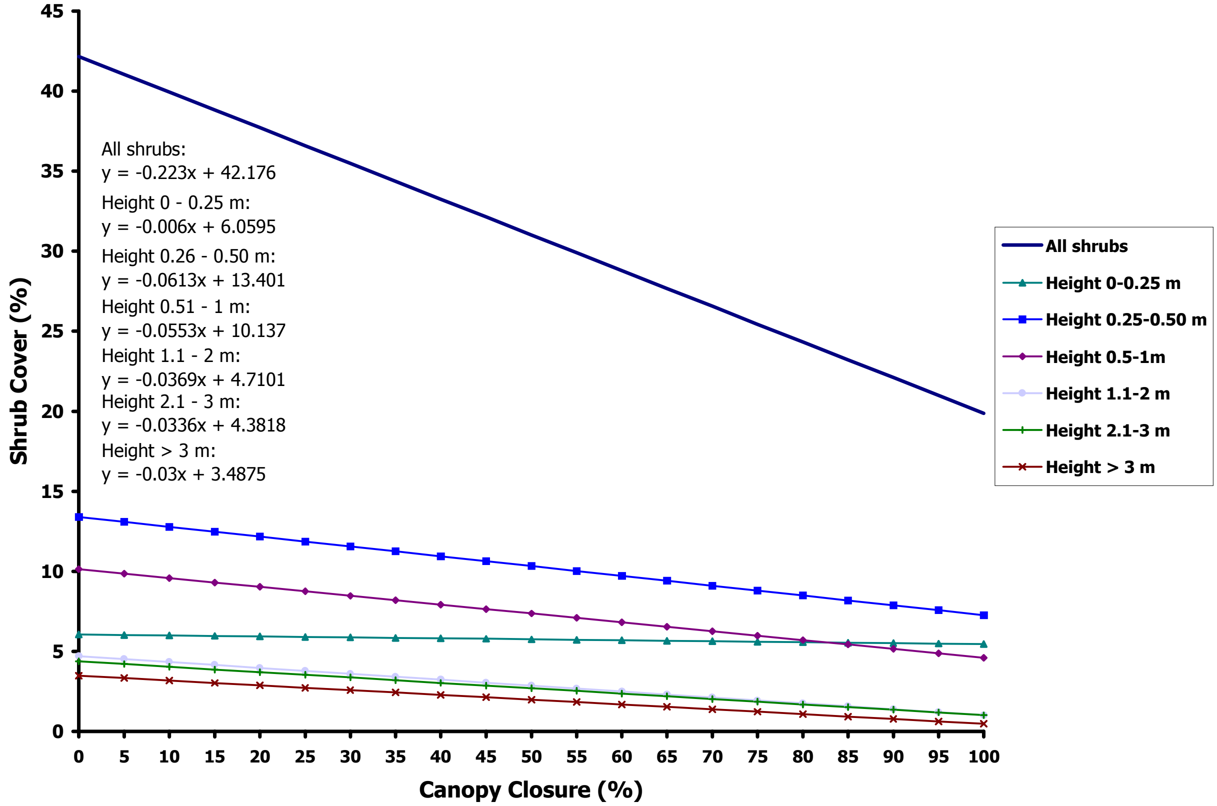

Figure 5.12. Shrub cover (%) by height classes in relation to canopy closure (%).

Herbaceous vegetation cover

For each type of herbaceous vegetation (forbs, grasses, ferns, and sedges), the relationship between plant cover and canopy closure on different ecosites was examined (Figures 5.13, 5.14, and 5.15, based on pre-identified relationships between canopy closure and basal area). Though there are ten ecosite types, information was available for only nine of these (*i.e.*, since too few PSP and TSPs were placed within the Lichen ecosites, this ecosite type was not represented). Since the Lichen and Hairy Wild Rye ecosite types are similar in condition, the Hairy Wild Rye ecosite was used as a proxy for the conditions of the Lichen ecosite in all SHE models that include ecosite as a subunit.

The relationship between forb, grass, and fern cover and canopy closure by ecosite follows the equation form: vegetation cover (%) = a + b(canopy closure (%)). For ecosites where changes in basal area (*i.e.,* canopy closure) were found to have very little effect on herbaceous vegetation cover, the value of constant b was set to 0 and mean herbaceous vegetation cover was used. That is, herbaceous vegetation cover remains constant regardless of canopy closure. These constant values are shown in Tables 5.7 to 5.10.

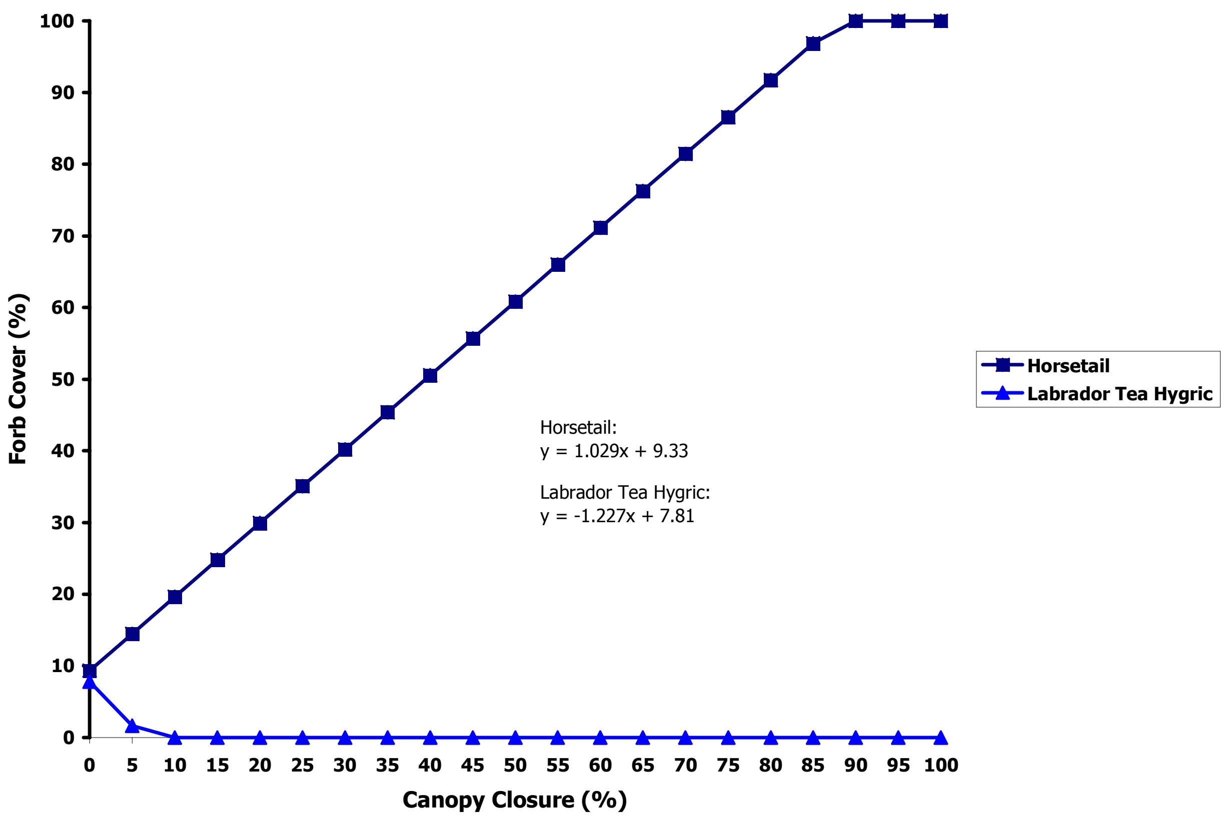

Figure 5.13. Forb cover (%) in relation to canopy closure (%) by ecosite.

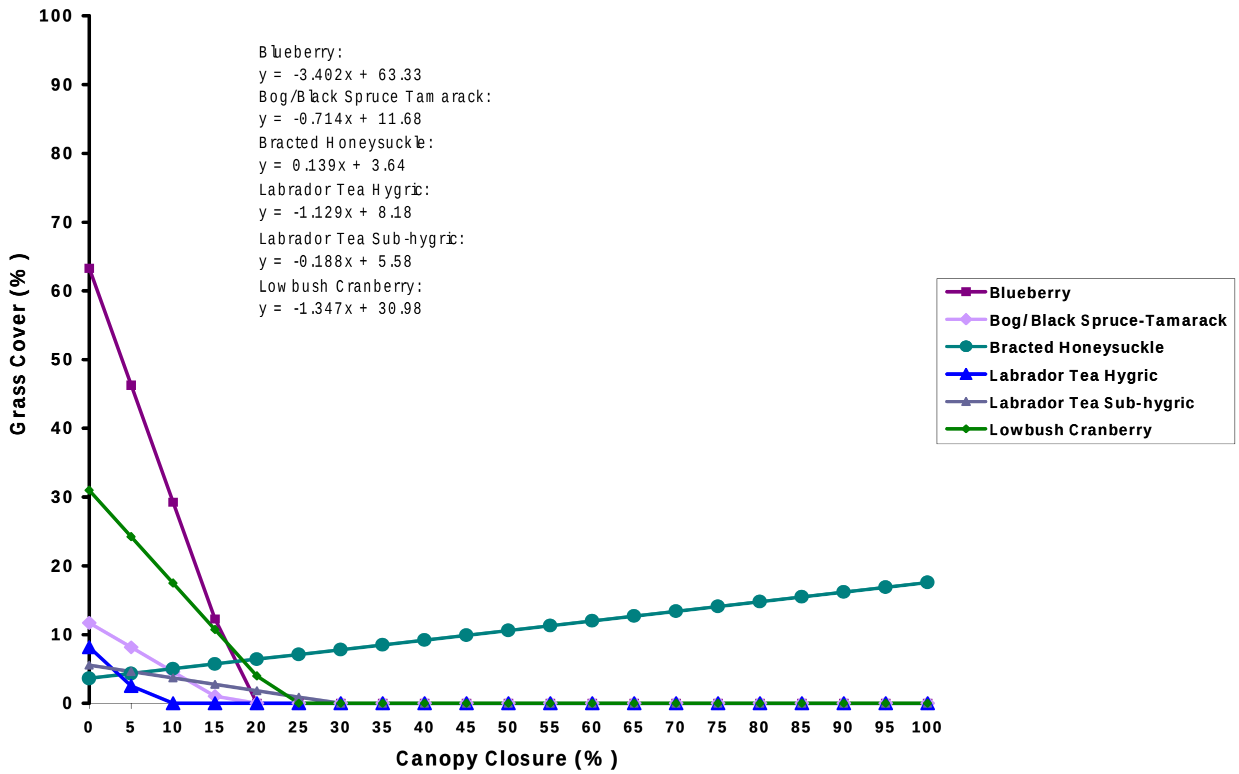

Figure 5.14. Grass cover (%) in relation to canopy closure (%) by ecosite.

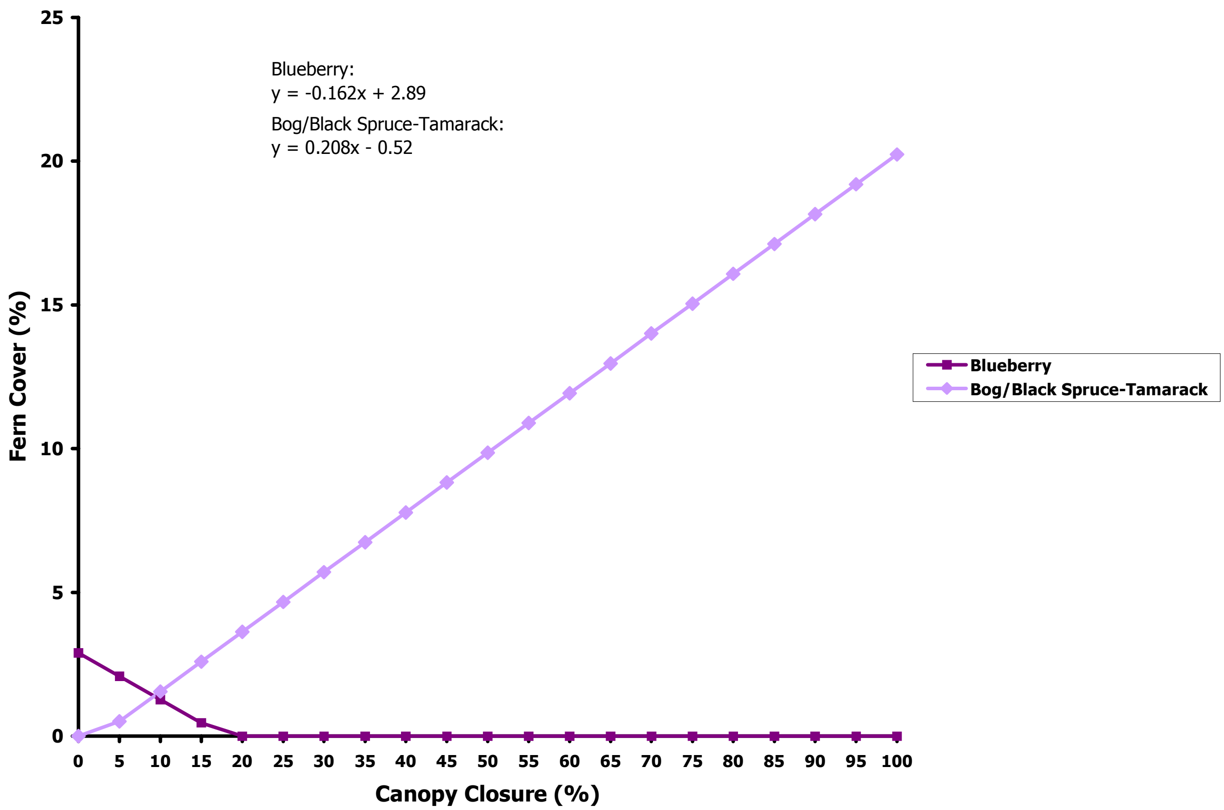

Figure 5.15. Fern cover (%) in relation to canopy closure (%) by ecosite.

Table 5.7. Forb cover (%) by ecosite.

Ecosite	Forb Cover (%)
Blueberry	12.28%
Bog/Black Spruce Tamarack	7.91%
Bracted Honeysuckle	6.79%
Hairy Wild Rye	15.00%
Labrador Tea Mesic	6.56%
Labrador Tea Sub-hygric	5.59%
Lichen	15.00%
Lowbush Cranberry	13.54%

Table 5.8. Grass cover (%) by ecosite.

Ecosite	Grass Cover (%)
Horsetail	9.61%
Hairy Wild Rye	37.00%
Labrador Tea Mesic	2.09%
Lichen	37.00%

Table 5.9. Fern cover (%) by ecosite.

Ecosite	Fern Cover (%)
Bracted Honeysuckle	0.45%
Horsetail	0.00%
Hairy Wild Rye	2.66%
Labrador Tea Hygric	0.00%
Labrador Tea Mesic	0.41%
Labrador Tea Sub-hygric	0.38%
Lichen	2.66%
Lowbush Cranberry	0.72%

Table 5.10. Sedge cover (%) by ecosite.

Ecosite	Sedge Cover (%)
Xeric	0.07%
Moist	0.33%
Hygric	3.37%
Wet	9.81%

Willow and rose cover

The relationship between willow and rose cover and canopy closure by ecosite follows the equation form: willow and rose cover (%) = a + b(canopy closure (%)). The values for the constants a and b differ by ecosite (Figure 5.16). For ecosites that were found not to have a significant relationship between willow and rose cover and canopy closure, the value of the constant b was set to 0 and mean willow and rose cover was used (Table 5.11).

Willow cover

The regression equation (Figure 5.17) determined from plotted data points from PSP and TSP databases follows the structure: willow cover (%) = a + b(canopy closure (%)). There is no significant relationship between ecosite type and willow cover. It is thought, however, that wetter sites support more willow than drier sites. Therefore, we propose that the willow cover equation be doubled for land existing within 50 m of water.

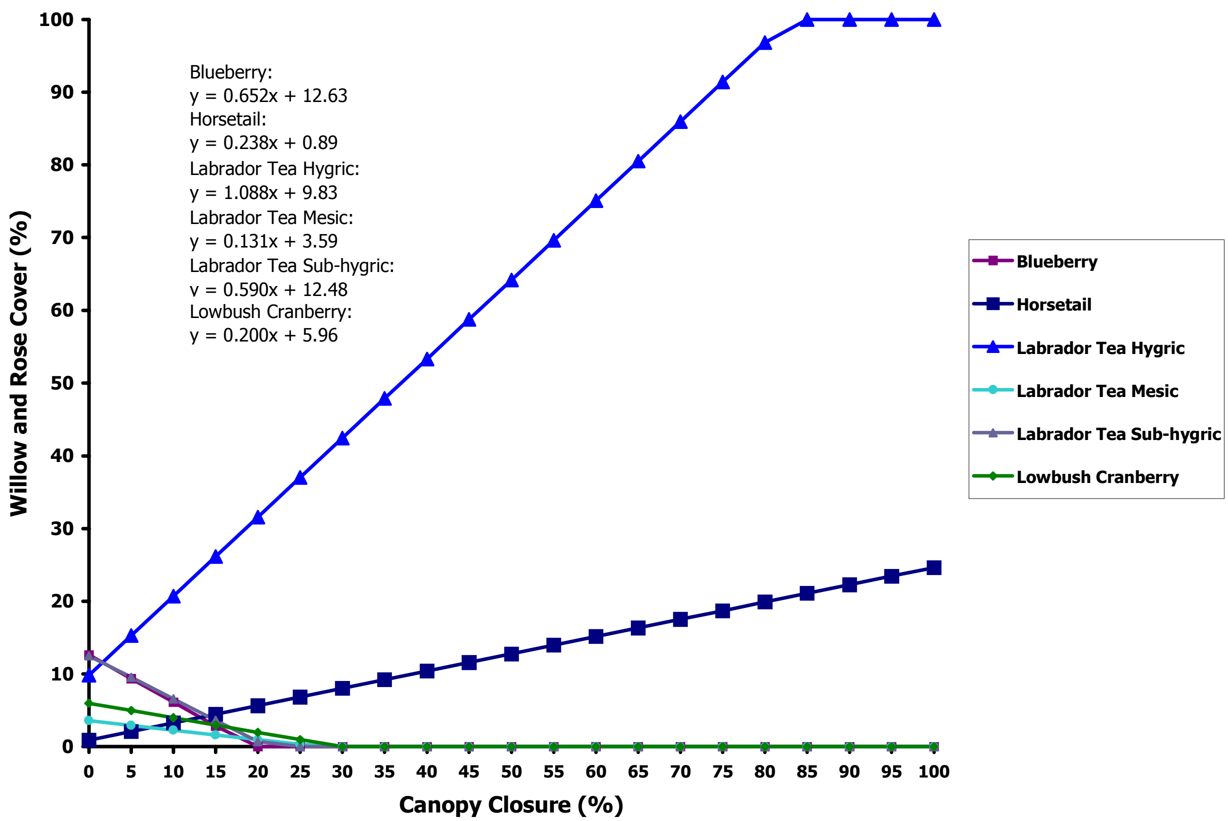

Figure 5.16. Willow and rose cover (%) in relation to canopy closure (%) by ecosite.

Table 5.11. Willow and rose cover (%) by ecosite.

Ecosite	Willow and Rose Cover (%)
Bog/Black Spruce Tamarack	6.86%
Bracted Honeysuckle	3.47%
Horsetail	16.00%
Lichen-bearberry	16.00%

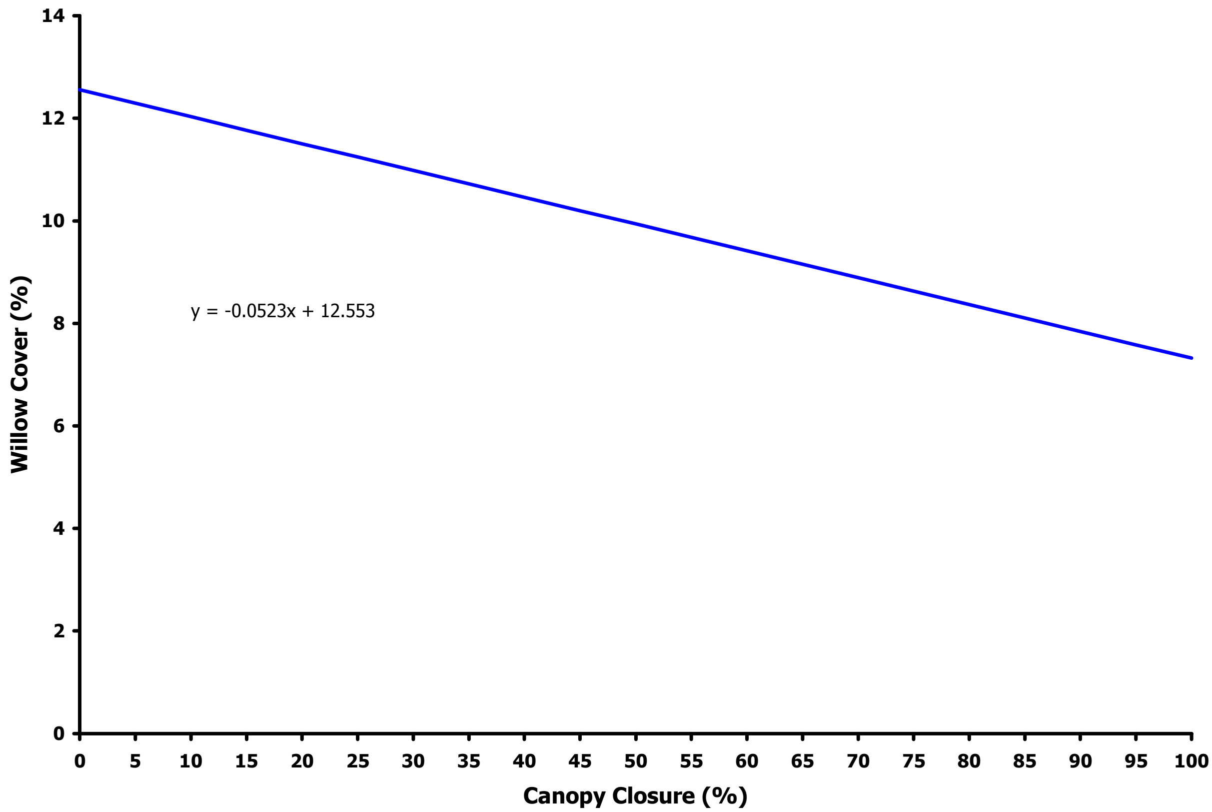

Figure 5.17. Willow cover (%) in relation to canopy closure.

Fruit-bearing shrub cover

The relationship between fruit-bearing shrub cover and basal area was examined for each ecosite. It was found that fruit-bearing shrub cover was the highest on Blueberry, Bracted Honeysuckle, Hairy Wild Rye, Horsetail, and Lowbush Cranberry ecosites. Only Blueberry, Labrador Tea Hygric, and Lowbush Cranberry ecosites showed a significant relationship between basal area (*i.e.*, canopy closure) and fruit-bearing shrub cover (Figure 5.18). For the other ecosites, mean fruit-bearing shrub coverage is used to predict fruit-bearing shrub cover by ecosite (Table 5.12). The relationship between fruit-bearing shrub cover and canopy closure follows the equation form: fruit-bearing shrub cover (%) = a + b(canopy closure (%)).

Lichen cover

The relationship between lichen cover and canopy closure on different ecosites was examined (Figure 5.19, based on the pre-identified relationship between lichen cover and basal area). The relationship between lichen cover and canopy closure by ecosite follows the equation form: lichen cover (%) = a + b(canopy closure (%)). For ecosites where changes in basal area (*i.e.,* canopy closure) were found to have very little effect on lichen cover, the value of constant b was set to 0 and mean lichen cover was used (Table 5.13).

Free-to-manoeuvre flying space

Based on the relationship described above that correlated free-to-manoeuvre flying space (FTMFS) and habitat type, a look-up table was created for the SHE model for free-to-manoeuvre flying space (Table 5.14).

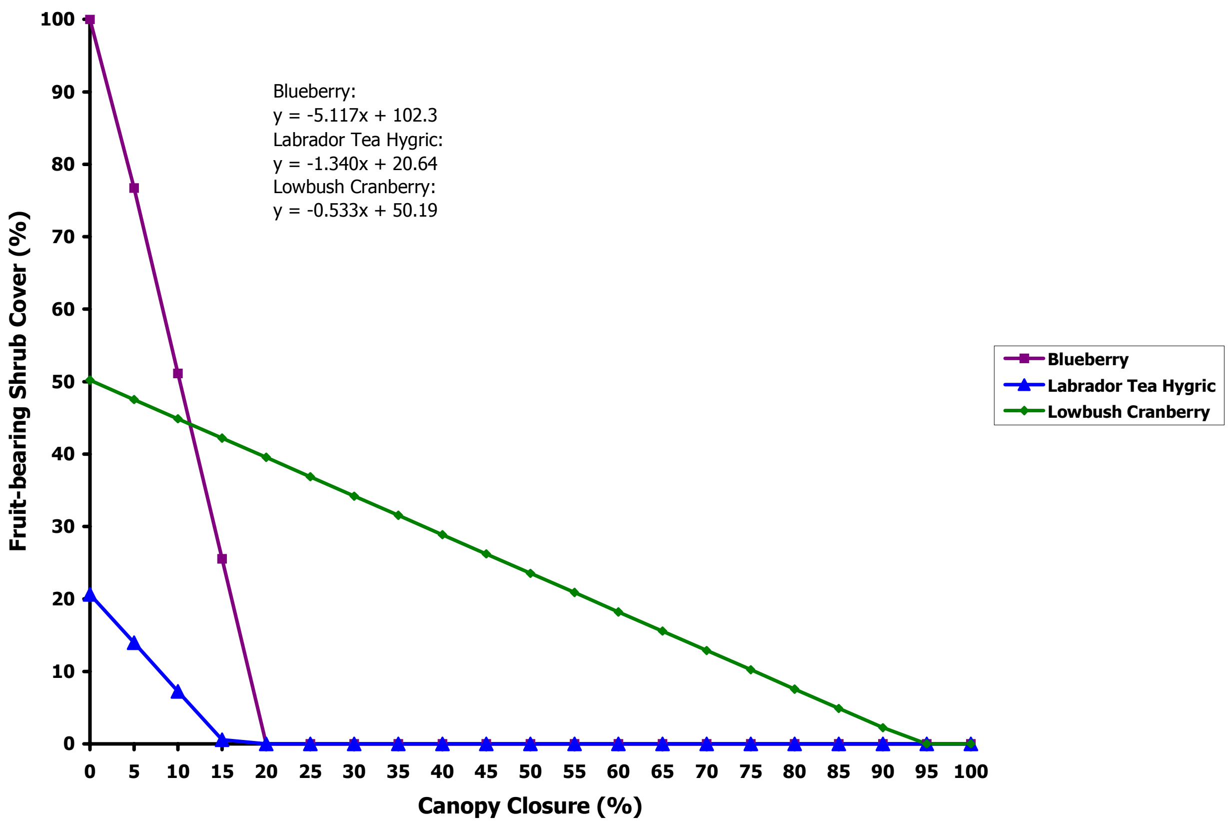

Figure 5.18. Fruit-bearing shrub cover (%) in relation to canopy closure (%) by ecosite.

Table 5.12. Fruit-bearing shrub cover (%) by ecosite.

Ecosite	Fruit-bearing Shrub Cover (%)
Bog/Black Spruce Tamarack	15.04%
Bracted Honeysuckle	27.37%
Horsetail	93.33%
Hairy Wild Rye	26.33%
Labrador Tea Mesic	19.88%
Labrador Tea Sub-hygric	13.14%
Lichen	93.33%

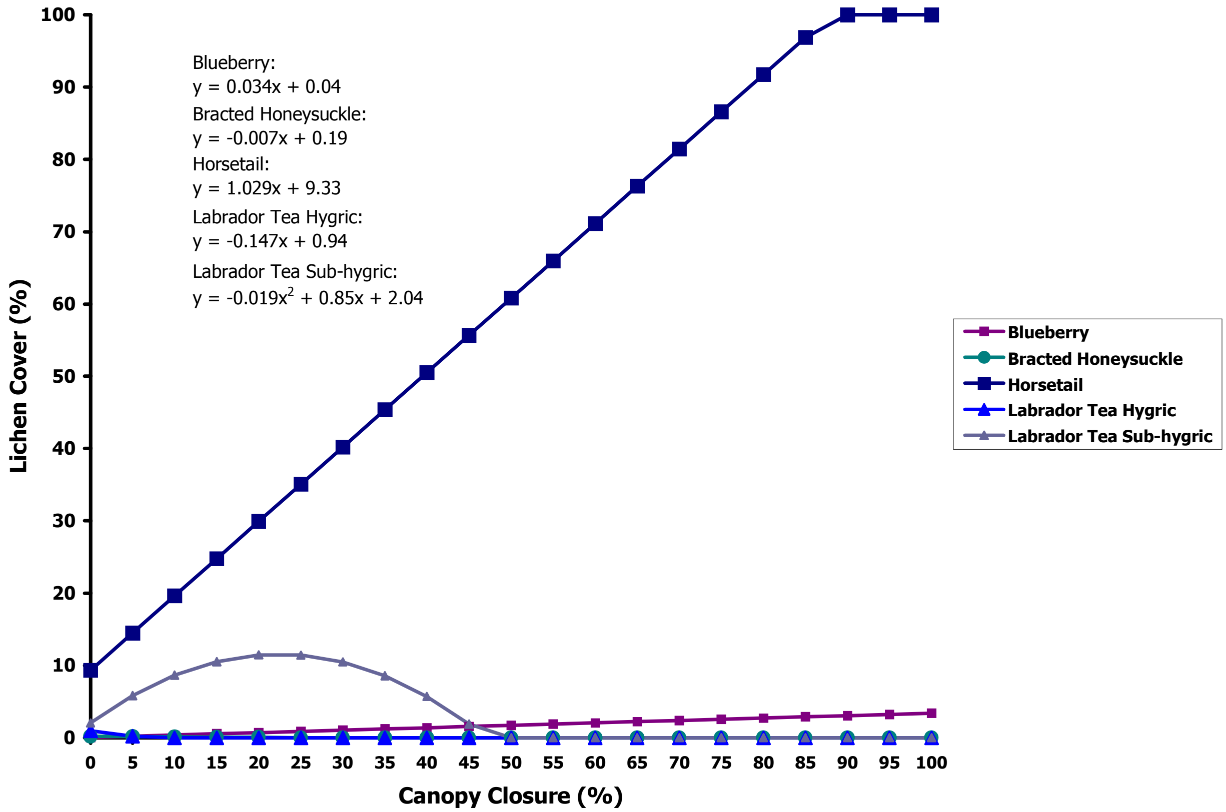

Figure 5.19. Lichen cover (%) in relation to canopy closure (%) by ecosite.

Table 5.13. Lichen cover (%) by ecosite.

Ecosite	Lichen Cover (%)
Bog/Black Spruce Tamarack	0.72%
Hairy Wild Rye	1.00%
Labrador Tea Mesic	3.21%
Lichen-bearberry	1.00%
Lowbush Cranberry	0.65%

Table 5.14. Free-to-manoeuvre flying space ranking for habitat types for use in both natural and managed scenarios.

Composition Class	Developmental Stage	FTMFS Rank
Hardwood	Opening	0
Hardwood	Developing	8
Hardwood	Forest	5
Hardwood	Old	3
Hardwood-dominated Mixedwood	Opening	0
Hardwood-dominated Mixedwood	Developing	7
Hardwood-dominated Mixedwood	Forest	6
Hardwood-dominated Mixedwood	Old	5
Softwood-dominated Mixedwood	Opening	0
Softwood-dominated Mixedwood	Developing	8
Softwood-dominated Mixedwood	Forest	4
Softwood-dominated Mixedwood	Old	2
Pine	Opening	0
Pine	Developing	10
Pine	Forest	7
Pine	Old	5
Other softwood	Opening	0
Other softwood	Developing	10
Other softwood	Forest	9
Other softwood	Old	9

Arboreal lichen cover

The relationship between arboreal lichen cover and habitat type developed above allowed the BAP team to assign an arboreal lichen index value to each habitat type present within the FMA area (Table 5.15).

Tree density

The BAP team estimated the density of trees of specific species and/or size from the TSP and PSP data. This information, stratified by habitat type is displayed in Table 5.16.

Height to live crown

Data collected from the TSPs and PSPs were analysed to identify the way in which height to live crown changes with forest succession for each habitat type. These graphs were converted into the look-up table shown in Table 5.17.

Downed woody debris cover

Data collected from the TSPs and PSPs were analysed to illustrate how downed woody debris coverage changes with forest succession for each habitat type. The trends identified in the data, in combination with the results of research completed by the Alberta Research Council (ARC), were used to produce the look-up table shown in Table 5.18.

Management modifiers

Canopy closure

Table 5.19 presents the effects of management on canopy closure. Because each treatment removes a different number of trees, it can be seen that the effect of spacing, precommercial thinning, and thinning reduces canopy closure by different amounts. Based on the crop plans, spacing is applied only to aspen stands and will only slightly reduce

Table 5.15. Arboreal lichen cover rankings by habitat type.

Composition Class	Developmental Stage	SHE Index
Hardwood	Opening	Low
Hardwood	Developing	Low
Hardwood	Forest	Medium
Hardwood	Old	Medium
Hardwood-dominated Mixedwood	Opening	Low
Hardwood-dominated Mixedwood	Developing	Medium
Hardwood-dominated Mixedwood	Forest	High
Hardwood-dominated Mixedwood	Old	Medium
Softwood-dominated Mixedwood	Opening	Low
Softwood-dominated Mixedwood	Developing	Medium
Softwood-dominated Mixedwood	Forest	High
Softwood-dominated Mixedwood	Old	Medium
Softwood	Opening	Low
Softwood	Developing	Low
Softwood	Forest	High
Softwood	Old	High

Table 5.16. Density of trees (stems/ha) of specific species, size, and/or condition by habitat type.

Variable	Composition Class	Opening	Regenerating	Young	Immature	Mature	Overmature
Density of all species > 25 cm dbh by habitat type	Hardwood	0	0	5	40	180	600
	Hardwood-dominated Mixedwood	0	0	5	100	200	300
	Softwood-dominated Mixedwood	0	0	5	200	250	350
	Black spruce	0	0	0	40	60	100
	Other softwoods	0	0	5	75	200	350
Density of trees (height to live crown < 1 m and dbh < 5 cm) by habitat type	Hardwood	0	37,000	12,000	1,500	800	500
	Hardwood-dominated Mixedwood	0	10,000	8,000	2,000	1,200	1,000
	Softwood-dominated Mixedwood	0	12,000	10,000	600	800	1,000
	Pine	0	20,000	8,000	1,200	1,000	800
	Black spruce	0	17,000	4,000	3,200	2,000	800
	White spruce	0	22,000	10,000	2,000	2,000	2,000
	Larch	0	11,000	10,000	3,600	400	0
Density of dead, damaged, and diseased trees (dbh < 16 cm)	Hardwood	0	0	0	10	20	40
	Mixedwood	0	0	0	10	20	40
	Softwood	0	0	0	10	20	40
Density of dead, damaged, and diseased trees (dbh > 25 cm and height > 20 m) by habitat type	Hardwood	0	0	0	5	10	18
	Mixedwood	0	0	0	8	10	20
	Softwood	0	0	0	5	8	15
Density of dead, damaged, and diseased trees (dbh 15-25 cm) by habitat type	Hardwood	0	0	0	10	10	10
	Mixedwood	0	0	0	10	15	23
	Softwood	0	0	0	13	20	33
Density of dead, damaged, and diseased trees (dbh > 25 cm) by habitat type	Hardwood	0	0	0	5	12	22
	Mixedwood	0	0	0	10	15	20
	Softwood	0	0	0	8	13	20
Density of dead, damaged, and diseased trees (dbh 25-40 cm) by habitat type	Hardwood	0	0	0	5	8	14
	Mixedwood	0	0	0	10	13	15
	Softwood	0	0	0	8	12	18
Density of dead, damaged, and diseased trees (dbh > 40 cm) by	Hardwood	0	0	0	0	2	8
	Mixedwood	0	0	0	0	3	5
	Softwood	0	0	0	0	1	3

Table 5.17. Height to live crown (m) by habitat type.

Composition Class	Opening	Regenerating	Young	Immature	Mature	Old
Hardwood	0	1	4	7	13	12
Mixedwood	0	0.75	3	6	11	12
Pine	0	1	4	8	14	15
Other softwoods	0	0.5	1	5	8	10

Table 5.18. Downed woody debris coverage (%) by habitat.

Composition Class	Opening	Regenerating	Young	Immature	Mature	Old
Hardwood	14	7	8	9	10	11
Mixedwood	16	9	10	11	12	13
Softwood	18	11	12	13	14	15

Table 5.19. Effect of management on canopy closure.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Spacing	90%	15%	100%
Pre-commercial thinning	60%	20%	100%
Thinning	65%	25%	100%

canopy closure. Thinnings in conifer stands have a greater impact. Following treatment, the stands will recover to 100% of that expected in a natural stand.

Stand height

It is thought that density control silviculture treatments can contribute to an increase in stand height due to an increased availability of resources such as light, water, and nutrients, to each individual tree. Therefore, when stands are intensively managed, individual stems will reach a certain height sooner than would have been possible with no management. In addition, since thinning is done from below, smaller trees, that reduce mean stand height, will be removed (Table 5.20).

Shrub cover

Density reduction treatments will influence canopy closure. These treatments will, in turn, affect shrub cover. Site preparation is also believed to affect shrub cover, reducing it to 50% of that expected in a natural stand (Table 5.21).

Herbaceous vegetation cover

As with shrub cover, cover of most types of herbaceous vegetation is closely related to canopy closure. Therefore, modifications of canopy closure that occur with silvicultural treatments will, in turn, influence herbaceous vegetation cover. In fact, the SHE model for canopy closure is used to determine the effect of silvicultural treatments on these vegetation covers.

Site preparation and subsequent vegetation controls are also likely to affect herbaceous vegetation cover. Indeed, when the area is treated, there will be a reduction in the coverage of herbaceous vegetation. This reduction will be followed by a considerable increase in cover. As herbaceous vegetation cover increases to the point that it impedes commercial seedling development, the crop plans suggest the implementation of vegetation control methods. However, the increase in herb cover can be so substantial, particularly on rich sites, that the growth rates of some grass species (e.g. *Calamagrostis spp.*) make veg-

Table 5.20. Effect of management on stand height.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Spacing	100%	5%	105%
Pre-commercial thinning	100%	5%	105%
Thinning	110%	4%	118%

Table 5.21. Effect of management on shrub cover.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Site preparation	50%	0%	-

etation control almost impossible. Similarly, the growth of sedge species is expected to increase substantially following site preparation since the seed bank will be released and establishment will be encouraged with the increased incidence of ponded soils in clearcut areas. Depending on its specific life history characteristics, each herbaceous vegetation type could be expected to recover from initial disturbance to varying degrees (Table 5.22).

Willow and rose cover

Density reduction treatments influence canopy closure. Therefore, for ecosites on which canopy closure is a significant independent variable for willow and rose cover, willow and rose cover will react in a manner similar to canopy closure to density reduction treatments. On ecosites on which willow and rose cover is not related to canopy closure, density reduction treatments will not have an influence on this SHE variable. It is believed that site preparation can reduce willow and rose shrub cover to 50% of conditions in unmanaged stands (Table 5.23).

Willow cover

Site preparation and vegetation control measures will effectively reduce willow cover following harvest in a manner similar to that described above. It is not expected to recover from these events (Table 5.24).

Fruit-bearing shrub cover

Density reduction treatments that reduce canopy closure will affect fruit-bearing shrub cover on ecosites in which basal area and fruit-bearing shrub cover are correlated. Site preparation is believed to reduce fruit-bearing shrub cover to 50% of that expected in natural stands (Table 5.25).

Lichen cover

Density reduction treatments that reduce canopy closure will affect lichen cover on ecosites in which basal area and lichen cover are correlated. Site preparation is believed to reduce lichen cover to 50% of that expected in natural stands (Table 5.26).

Free-to-manoeuvre flying space

Managed stands are expected to have more subcanopy flying space than unmanaged stands. This is particularly true once thinning from below has taken place. However, it was assumed that after a short period of time (*i.e.*, within one time step), shrub and small tree cover will develop and the understorey will, again, become crowded (Table 5.27).

Table 5.22. Effect of management on herbaceous cover. Fo = Forb, G = Grass, Fe = Fern, Se = Sedge.

Treatment	Disturbance Factor				Recovery Factor				Maximum Recovery Factor			
	Fo	G	Fe	Se	Fo	G	Fe	Se	Fo	G	Fe	Se
Site preparation	50	50	50	500	25	100	25	100	100	300	100	100

Table 5.23. Effect of management on willow and rose shrub cover.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Site preparation	50%	0%	-

Table 5.24. Effect of management on willow cover.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Site preparation	50%	0%	-

Table 5.25. Effect of management on fruit-bearing shrub cover.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Site preparation	50%	0%	-

Table 5.26. Effect of management on lichen cover.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Site preparation	50%	0%	-

Table 5.27. Effect of management on free-to-manoeuvre flying space index. The numbers indicate the change in the free-to-manoeuvre flying space rank index following treatment and in the following periods; where: 0 £ free-to-manoeuvre flying space rank index £ 10.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Spacing	-1	0	-
Pre-commercial thinning	-2	1	One step
Thinning	-3	1	One step

Arboreal Lichen Cover

Intensive silviculture practices that apply density reduction treatments will affect arboreal lichen cover. There will be no visible effect on arboreal lichen cover after spacing or pre-commercial thinning. However, commercial thinning will reduce arboreal lichen cover. Therefore, immediately following thinning, a stand's arboreal lichen index will be lowered by one level and remain at that level for 30 years. Following this, the stand's arboreal lichen cover will recover to the state expected in a natural stand (Table 5.28).

Tree Density

Several general principles have been followed in the production of tree density SHE models for managed stands:

- Spacing and thinning procedures allow a greater proportion of the trees to become large (in terms of diameter and height) representatives of the stand.
- The effects of spacing and thinning procedures on tree size are not visible immediately but will occur at later time-steps.
- By the crop planning system, hardwood regeneration will be encouraged to replace trees removed from pure hardwood stands. Similarly, in pure softwood stands, softwood regeneration is encouraged. In mixedwood stands harvested by the crop planning system, only softwood regeneration is encouraged, in an attempt to shift the broad composition class from mixedwood to softwood.
- The purpose of spacing and thinning procedures is to encourage the growth of large trees with high commercial value. Thinnings are done 'from-below' which means that weaker and smaller trees are removed from the stand. Therefore, there is less potential for suppression of trees and development of snags.

There are several cases in which timber management has similar effects on different tree density-related SHE variables. For the purposes of the following discussion, tree density models are grouped based on similarity.

Group 1: Density of small trees, including both hardwood and softwood species:

- Density of trees with height to live crown < 1 m and dbh > 5 cm.

During spacing, the forest manager specifies that 5,000 small trees per ha will remain on site. Therefore, regardless of the natural density of small trees (Table 5.16), there will be 5,000 small individuals remaining per ha following spacing. Pre-commercial thinning will remove about 75% of the natural stock of small trees from the stand. Since the stand is managed to promote growth of large trees, there is no recovery. At the time of commercial thinning, small trees will no longer influence the development of crop trees. They will, therefore, be left on site (Table 5.29).

Group 2: Density of dead, damaged, and diseased trees:

- Density of dead trees (snags);
- Density of dead, damaged, and diseased trees > 16 cm dbh;
- Density of dead, damaged, and diseased trees > 20 m height and dbh > 25 cm;
- Density of dead, damaged, and diseased trees > 25 cm dbh;
- Density of dead, damaged, and diseased trees 25-40 cm dbh; and
- Density of dead, damaged, and diseased trees > 40 cm dbh.

The crop plan management system promotes development of suitable crop trees. This tends to reduce the density of dead, damaged, and diseased trees. We assume that the crop planning system would reduce the density of these trees by half (Tables 5.30), compared to that expected in a natural stand (Table 5.16).

Table 5.28. Effect of management on arboreal lichen cover.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Spacing	-	-	-
Pre-commercial thinning	-	-	-
Thinning	Reduce by one level (e.g. M to L)	No change for 30 years, then recover in 1 time step	100%

Table 5.29. Effect of management on density of small trees, including both hardwood and softwood species.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Spacing	5,000 trees	0%	-
Pre-commercial thinning	25%	0%	-
Thinning	-	-	-

Table 5.30. Density of dead, damaged, and diseased trees after crop planning.

Variable	Composition Class	Opening	Regenerating	Young	Immature	Mature	Overmature
Density of dead, damaged, and diseased trees (dbh > 16 cm) by habitat type	Hardwood	0	0	0	5	10	20
	Mixedwood	0	0	0	5	10	20
	Softwood	0	0	0	5	10	20
Density of dead, damaged, and diseased trees (dbh > 25 cm and height > 20 m) by habitat type	Hardwood	0	0	0	3	5	9
	Mixedwood	0	0	0	4	5	10
	Softwood	0	0	0	3	4	8
Density of dead, damaged, and diseased trees (dbh > 25 cm) by habitat type	Hardwood	0	0	0	3	6	11
	Mixedwood	0	0	0	5	8	10
	Softwood	0	0	0	4	7	10
Density of dead, damaged, and diseased trees (dbh 25-40 cm) by habitat type	Hardwood	0	0	0	3	4	7
	Mixedwood	0	0	0	5	7	8
	Softwood	0	0	0	4	6	9
Density of dead, damaged, and diseased trees (dbh > 40 cm) by habitat type	Hardwood	0	0	0	0	1	4
	Mixedwood	0	0	0	0	2	3
	Softwood	0	0	0	0	0	2

Height to live crown

When trees grow in shady conditions (dense stands), the lower branches die back, increasing the height to live crown. When light is available, however, the lower branches are able to survive and height to live crown is lower. Spacing, pre-commercial thinning, and commercial thinning increase available light to all trees in the stand. Therefore, the height to live crown decreases with spacing and thinning. As the stand begins to close in again following spacing or thinning, the height to live crown returns to its pre-activity level at a rate of 10% per time step (Table 5.31).

Downed woody debris cover

The percentage of the forest floor covered with downed woody debris following a timber-harvesting event varies with intensity of management (Table 5.32). During scarification, some of the downed woody debris is realigned, perhaps loosing some utility for wildlife. During spacing and pre-commercial thinning, small unmerchantable pieces of wood are left on the forest floor, contributing immediately to downed woody debris coverage. Alternatively, commercial thinnings immediately result in a small increase from residual slash. This is followed by a reduction in downed woody debris due to the removal of suppressed trees that would have provided material through self-thinning if no treatment had been applied. We assumed that this effect is detectable until the stand reaches 50% of the coverage expected in a natural stand. Sequential thinnings will have an additive effect.

After a clearcut there will be a substantial amount of downed woody debris remaining on the forest floor. After this material decomposes, very little will be subsequently added. Millar Western's cut-to-length harvesting system will remove a maximum amount of fibre from the site. Therefore, there will be less downed woody debris remaining and we predict that only 50% of what is seen in natural stands will be observed in managed stands after the second harvest when the legacy of downed woody debris from the natural stand has vanished.

SHE models for non-forested land

The forested habitat types considered in the BAP analysis are designed to change in reaction to forest succession and to disturbance by fire and management, as described above. Non-forest SHE models are created for those habitat types whose characteristics are thought to remain relatively constant throughout the simulation. These habitat types are listed below:

- Water;
- Anthropogenic structures;
- Barren & scattered vegetation;
- Treed muskeg;
- Farm;
- Shrub (open & closed shrub canopies);
- Marsh; and
- Meadow.

Since the condition of non-forested habitat types is thought to remain static (see BAP Report #3: Habitat Classification Doyon 2000), this set of SHE models need not illustrate how the SHE variables will react to disturbance or succession. Instead, one number was designated to each non-forested habitat type for each SHE variable as shown in Table 5.33.

Table 5.31. Effect of management on height to live crown.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Thinning	75%	10%	100%

Table 5.32. Effect of management on downed woody debris coverage.

Treatment	Disturbance Factor	Recovery Factor	Maximum Recovery Factor
Spacing	110%	0%	100%
Pre-commercial thinning	150%	0%	100%
Scarification	80%	0%	100%
Thinning	110%	-20%	50%
Clearcut	120%	-50%	50%

Table 5.33. Expected SHE variable condition for non-forested habitat types.

SHE VARIABLE	Water	Anthropogenic	Barren & Scattered	Treed Muskeg	Farm	Shrub-open	Shrub-closed	Marsh	Herb-grassland
% forb	-	-	-	15	30	60	20	15	25
% lichen	-	-	30	50	-	10	-	-	-
% willow	-	-	5	10	-	15	40	1	-
% willow and rose	-	-	5	15	-	20	50	1	-
arboreal lichen cover	-	-	L	H	-	-	-	-	-
% moss	-	20	40	100	5	20	10		10
% grass	-	5	20	15	100	30	15	10	100
% fern	-	-	5	10	5	15	10	-	5
% fruit-bearing shrub	-	5	25	40	-	30	50	-	-
% alder	-	-	-	25	-	25	30	15	-
% shrub total	-	5	30	50	-	55	75	15	-
% shrub >1	-	5	5	30	-	25	50	5	-
% 1<shrub <2	-	-	15	10	-	20	15	5	-
% 2<shrub <3	-	-	5	5	-	5	10	10	-
% shrub >3	-	-	5	5	-	5	10	5	-
Basal area	-	-	5	20	-	-	5	-	-
Canopy closure	-	-	10	30	-	5	15	-	-
Density of dead, diseased, and damaged trees > 16 cm dbh	-	-	-	5	-	-	-	-	-
Density of dead, diseased, and damaged trees with height > 20 m	-	-	-	10	-	-	-	-	-
Density of trees with dbh > 25 cm	-	-	-	-	-	-	-	-	-
Density of trees with height to live crown < 1 m	-	-	-	150	-	-	-	-	-
DWD cover	-	-	-	20	-	5	10	-	-
Height to live crown	-	-	0.5	0.5	-	-	-	-	-
Free-to-manoeuver flying space (see codes in the report)	1	1	2	3	1	2	3	1	1

5.4 FURTHER STUDIES

Canopy closure

Since data on canopy closure at the plot level were not available, it was not possible to test our assumption that canopy closure is linearly related to basal area within Millar Western's FMA area. Therefore, the validity of the model is difficult to determine. Although our model captured the differences in canopy closure between composition and productivity classes, it is recommended that information on canopy closure related to basal area be collected from PSPs and TSPs.

Since canopy closure dominates so many other SHE models, our imperfect understanding of canopy closure dynamics poses some unique problems. First, is canopy closure the result of stochastic processes rather than aging? If so, can it be predicted on a stand by stand basis? If we cannot predict canopy closure, its application in other SHE models is questionable. Furthermore, the entire modelling framework applies broad cover type averages to stand polygons that will dampen the variability present in the real system. If one characterises an intensively managed forest as having less variability in canopy closure compared to natural stands, we cannot determine these effects upon habitat distribution within the current framework. For these reasons, canopy closure dynamics will demand careful consideration over the next several years in preparation for the next DFMP.

Stand height

For many of the developmental, productivity, and composition classes, data were not available, particularly for hardwood and mixedwood stands. However, based on stand development and expert judgement, we are confident that the SHE model for stand height is realistic. As more data are collected, they will be used to fill the information gaps and validate the assumptions made. The way in which average stand height changes with management in the model corresponds to the growth hypotheses for the timber supply analysis, developed by the silviculturalists at Millar Western.

Shrub cover

The number of species included in the SHE models can explain the high level of variation between shrub cover and canopy closure. The abundance of shrub species is dependent in part on current site conditions but also, to a large extent, on the disturbance history of the site. It was necessary to model each species of shrub first, before combining them together into a general shrub cover category. Because of this, final model output may not be completely reliable. In addition, empirical data showing the relationship between shrub cover and site preparation are required to validate the estimates underlying this model. This should be considered a best first attempt at shrub cover SHE model creation, based on professional judgement.

Herbaceous vegetation cover

The strength of the relationship between canopy closure and herbaceous vegetation was improved when ecosite was included as an independent variable. However, these relationships should be further investigated. Field documentation and/or testing should be performed to clarify the assumptions concerning post-treatment behaviour of herbaceous vegetation.

Willow and rose cover

We are confident in the results shown by the SHE model for willow and rose shrub cover. As some ecosites were not sampled as thoroughly as others, it is recommended that sampling of TSPs and PSPs on these ecosites should be increased. The response of willow and rose to silvicultural treatments is not well known and their responses to changes in canopy closure are not well documented. In the SHE model modified to include the effects of management, it is assumed that site preparation will destroy most of the recolonising source. Therefore, we did not include recovery factors. This idea should be tested in the future.

Willow cover

Lacking empirical data on the way willow cover changes with management and disturbance, this model is based strongly on professional judgement. The relationships explained within it require field validation.

Fruit-bearing shrub cover

Though, in general, fruit-bearing shrub species have different ecological requirements, most of the species considered in this SHE model are of the Heath family which share similar habitat requirements. It is known that many of these fruit-bearing species use the seedbank strategy to recolonise the site after a disturbance. Therefore, following site preparation, it could be assumed that these species would begin to establish themselves on the site in this way. However, with the implementation of intensive management strategies, of which site preparation is a part, vegetation control measures will hinder their propagation to favour commercial tree species. Therefore, there is no recovery factor following the loss of fruit-bearing shrub species with management.

Free-to-manoeuvre flying space

We are confident in the validity of the procedure used to develop this model.

Arboreal lichen cover

We are confident that our classification system connecting arboreal lichen cover and habitat type as defined in this SHE model gives reliable results. The effect of density reduction on arboreal lichen must be empirically demonstrated in the future.

Tree density

We are confident that the data from which the natural tree density SHE models were created are reliable. It is important, however, that our assumptions regarding the way in which density of trees of specific characteristics will change with management are tested empirically in the future.

Height to live crown

We are confident that the data from which the height to live crown curves were drawn are reliable. In addition, the look-up tables give feasible results. The way in which height to live crown changes with disturbance must be tested empirically in the future.

Downed woody debris cover

The original intention was to create different SHE models for downed woody debris in different size and decay classes since these variables are of significance to the wildlife species selected for study in BAP. Unfortunately, the data collected from the TSPs and PSPs were not sufficiently detailed to successfully identify the relationships between downed woody debris coverage of specific condition and habitat type. Therefore, total downed woody debris coverage is the only variable related to downed woody debris in the set of SHE models. Future sampling efforts should be structured to provide the necessary information. In addition, although the way in which downed woody debris coverage changes with disturbance by management is based on research by ARC, empirical studies within Millar Western's FMA area should be carried out to ensure that the same patterns are apparent locally.

SHE models for non-forested land

The static values presented in Table 5.33 represent the BAP team's best approximations of the condition of SHE variables within non-forested habitat types, based on professional judgement. These estimates require field validation to ensure local applicability.

5.5 LITERATURE CITED

Beckingham, J.D. and J.H. Archibald. 1996. Field guide to ecosite of west-central Alberta. Canadian Forest Service, Northwest Region, Northern Forestry Centre. Edmonton, AB.

Beckingham, J.D. and D. Nielsen. 2000. Summary Report and Ecosite Map for Millar Western's FMA area: Ecological mapping using SiteLogix Modelling System. Prepared for Millar Western Forest Products. Prepared by Geographic Dynamics Corp., Edmonton, AB. 80 p.

Doyon, F. 2000. Habitat Classification. Biodiversity Assessment Project for Millar Western Forest Products. BAP Report 3. Chair in Forest Management and Policy, Faculty of Forestry, Lakehead University, Thunder Bay, ON. 7 p.

Doyon, F. and P. Duinker. 2000. The Species Selection Procedure. Biodiversity Assessment Project for Millar Western Forest Products. BAP Report 2. Chair in Forest Management and Policy, Faculty of Forestry, Lakehead University, Thunder Bay, ON. 11 p.

Higgelke, P.E., H.L. MacLeod, and F. Doyon. 2000. Habitat Supply Models. Biodiversity Assessment Project for Millar Western Forest Products. BAP Report 6. KBM Forestry Consultants Inc., Thunder Bay, ON. 10 p.

Millar Western Forest Products. 1998. Permanent Sample Plot Manual. Millar Western Forest Products, Whitecourt, AB. 22 pp. + Appendices.

Millar Western Forest Products. 2000. Detailed Forest Management Plan 1997-2006. Prepared by The Forestry Corp. as Chapter 6: Timber Supply Analysis of Millar Western's DFMP.

APPENDIX A – SHE MODEL STATISTICS

CONTINUOUS SHE MODELS

Canopy Closure

A trend line was fit to the basal area and stand age data and it was determined that a general third-order polynomial relationship existed between these two variables as discussed in the report. The R^2 value for this relationship was 0.2385.

The R^2 values for the third-order polynomial equations for each of the composition classes on medium productivity sites are shown in Table A1.

Table A1. R^2 values for the third-order polynomial equations for each of the composition classes on medium productivity sites.

Composition Class	Productivity	R^2
Hardwood	Medium	0.4102
Mixedwood	Medium	0.2065
Softwood	Fair	0.1744
Softwood	Medium	0.2377
Softwood	Good	0.3457

Arboreal Lichen Cover

Table A2. Mean and standard deviation of the arboreal lichen index by broad composition and structure stage. SHE index based on the rank of the mean obtained.

Composition Class	Structure Stage	N	Mean	Standard Deviation
Hardwood	Opening	5	0.0022	0.0022
Hardwood	Regenerating	1	0.0002	-
Hardwood	Forest	50	0.7505	0.8419
Hardwood	Overmature	-	-	-
Hardwood dom. Mixedwood	Opening	4	0.0009	0.0009
Hardwood dom. Mixedwood	Regenerating	6	0.3096	0.6136
Hardwood dom. Mixedwood	Forest	31	1.383	1.4944
Hardwood dom. Mixedwood	Overmature	-	-	-
Softwood dom. Mixedwood	Opening	6	0.0015	0.5376
Softwood dom. Mixedwood	Regenerating	2	0.4585	1.5826
Softwood dom. Mixedwood	Forest	46	1.5725	-
Softwood dom. Mixedwood	Overmature	1	0.5933	0.0038
Conifer	Opening	13	0.0026	0.144
Conifer	Regenerating	26	0.1042	1.3522
Conifer	Forest	257	0.9972	0.8725
Conifer	Overmature	19	1.0427	1.287

Willow and Rose Shrub Cover

We did not find a significant relationship between willow and rose cover and stand basal area for any of the nine tested ecosites (Table A3).

Table A3. Mean, standard deviation, parameters, and statistics of the relationship between willow and rose cover and basal area, by ecosite.

Ecosite	N	Mean	Standard deviation	R^2	P
Blueberry	13	4.38	10.96	0.22	0.1
Bog/Black spruce-Tamarack	28	6.86	15.65	0.03	0.38
Bracted honeysuckle	19	3.47	6.8	0	0.93
Hairy wild rye	3	16	25.16	-	-
Horsetail	9	0.89	1.54	0.32	0.11
Labrador tea hygric	6	9.83	19.77	0.04	0.72
Labrador tea mesic	108	1.81	4.42	0.05	0.02
Labrador tea sub-hygric	42	6.52	13.04	0.09	0.06
Lichen	0	-	-	-	-
Lowbush	354	3.69	8.41	0.05	0

Alder Cover

The only significant relationship between alder cover and basal area was found for the lowbush cranberry ecosite. The R^2 value for this relationship was still quite low, however (Table A4).

Stratifying alder cover by moisture regime did not seem to assist in predicting the presence of alder (Table A5).

Table A4. Mean, standard deviation, parameters, and statistics of the relationship between alder cover and basal area, by ecosite.

Ecosite	N	Mean	Standard deviation	R^2	P
Blueberry	13	0	0	-	-
Bog/Black spruce-Tamarack	28	1.96	5.5	0.05	0.25
Bracted honeysuckle	19	4.47	16.06	0.06	0.32
Hairy wild rye	3	6.67	11.55	-	-
Horsetail	9	0	0	-	-
Labrador tea hygric	6	0	0	-	-
Labrador tea mesic	108	2.278	11.38	0	0.92
Labrador tea sub-hygric	42	1	3.7	0.05	0.15
Lichen	0	-	-	-	-
Lowbush cranberry	354	6.63	16.74	0.02	0.01

Table A5. Mean alder cover by moisture regime class.

Moisture regime class	Mean	Standard Deviation
Xeric	0	0
Mesic	4.87	14.48
Hygric	4.75	15.56
Wet	2.69	7.66

Fruit-bearing Shrub Cover

For each ecosite, we tested the relationship between fruit-bearing shrub cover and basal area. Fruit-bearing shrub cover was the highest on Blueberry, Bracted honeysuckle, Hairy wild rye, Horsetail and Lowbush cranberry ecosites (Table A6). Three (Blueberry, Labrador tea mesic, Lowbush cranberry) of the nine tested ecosites showed a significant relationship but the R^2 was sufficiently high only for Blueberry and Lowbush cranberry (Table A6). The relationship for the Labrador tea hygric had high R^2 but was not significant.

Table A6. Mean, standard deviation, parameters, and statistics for the relationship between fruit bearing shrub cover and basal area, by ecosite.

Ecosite	N	Mean	Standard deviation	R^2	P
Blueberry	13	37.54	50.46	0.66	0
Bog/Black spruce-Tamarack	28	15.04	14.39	0.02	0.45
Bracted honeysuckle	19	27.37	28.83	0.06	0.31
Hairy wild rye	3	93.33	59.07	-	-
Horsetail	9	26.33	32.12	0.13	0.34
Labrador tea hygric	6	16.67	6.89	0.46	0.14
Labrador tea mesic	108	19.88	20.34	0.04	0.03
Labrador tea sub-hygric	42	13.14	15.69	0.01	0.56
Lichen	0	-	-	-	-
Lowbush cranberry	354	35.2	37.37	0.11	0

DISCRETE SHE MODELS

Free-to-manouvre Flying Space

Chi-square values for each of the four independent variables in the SHE model for FTMFS are shown in Table A7, with degrees of freedom (Df) and probabilities.

The model built using log-linear procedures to predict FTMFS conditions was highly significant (*P* = 0.98).

Table A7. Chi-square, degrees of freedom, and probability for independent variables involved with the free to manoeuvre flying space model.

Independent Variable	Chi-square	Df	Probability
Structure stage (1-4)	18.006	6	0.006
Stand stage (1-6)	40.786	10	0
Broad composition (1-4)	22.583	6	0.001
Specific composition (1-19)	45.565	28	0.019

APPENDIX B: LOOK-UP TABLES

Table B1. Canopy closure look-up table.

	Fair			Medium			Good		
Age	Hardwood	Mixedwood	Softwood	Hardwood	Mixedwood	Softwood	Hardwood	Mixedwood	Softwood
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	6.8	7.3	5.7	12.3	9.9	9.2	15.9	11.6	11.8
10	13.1	14.1	11.1	23.5	19.1	17.8	29.9	22.4	22.6
15	18.9	20.5	16.2	33.6	27.7	25.7	42.1	32.3	32.5
20	24.2	26.5	20.9	42.5	35.6	33.0	52.6	41.4	41.4
25	29.1	32.0	25.2	50.5	42.9	39.7	61.5	49.7	49.4
30	33.6	37.2	29.3	57.4	49.6	45.9	69.0	57.2	56.6
35	37.6	41.9	33.0	63.5	55.7	51.5	75.0	64.1	62.9
40	41.2	46.3	36.4	68.6	61.2	56.6	79.8	70.2	68.5
45	44.4	50.3	39.6	72.9	66.2	61.1	83.3	75.6	73.3
50	47.3	53.9	42.4	76.3	70.7	65.2	85.7	80.5	77.4
55	49.8	57.1	45.0	79.1	74.7	68.8	87.1	84.7	80.9
60	51.9	60.1	47.3	81.1	78.2	72.0	87.5	88.3	83.7
65	53.7	62.6	49.4	82.4	81.2	74.7	87.5	91.4	85.9
70	55.2	64.9	51.2	83.2	83.9	77.0	87.4	94.0	87.6
75	56.4	66.9	52.8	83.3	86.1	78.9	87.3	96.0	88.7
80	57.2	68.6	54.2	83.3	87.9	80.5	87.2	97.6	89.4
85	57.9	69.9	55.4	83.2	89.3	81.7	87.0	98.8	89.6
90	58.2	71.0	56.3	83.0	90.4	82.5	86.7	99.6	89.6
95	58.3	71.9	57.1	82.7	91.1	83.1	86.5	99.9	89.5
100	58.3	72.5	57.6	82.4	91.5	83.3	86.2	100.0	89.4
105	58.2	72.8	58.0	82.0	91.7	83.3	85.8	100.0	89.2
110	58.1	72.9	58.3	81.6	91.6	83.3	85.5	99.9	89.0
115	58.0	72.9	58.3	81.1	91.6	83.1	85.1	99.7	88.8
120	57.7	72.9	58.3	80.6	91.5	83.0	84.6	99.6	88.5
125	57.5	72.8	58.2	80.0	91.4	82.7	84.2	99.4	88.2
130	57.2	72.7	58.1	79.3	91.3	82.5	83.7	99.1	87.8
135	56.9	72.6	57.9	78.6	91.1	82.1	83.2	98.9	87.5
140	56.5	72.5	57.7	77.9	90.9	81.8	82.6	98.5	87.1
145	56.1	72.4	57.5	77.1	90.6	81.4	82.0	98.2	86.6
150	55.7	72.2	57.2	76.3	90.4	80.9	81.4	97.8	86.1
155	55.2	72.0	56.8	75.5	90.1	80.4	80.8	97.4	85.6
160	54.7	71.8	56.4	74.6	89.8	79.9	80.1	97.0	85.1
165	54.2	71.6	56.0	73.7	89.4	79.3	79.5	96.5	84.5
170	53.7	71.3	55.6	72.7	89.1	78.7	78.8	96.0	84.0
175	53.1	71.1	55.1	71.7	88.7	78.1	78.1	95.5	83.4
180	52.5	70.8	54.6	70.7	88.3	77.5	77.3	95.0	82.7
185	51.8	70.5	54.1	69.7	87.9	76.8	76.6	94.4	82.1
190	51.2	70.2	53.6	68.6	87.4	76.1	75.8	93.8	81.4
195	50.5	69.8	53.0	67.6	87.0	75.3	75.1	93.2	80.7
200	49.8	69.5	52.4	66.5	86.5	74.6	74.3	92.6	80.1
205	49.1	69.1	51.8	65.4	86.0	73.8	73.5	92.0	79.3
210	48.4	68.7	51.2	64.3	85.5	73.0	72.7	91.4	78.6
215	47.7	68.3	50.6	63.2	84.9	72.2	71.8	90.7	77.9
220	46.9	67.9	49.9	62.0	84.4	71.4	71.0	90.0	77.2
225	46.2	67.4	49.3	60.9	83.8	70.6	70.1	89.4	76.4
230	45.4	67.0	48.6	59.7	83.3	69.7	69.3	88.7	75.7
235	44.6	66.5	48.0	58.6	82.7	68.9	68.4	88.0	74.9
240	43.8	66.1	47.3	57.5	82.1	68.0	67.6	87.3	74.1
245	43.0	65.6	46.6	56.3	81.5	67.2	66.7	86.6	73.4
250	42.3	65.1	46.0	55.2	80.9	66.3	65.9	85.9	72.6
255	41.5	64.5	45.3	54.1	80.3	65.5	65.0	85.2	71.8
260	40.7	64.0	44.7	53.0	79.7	64.6	64.1	84.5	71.1
265	39.9	63.5	44.0	51.9	79.1	63.8	63.2	83.8	70.3
270	39.1	62.9	43.4	50.8	78.4	62.9	62.4	83.1	69.6
275	38.3	62.4	42.8	49.7	77.8	62.1	61.5	82.4	68.8
280	37.5	61.8	42.2	48.7	77.2	61.3	60.7	81.7	68.1
285	36.8	61.2	41.6	47.7	76.6	60.5	59.8	81.1	67.4
290	36.0	60.6	41.1	46.7	75.9	59.7	59.0	80.4	66.6
295	35.2	60.0	40.5	45.7	75.3	58.9	58.1	79.8	65.9
300	34.5	59.4	40.0	44.8	74.7	58.2	57.3	79.1	65.3
305	33.8	58.8	39.5	43.9	74.0	57.5	56.5	78.5	64.6
310	33.1	58.1	39.1	43.0	73.4	56.8	55.7	77.9	63.9
315	32.4	57.5	38.6	42.1	72.8	56.1	54.9	77.3	63.3
320	31.7	56.8	38.2	41.3	72.2	55.4	54.1	76.7	62.7
325	31.0	56.2	37.9	40.6	71.6	54.8	53.3	76.2	62.1
330	30.4	55.5	37.5	39.9	71.0	54.2	52.6	75.7	61.5
335	29.8	54.8	37.2	39.2	70.4	53.7	51.8	75.1	60.9
340	29.2	54.2	37.0	38.6	69.8	53.2	51.1	74.7	60.4
345	28.6	53.5	36.8	38.0	69.2	52.7	50.4	74.2	59.9
350	28.1	52.8	36.6	37.5	68.7	52.2	49.7	73.8	59.4
355	27.6	52.1	36.5	37.0	68.1	51.8	49.1	73.4	59.0

Table B2. Mean stand height look-up table.

Productivity Class	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125
Fair	0.0	1.0	3.0	4.0	6.0	7.0	8.8	10.2	12.0	13.0	14.0	15.0	16.0	16.5	17.0	17.5	18.0	18.2	18.3	18.4	18.5	18.3	18.0	17.5	17.0	16.5
Medium	0.0	0.5	1.1	1.9	3.0	5.5	8.8	11.5	13.0	14.5	15.8	17.0	18.0	19.2	20.0	21.0	22.0	22.5	23.0	23.5	24.0	24.4	24.8	24.9	25.0	24.9
Good	0.0	2.0	3.5	5.5	7.5	10.0	12.0	14.0	16.0	17.3	18.0	19.0	20.0	21.0	21.9	22.5	23.3	24.0	24.9	25.5	26.0	26.3	26.5	26.8	27.0	26.8
Fair	0.0	1.0	3.0	4.0	6.0	7.0	8.8	10.2	12.0	13.0	14.0	15.0	16.0	16.5	17.0	17.5	18.0	18.2	18.3	18.2	18.1	17.9	17.8	17.7	17.5	17.3
Medium	0.0	1.5	3.0	5.0	7.0	9.0	10.2	12.0	13.5	15.0	16.0	17.1	18.0	19.5	20.4	21.3	22.0	22.4	22.6	22.9	23.0	22.9	22.5	22.2	22.0	21.8
Good	0.0	1.6	3.1	5.2	7.4	9.4	10.6	12.5	14.0	15.7	16.9	18.2	19.6	21.2	22.2	23.2	23.9	24.3	25.1	25.3	25.5	25.4	25.7	25.8	25.9	25.8
Fair	0.0	1.0	2.0	3.2	4.1	5.5	6.5	7.6	8.8	9.6	10.5	11.1	11.9	12.3	13.0	13.5	13.9	14.2	14.5	14.8	15.0	15.3	15.4	15.5	15.6	15.6
Medium	0.0	1.0	2.1	3.5	4.6	6.3	7.6	9.1	10.8	12.1	13.5	14.3	15.4	16.0	17.0	17.7	18.3	18.7	19.2	19.7	20.0	20.3	20.4	20.5	20.6	20.7
Good	0.0	1.0	2.2	3.7	4.9	6.9	8.5	10.3	12.3	14.1	16.0	17.0	18.4	19.1	20.4	21.3	22.1	22.7	23.4	24.0	24.5	25.2	25.6	26.0	26.4	26.8

Productivity Class	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	205	210	215	220	225	230	235	240	245	250
Fair	15.1	14.0	13.0	12.4	12.0	11.2	10.8	10.1	9.8	9.3	9.0	8.5	8.2	7.7	7.5	7.2	7.0	6.6	6.3	6.0	5.8	5.5	5.2	5.0	4.9
Medium	24.4	23.8	23.0	22.5	21.9	21.0	20.4	20.2	19.9	19.5	19.0	18.5	18.1	17.7	17.2	17.0	16.6	16.4	16.0	15.8	15.5	15.2	15.1	15.0	14.9
Good	26.6	26.3	26.0	25.6	25.3	25.0	24.6	24.1	23.8	23.3	23.0	22.4	22.0	21.6	21.3	21.1	20.8	20.5	20.2	20.0	19.9	19.8	19.6	19.4	19.3
Fair	16.9	16.4	16.0	15.5	15.1	14.5	14.2	13.6	13.2	12.9	12.5	12.2	11.9	11.5	11.2	11.0	10.6	10.2	10.0	9.8	9.5	9.3	9.1	8.8	8.6
Medium	21.5	21.2	21.0	20.6	20.2	20.0	19.6	19.1	18.9	18.5	18.0	17.6	17.2	16.7	16.4	16.0	15.8	15.4	15.1	15.0	14.7	14.3	14.0	13.8	13.5
Good	25.7	25.6	25.5	25.3	25.0	24.8	24.5	24.0	23.7	23.3	23.0	22.5	22.0	21.5	21.0	20.6	20.1	19.7	19.4	19.0	18.7	18.3	18.0	17.6	17.2
Fair	15.5	15.4	15.3	15.2	15.1	14.9	14.7	14.5	14.1	13.9	13.6	13.3	13.0	12.6	12.0	11.5	11.0	10.3	9.8	9.4	8.9	8.2	7.5	6.9	6.0
Medium	20.7	20.8	20.7	20.6	20.5	20.4	20.2	20.0	19.9	19.6	19.3	19.0	18.8	18.3	18.0	17.5	17.0	16.5	16.0	15.5	15.0	14.4	13.9	13.0	12.5
Good	27.1	27.5	27.7	27.8	28.0	28.1	28.1	28.1	28.2	28.1	27.9	27.7	27.7	27.1	27.0	26.7	26.4	26.0	25.7	25.3	24.8	24.2	23.7	22.5	22.0

Table B3. Shrub cover look-up table.

	Height Classes				
Canopy Closure	All shrubs	Height <= 1 m	Height 1.1 to 2 m	Height 2.1 to 2 m	Height > 3 m
0	124.7	92.1	14.0	7.8	10.9
5	120.5	89.5	13.2	7.4	10.3
10	116.3	86.9	12.4	7.0	9.7
15	112.2	84.3	11.6	6.6	9.1
20	108.0	81.7	10.8	6.3	8.6
25	103.8	79.1	10.0	5.9	8.0
30	99.6	76.5	9.2	5.5	7.4
35	95.4	73.9	8.3	5.2	6.8
40	91.2	71.3	7.5	4.8	6.2
45	87.0	68.7	6.7	4.4	5.6
50	82.9	66.1	5.9	4.1	5.0
55	78.7	63.5	5.1	3.7	4.4
60	74.5	60.9	4.3	3.3	3.8
65	70.3	58.3	3.5	2.9	3.2
70	66.1	55.7	2.7	2.6	2.7
75	61.9	53.1	1.9	2.2	2.1
80	57.8	50.5	1.1	1.8	1.5
85	53.6	47.9	0.2	1.5	0.9
90	49.4	45.3	-0.6	1.1	0.3
95	45.2	42.7	-1.4	0.7	-0.3
100	41.0	40.1	-2.2	0.4	-0.9

Table B4. Forb cover look-up table.

Canopy Closure (%)	Blueberry	Bog/Black Spruce-Tamarack	Bracted Honeysuckle	Hairy Wild Rye	Horsetail	Labrador Tea Hygric	Labrador Tea Mesic	Labrador Tea Sub-hygric	Lichen
0	12.3	7.9135	6.7871	15	9.33	7.81	6.5664	5.5908	15
5	12.3	7.9135	6.7871	15	14.48	1.66	6.5664	5.5908	15
10	12.3	7.9135	6.7871	15	19.63	0	6.5664	5.5908	15
15	12.3	7.9135	6.7871	15	24.78	0	6.5664	5.5908	15
20	12.3	7.9135	6.7871	15	29.93	0	6.5664	5.5908	15
25	12.3	7.9135	6.7871	15	35.08	0	6.5664	5.5908	15
30	12.3	7.9135	6.7871	15	40.23	0	6.5664	5.5908	15
35	12.3	7.9135	6.7871	15	45.38	0	6.5664	5.5908	15
40	12.3	7.9135	6.7871	15	50.53	0	6.5664	5.5908	15
45	12.3	7.9135	6.7871	15	55.68	0	6.5664	5.5908	15
50	12.3	7.9135	6.7871	15	60.83	0	6.5664	5.5908	15
55	12.3	7.9135	6.7871	15	65.98	0	6.5664	5.5908	15
60	12.3	7.9135	6.7871	15	71.13	0	6.5664	5.5908	15
65	12.3	7.9135	6.7871	15	76.28	0	6.5664	5.5908	15
70	12.3	7.9135	6.7871	15	81.43	0	6.5664	5.5908	15
75	12.3	7.9135	6.7871	15	86.58	0	6.5664	5.5908	15
80	12.3	7.9135	6.7871	15	91.73	0	6.5664	5.5908	15
85	12.3	7.9135	6.7871	15	96.88	0	6.5664	5.5908	15
90	12.3	7.9135	6.7871	15	102.03	0	6.5664	5.5908	15
95	12.3	7.9135	6.7871	15	107.18	0	6.5664	5.5908	15
100	12.3	7.9135	6.7871	15	112.33	0	6.5664	5.5908	15

Table B5. Grass cover look-up table.

Canopy Closure (%)	Blueberry	Bog/Black Spruce-Tamarack	Bracted Honeysuckle	Hairy Wild Rye	Horsetail	Labrador Tea Hygric	Labrador Tea Mesic	Labrador Tea Sub-hygric	Lichen
0	63.3	11.7	3.6397	37	9.61	8.18	2.09	5.5541	37
5	46.3	8.15	4.3355333	37	9.61	2.53	2.09	4.61555835	37
10	29.3	4.6	5.0313666	37	9.61	0	2.09	3.6770167	37
15	12.3	1.05	5.7271999	37	9.61	0	2.09	2.73847505	37
20	0.0	0	6.4230332	37	9.61	0	2.09	1.7999334	37
25	0.0	0	7.1188665	37	9.61	0	2.09	0.86139175	37
30	0.0	0	7.8146998	37	9.61	0	2.09	0	37
35	0.0	0	8.5105331	37	9.61	0	2.09	0	37
40	0.0	0	9.2063664	37	9.61	0	2.09	0	37
45	0.0	0	9.9021997	37	9.61	0	2.09	0	37
50	0.0	0	10.598033	37	9.61	0	2.09	0	37
55	0.0	0	11.2938663	37	9.61	0	2.09	0	37
60	0.0	0	11.9896996	37	9.61	0	2.09	0	37
65	0.0	0	12.6855329	37	9.61	0	2.09	0	37
70	0.0	0	13.3813662	37	9.61	0	2.09	0	37
75	0.0	0	14.0771995	37	9.61	0	2.09	0	37
80	0.0	0	14.7730328	37	9.61	0	2.09	0	37
85	0.0	0	15.4688661	37	9.61	0	2.09	0	37
90	0.0	0	16.1646994	37	9.61	0	2.09	0	37
95	0.0	0	16.8605327	37	9.61	0	2.09	0	37
100	0.0	0.0	17.556366	37	9.61	0.0	2.09	0	37

Table B6. Fern cover look-up table.

Canopy Closure (%)	Blueberry	Bog/Black Spruce-Tamarack	Bracted Honeysuckle	Hairy Wild Rye	Horsetail	Labrador Tea Hygric	Labrador Tea Mesic	Labrador Tea Sub-hygric	Lichen
0	2.9	0	0.4507	2.66	0	0	0.408	0.378	2.66
5	2.1	0.518	0.4507	2.66	0	0	0.408	0.378	2.66
10	1.3	1.5555	0.4507	2.66	0	0	0.408	0.378	2.66
15	0.5	2.593	0.4507	2.66	0	0	0.408	0.378	2.66
20	0.0	3.6305	0.4507	2.66	0	0	0.408	0.378	2.66
25	0.0	4.668	0.4507	2.66	0	0	0.408	0.378	2.66
30	0.0	5.7055	0.4507	2.66	0	0	0.408	0.378	2.66
35	0.0	6.743	0.4507	2.66	0	0	0.408	0.378	2.66
40	0.0	7.7805	0.4507	2.66	0	0	0.408	0.378	2.66
45	0.0	8.818	0.4507	2.66	0	0	0.408	0.378	2.66
50	0.0	9.8555	0.4507	2.66	0	0	0.408	0.378	2.66
55	0.0	10.893	0.4507	2.66	0	0	0.408	0.378	2.66
60	0.0	11.9305	0.4507	2.66	0	0	0.408	0.378	2.66
65	0.0	12.968	0.4507	2.66	0	0	0.408	0.378	2.66
70	0.0	14.0055	0.4507	2.66	0	0	0.408	0.378	2.66
75	0.0	15.043	0.4507	2.66	0	0	0.408	0.378	2.66
80	0.0	16.0805	0.4507	2.66	0	0	0.408	0.378	2.66
85	0.0	17.118	0.4507	2.66	0	0	0.408	0.378	2.66
90	0.0	18.1555	0.4507	2.66	0	0	0.408	0.378	2.66
95	0.0	19.193	0.4507	2.66	0	0	0.408	0.378	2.66
100	0.0	20.2305	0.4507	2.66	0	0	0.408	0.378	2.66

Table B7. Herbaceous vegetation cover look-up table.

Canopy Closure (%)	Blueberry	Bog/Black Spruce-Tamarack	Bracted Honeysuckle	Hairy Wild Rye	Horsetail	Labrador Tea Hygric	Labrador Tea Mesic	Labrador Tea Sub-hygric	Lichen
0	78.5	19.6	10.9	54.7	18.9	16.0	9.1	11.5	54.7
5	60.7	16.6	11.6	54.7	24.1	4.2	9.1	10.6	54.7
10	42.8	14.1	12.3	54.7	29.2	0.0	9.1	9.6	54.7
15	25.0	11.6	13.0	54.7	34.4	0.0	9.1	8.7	54.7
20	12.3	11.5	13.7	54.7	39.5	0.0	9.1	7.8	54.7
25	12.3	12.6	14.4	54.7	44.7	0.0	9.1	6.8	54.7
30	12.3	13.6	15.1	54.7	49.8	0.0	9.1	6.0	54.7
35	12.3	14.7	15.7	54.7	55.0	0.0	9.1	6.0	54.7
40	12.3	15.7	16.4	54.7	60.1	0.0	9.1	6.0	54.7
45	12.3	16.7	17.1	54.7	65.3	0.0	9.1	6.0	54.7
50	12.3	17.8	17.8	54.7	70.4	0.0	9.1	6.0	54.7
55	12.3	18.8	18.5	54.7	75.6	0.0	9.1	6.0	54.7
60	12.3	19.8	19.2	54.7	80.7	0.0	9.1	6.0	54.7
65	12.3	20.9	19.9	54.7	85.9	0.0	9.1	6.0	54.7
70	12.3	21.9	20.6	54.7	91.0	0.0	9.1	6.0	54.7
75	12.3	23.0	21.3	54.7	96.2	0.0	9.1	6.0	54.7
80	12.3	24.0	22.0	54.7	101.3	0.0	9.1	6.0	54.7
85	12.3	25.0	22.7	54.7	106.5	0.0	9.1	6.0	54.7
90	12.3	26.1	23.4	54.7	111.6	0.0	9.1	6.0	54.7
95	12.3	27.1	24.1	54.7	116.8	0.0	9.1	6.0	54.7
100	12.3	28.1	24.8	54.7	121.9	0.0	9.1	6.0	54.7

Table B8. Willow and rose cover look-up table.

Canopy Closure (%)	Blueberry	Bog/Black Spruce-Tamarack	Bracted Honeysuckle	Hairy Wild Rye	Horsetail	Labrador Tea Hygric	Labrador Tea Mesic	Labrador Tea Sub-hygric	Lichen
0	12.6	6.86	3.47	16	0.89	9.83	3.589	12.48	16
5	9.4	6.86	3.47	16	0.89	9.83	2.9325	9.532	16
10	6.1	6.86	3.47	16	0.89	9.83	2.276	6.584	16
15	2.8	6.86	3.47	16	0.89	9.83	1.6195	3.636	16
20	0.0	6.86	3.47	16	0.89	9.83	0.963	0.688	16
25	0.0	6.86	3.47	16	0.89	9.83	0.3065	0	16
30	0.0	6.86	3.47	16	0.89	9.83	0	0	16
35	0.0	6.86	3.47	16	0.89	9.83	0	0	16
40	0.0	6.86	3.47	16	0.89	9.83	0	0	16
45	0.0	6.86	3.47	16	0.89	9.83	0	0	16
50	0.0	6.86	3.47	16	0.89	9.83	0	0	16
55	0.0	6.86	3.47	16	0.89	9.83	0	0	16
60	0.0	6.86	3.47	16	0.89	9.83	0	0	16
65	0.0	6.86	3.47	16	0.89	9.83	0	0	16
70	0.0	6.86	3.47	16	0.89	9.83	0	0	16
75	0.0	6.86	3.47	16	0.89	9.83	0	0	16
80	0.0	6.86	3.47	16	0.89	9.83	0	0	16
85	0.0	6.86	3.47	16	0.89	9.83	0	0	16
90	0.0	6.86	3.47	16	0.89	9.83	0	0	16
95	0.0	6.86	3.47	16	0.89	9.83	0	0	16
100	0.0	6.86	3.47	16	0.89	9.83	0	0	16

Table B9. Alder cover look-up table.

Canopy Closure (%)	Blueberry	Bog/Black Spruce-Tamarack	Bracted Honeysuckle	Hairy Wild Rye	Horsetail	Labrador Tea Hygric	Labrador Tea Mesic	Labrador Tea Sub-hygric	Lichen
0	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
5	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
10	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
15	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
20	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
25	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
30	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
35	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
40	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
45	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
50	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
55	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
60	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
65	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
70	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
75	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
80	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
85	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
90	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
95	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67
100	0.0	1.96	4.47	6.67	0	0	2.278	1	6.67

Table B10. Fruit-bearing shrub cover look-up table.

Canopy Closure (%)	Blueberry	Bog/Black Spruce-Tamarack	Bracted Honeysuckle	Hairy Wild Rye	Horsetail	Labrador Tea Hygric	Labrador Tea Mesic	Labrador Tea Sub-hygric	Lichen
0	102.3	15.04	27.37	93.33	26.33	20.64	19.88	13.14	93.33
5	76.7	15.04	27.37	93.33	26.33	13.94	19.88	13.14	93.33
10	51.1	15.04	27.37	93.33	26.33	7.24	19.88	13.14	93.33
15	25.5	15.04	27.37	93.33	26.33	0.54	19.88	13.14	93.33
20	0.0	15.04	27.37	93.33	26.33	-6.16	19.88	13.14	93.33
25	-25.6	15.04	27.37	93.33	26.33	-12.86	19.88	13.14	93.33
30	-51.2	15.04	27.37	93.33	26.33	-19.56	19.88	13.14	93.33
35	-76.8	15.04	27.37	93.33	26.33	-26.26	19.88	13.14	93.33
40	-102.4	15.04	27.37	93.33	26.33	-32.96	19.88	13.14	93.33
45	-128.0	15.04	27.37	93.33	26.33	-39.66	19.88	13.14	93.33
50	-153.6	15.04	27.37	93.33	26.33	-46.36	19.88	13.14	93.33
55	-179.1	15.04	27.37	93.33	26.33	-53.06	19.88	13.14	93.33
60	-204.7	15.04	27.37	93.33	26.33	-59.76	19.88	13.14	93.33
65	-230.3	15.04	27.37	93.33	26.33	-66.46	19.88	13.14	93.33
70	-255.9	15.04	27.37	93.33	26.33	-73.16	19.88	13.14	93.33
75	-281.5	15.04	27.37	93.33	26.33	-79.86	19.88	13.14	93.33
80	-307.1	15.04	27.37	93.33	26.33	-86.56	19.88	13.14	93.33
85	-332.6	15.04	27.37	93.33	26.33	-93.26	19.88	13.14	93.33
90	-358.2	15.04	27.37	93.33	26.33	-99.96	19.88	13.14	93.33
95	-383.8	15.04	27.37	93.33	26.33	-106.66	19.88	13.14	93.33
100	-409.4	15.04	27.37	93.33	26.33	-113.36	19.88	13.14	93.33

Table B11. Lichen cover look-up table.

Canopy Closure (%)	Blueberry	Bog/Black Spruce-Tamarack	Bracted Honeysuckle	Hairy Wild Rye	Horsetail	Labrador Tea Hygric	Labrador Tea Mesic	Labrador Tea Sub-hygric	Lichen
0	0.0	0.7219	0.1923	1	9.33	0.94	3.2103	2.0368	1
5	0.2	0.7219	0.156883335	1	14.48	0.205	3.2103	5.812841675	1
10	0.4	0.7219	0.12146667	1	19.63	0	3.2103	8.6409667	1
15	0.5	0.7219	0.086050005	1	24.78	0	3.2103	10.52117508	1
20	0.7	0.7219	0.05063334	1	29.93	0	3.2103	11.4534668	1
25	0.9	0.7219	0.015216675	1	35.08	0	3.2103	11.43784188	1
30	1.0	0.7219	0	1	40.23	0	3.2103	10.4743003	1
35	1.2	0.7219	0	1	45.38	0	3.2103	8.562842075	1
40	1.4	0.7219	0	1	50.53	0	3.2103	5.7034672	1
45	1.5	0.7219	0	1	55.68	0	3.2103	1.896175675	1
50	1.7	0.7219	0	1	60.83	0	3.2103	0	1
55	1.9	0.7219	0	1	65.98	0	3.2103	0	1
60	2.1	0.7219	0	1	71.13	0	3.2103	0	1
65	2.2	0.7219	0	1	76.28	0	3.2103	0	1
70	2.4	0.7219	0	1	81.43	0	3.2103	0	1
75	2.6	0.7219	0	1	86.58	0	3.2103	0	1
80	2.7	0.7219	0	1	91.73	0	3.2103	0	1
85	2.9	0.7219	0	1	96.88	0	3.2103	0	1
90	3.1	0.7219	0	1	102.03	0	3.2103	0	1
95	3.2	0.7219	0	1	107.18	0	3.2103	0	1
100	3.4	0.7219	0	1	112.33	0	3.2103	0	1